Community Assistantship Program

Eco-Rehab: An ecological Guide for the Rehabilitation of Cabins at the Arcola Mills Center

Eco-Rehab: An ecological Guide for the Rehabilitation of Cabins at the Arcola Mills Center

Prepared in partnership with
Arcola Mills Historic Foundation

Prepared by
Rachel Hilvert
Graduate Student
University of Minnesota
October, 2005

CAP Report 086

May 2005

CAP is a cross-college, cross-campus University of Minnesota initiative coordinated by the Center for Urban and Regional Affairs.

Funds for this project were generously provided by the West Central Regional Sustainable Development Partnership and the Otto Bremer Foundation.

This is a publication of the Center for Urban and Regional Affairs (CURA), an all-University applied research and technology center at the University of Minnesota that connects faculty and students with community organizations and public institutions working on significant public policy issues in Minnesota. The content of this report is the responsibility of the author and is not necessarily endorsed by CAP, CURA or the University of Minnesota..

CAP Report 086

Center for Urban and Regional Affairs (CURA)
University of Minnesota
330 HHH Center
301--19th Avenue South
Minneapolis, Minnesota 55455

Phone: (612) 625-1551
Fax: (612) 626-0273
E-mail: cura@umn.edu
Web site: http://www.cura.umn.edu

Eco-Rehab

An Ecological Guide for the Rehabilitation of Cabins at the Arcola Mills Center

Rachel Hilvert

Contents

Contents

Introduction

Introduction

Purpose and Organization

The Arcola Mills Center is poised to be a unique site for education and retreat. The stories held in the land and buildings along this section of the St. Croix River span a number of distinct eras. The site has been host to everything from American Indian settlements, to a sawmill, to an artists' retreat. All of these eras are united by their connection to the St. Croix River and their dependence on the environmental health of the immediate area. It is therefore fitting that the rehabilitation of buildings on the Arcola site be instilled with a sense of environmental responsibility.

This report has been made to aid the Arcola Mills Center in the rehabilitation of the cabins on the site in an environmentally responsible fashion. The cabins will be rehabilitated to provide overnight retreat spaces and will include educational features highlighting the historical and environmental aspects of the site and buildings. The intent of this report is to provide guiding principles, a solid body of information on "green" building, and a general plan for rehabilitating three of the site's buildings (Mill House, Bungalow, and Houseboat).

The report is organized in three main sections. The first section contains general information about building materials and systems, with a focus on sustainable choices. This section is organized by topic. For each topic, general information is provided along with a matrix outlining the specific environmental pros and cons, as well as the situational appropriateness of various materials, products, and systems. The matrix also includes specific manufacturers and details about their products. More details and contacts for the manufacturers can be found in the third section of the report.

Although the report specifically addresses the rehabilitation of only three cabins, it is meant to be a general resource for the future rehabilitation of other structures on the site. For this reason much of the information included in the first section may not directly relate to the three cabins addressed in the report. Hopefully, this information will prove helpful in the later rehabilitation of other cabins or construction for Arcola Mills.

The second section of the report consists of more specific suggestions for the environmentally responsible rehabilitation of three of the cabins on the Arcola Mills site (Mill House, Bungalow, Houseboat). The recommendations made in this section of this report are suggestions, not specific instructions or plans. Before any construction takes place, decisions will require consultations with architects, contractors, and/or structural engineers in order to confirm the viability of any construction method or material, and to organize a more detailed sequence and plan for work.

The recommendations section also identifies areas of thematic emphasis for each cabin. The hope is that providing a thematic lens through which guests can learn about the materials and systems will make the sustainable aspects of each cabin more accessible.

The thematic emphasis for the Mill House is "wood." This theme nicely ties together the history of the cabin with key aspects of its rehabilitation. Guests will be introduced to the sustainable potential of wood as well as the ecological devastation that results from irresponsible logging. Highlighted items in the cabin will include original wood that was sawn in the old sawmill, reclaimed wood for flooring, and FSC certified wood that has been harvested from sustainably managed forests. Cellulose insulation (made from recycled wood products) will help keep the cabin warm.

"Energy" is the theme for the Bungalow. Guests will be introduced to information about the embodied energy of building materials (all of the energy required to manufacture and install a product), the energy

sources tapped for use in the cabin, as well as ways in which the rehabilitated cabin saves energy consumption through efficient design. The rehabilitated Bungalow will be a super-insulated structure, minimizing the heat load on a new, efficient condensing gas boiler. A pellet burning stove will be installed for highly efficient space heating and materials with a low embodied energy will be preferred during the rehabilitation process.

The Houseboat will focus on "water," connecting its new sustainable features to its past life on the river. Information will be provided to guests about the importance of water conservation and how to prevent water pollution. Water in the cabin will be conserved with a composting (or dual flush) toilet, low-flow fixtures, and a recirculating greywater system. Wastewater from the Houseboat will not pollute the groundwater or the St. Croix River thanks to a special pre-treatment system that uses the cleansing power of plants to render wastewater harmless.

The third section of the report lists detailed information about manufacturers and products, organized by topic in the same order as the first section. This is the place to find photographs and details about specific products, as well as contact information for manufacturers, distributors, and retailers. The list is meant as a starting point for locating manufacturers of environmentally responsible products; it is by no means exhaustive. Nor is the inclusion of any manufacturer meant as an endorsement. Before making any final decisions, the specific product and its appropriateness for use at Arcola Mills should be carefully investigated.

What is Sustainability?

Sustainable, environmental, and green have all become popular terms for a relatively new way of thinking about building design. Unfortunately, the terms' definitions are not always made explicit. For the purposes of this report, the terms are used interchangeably and reflect the understanding of sustainability articulated at the 1992 Earth Summit in Rio de Janeiro: "meeting the needs of the present without compromising the ability of future generations to meet their own needs."

While the logic of the definition seems obvious and intuitive, the actual process of building sustainably is much more complicated. Creating an evironmentally responsible structure means considering the embodied energy of materials as well as the resources consumed in their manufacture. The responsible designer must consider how the design of the building will affect energy and resource consumption during use. Building sustainably also means considering the effects the materials and systems of the building will have on indoor air quality, and the immediate exterior environment. Finally, sustainability requires designing with an eye on the end of a building's life-cycle. Can its materials be recycled, or better yet, reused? Or will its pieces end up in a landfill?

There are no blanket solutions or universally right answers. Each individual detail must be considered in concert with other elements and the site itself. What may be an environmentally friendly choice under one set of conditions, may be a poor choice under a different set. Therefore, it is important to consider the specific aspects of a given site, including macro- and micro-climates, topography, and ecology.

Though the process can be daunting, green design is possible, even necessary. The rehabilitation project at Arcola Mills affords a special opportunity to employ a variety of "green" strategies while exposing guests to the urgency and possibilities of environmentally responsible living.

Information

Insulation (placement)

Permanent Insulation

The total heat produced by a building is equal to the total heat lost by a building to the outside. Insulation slows this inevitable process, and thus requires the building to produce less heat and consume less energy. Therefore, the first priority in making the cabins more environmentally responsible is to make sure they are adequately insulated. The efficacy of other features (heating, high-performance windows, ventilation, mold prevention, etc.) is largely dependent on establishing a well-insulated and well-sealed building envelope. Because of the high surface area to volume ratio in small buildings like the cabins, energy consumption is especially affected by the performance of the building's skin.

Insulation is necessary:

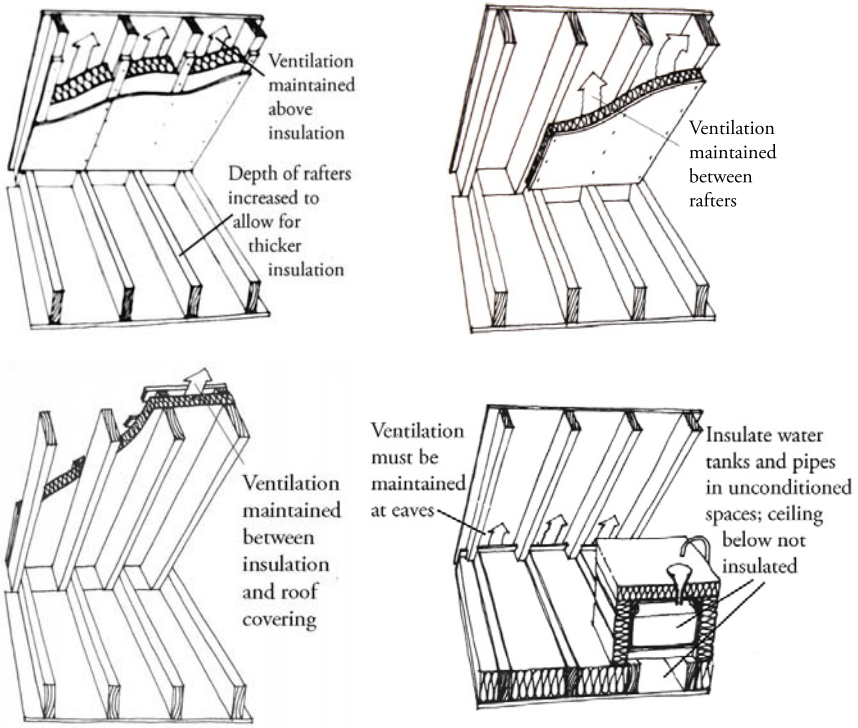
- On all ceilings or roofs in between heated and unheated spaces
- Below floors above unheated spaces
- On all exterior walls.

For a super-insulated home, the exterior walls should have an R-value of at least R-30 (R-20 in basement walls). Insulation should be even greater at the roof (R-50, ideally) where buildings lose most of their heat.

It is important to maintain full R-value wherever it is needed. For example, if batt insulation is used, it must not be compressed under sloped roofs at the eaves. Instead, design rafters to rest on a raised rafter plane so that ceiling insulation can continue to the exterior wall surface at full thickness. To prevent moisture build-up on wooden rafters (which can cause a number of problems, from rot to mold), always maintain a 2″ gap between insulation and roof felt for ventilation.

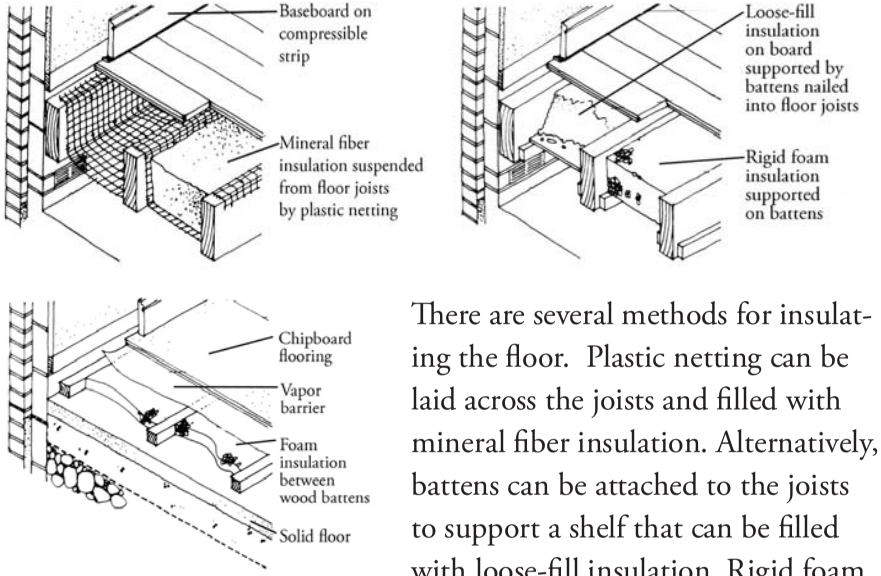
Walls, roofs, etc. can be insulated either on the interior or exterior. In general, insulating externally is most effective since it keeps the entire structure warm. This is usually the more difficult solution, however, and may not be feasible in all situations as it can create design problems in some situations (e.g. around windows). If adding insulation externally, be sure the roof eaves are long enough to overhang the added thickness. To avoid thermal bridging, insulation must cover window and door reveals; this may necessitate their replacement or modification. Placing insulation above the rafters of the roof involves the redesign of the eaves to allow for added thickness. The old roof needs to be stripped, insulation board placed on the rafters with a water vapor barrier in between and a layer of building board or roofing lath above to attach to the finished roof surface.

Floors above unconditioned areas also need to be insulated. The simplest solution is to insert insulation from below between floor joists. If this space is inaccessible, the floorboards will have to be removed.



Attic/Roof Insulation: images from *Eco-Renovation*

Insulation (placement)



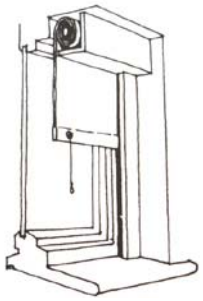
Floor insulation; images from *Eco-Renovation*

There are several methods for insulating the floor. Plastic netting can be laid across the joists and filled with mineral fiber insulation. Alternatively, battens can be attached to the joists to support a shelf that can be filled with loose-fill insulation. Rigid foam insulation can rest directly on battens on floor joists. In any case, care should be taken that there is a seal between the baseboard and floor by installing the baseboard on a compressible strip.

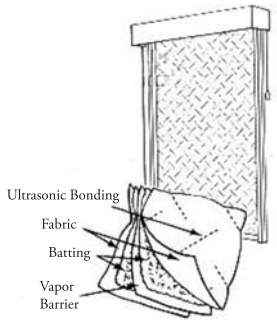
In addition to these basic placements, all hot and cold water pipes should be fully insulated as well as any ducts that run through unconditioned spaces. Bathrooms should also be insulated to prevent water heat loss during use (and to reduce noise).

Moveable insulation

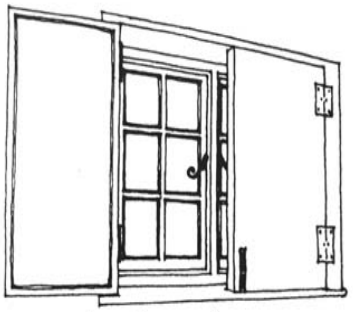
Not all insulation needs to be permanent. In fact, moveable insulation over windows is a highly effective way of preventing unwanted heat loss overnight or in cloudy conditions. It can also prevent unwanted heat gain during hot periods. Most moveable insulation functions by sealing an air space between the insulation and the window. Moveable insulation may consist of interior or exterior shutters, window quilts, or pop-in panels. Thermal curtains and window quilts seal around the window and include one or more layers of insulation material. They may also include a reflective liner or vapor retarder. Shutters are available in a variety of configurations, hinging at tops, sides, or bottom. They can be installed as both interior and exterior features. Pop-in panels are less expensive than other options and made of rigid lightweight insulation like polystyrene or polyurethane. They can be covered in decorative fabric on the interior side. It should be noted, though, that none of these window insulation options are an adequate alternative to installing well-sealed, double glazed windows, ideally with a low-e glazing (see Windows section, pg. 15). In addition, moveable insulation requires user participation to be effective. Users must be willing and able to adjust the insulation with changing conditions. It should therefore be durable and easy to adjust.



Insulated blinds running in channels; images from *Eco-Renovation*



Window quilt; image from <*www.1window quiltscom/product.html*>



Close-fitting Shutters; image from *Eco-Renovation*

In choosing moveable insulation, carefully examine the R-value and air-tightness of the product, as these two qualities will determine the insulation's efficacy. **Edge seals** should be precisely fit to the particular

dimensions of a specific window, especially in the case of older windows where the frame may not be perfectly square. Edge seals may be roller tracks, wooden clamp strips, Velcro, magnets, or sail tracks. The bottom edge seal is the most important for winter insulation. Also consider the potential for water condensation which may rot wooden window frames. Tight seals and vapor retarders can prevent condensation on the window or insulation. The vapor retarder should be on the warm side of the insulation (i.e. facing the room).

Draft-Proofing

Another important aspect of insulating is draft-proofing. All unused fireplaces must be completely sealed; operational ones need high-quality dampers. Exterior doors and windows should have weatherstripping. Ideally, doors should be kept away from corners and out of the path of prevailing winds. An entry porch added to the main entry can significantly reduce drafts. The porch door should be perpendicular to the main door if possible and opposite the prevailing winds. Storm windows and caulk can help seal cracks around windows. When there is a large temperature difference between the interior and exterior, high, warm air is pushed out of the building and cold air is sucked in at the bottom. For this reason it is especially important to make sure all baseboards are fully sealed at the floor and wall and installed on a compressible strip.

For additional energy savings, rooms that will not need heat for five days or more should be closed off.

Moveable Insulation

Option	Environmental Pros	Environmental Cons	Appropriateness
Window Quilts/ Thermal Curtains	• Air and-moisture tight fabric	• No guarantee of environmentally-friendly materials/production processes	• R-value about 5 • May not be aesthetically appropriate for all situations • Must seal tightly around edges of window frame
1 *Window Quilts*	• Exterior: 70% polyester and 30% cotton; Fill: 100% polyester • Available in regular light diffusing or room darkening • Several colors available • Available with fire retardant • R-value: 4.99		
Pop-in Panels	• Can be homemade • High insulation value: R-4 per inch	• See information for rigid insulation (polystyrene and polyurethane) • Toxic if burned, must be covered with fire-retarding material (like hardboard or plywood)	• Cheap and effective • Rigid sheet of insulation sandwiched between aluminum foil and card; side facing room covered in fabric • Requires storage during day

Insulation (placement)

Option	Environmental Pros	Environmental Cons	Appropriateness
Curtains	• Can reduce downdrafts	• Minimal effectiveness, depending on material and proper installation • May trap hot air between curtain and window if improperly placed	• Thick material provides greatest benefit • Ideally, should have a well-fitted valance, sides should connect as well as possible to the frame and to themselves at seams, should rest on the sill • Make sure radiator convection current doesn't go behind the curtain
Blinds	• Easier to seal than curtains • Can be treated with special coatings or include thin insulating film	• Low R-value	• Should fit in slides at sides • Minimal R-value without special treatment
Shutters	• May have high R-value if they include foam between layers of wood.	• External shutters are often left unused	• Can be hinged to fit in sides when not in use • External shutters are more effective • Internal shutters may cause condensation, though residents are more likely to use them

Insulation (type)

There are three general types of insulation materials:

- Inorganic, mineral based (fiber or cellular)
- Organic synthetic, derived from oils
- Natural organic, derived from animals and plants.

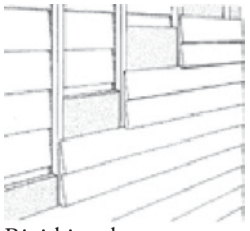
While, in general, natural organic materials tend to be the most environmentally friendly and synthetics the least, it is important to balance the environmental costs of production with the benefits and efficiency of use. In some cases, it may be appropriate to use a less environmentally-friendly product because the benefit in operation compensates for the negative aspects of production. A low-impact product with low R-value or degradation over-time can create a negative environmental impact if it causes increased energy consumption by increasing the heating load.

In addition to the material itself, insulation should be chosen in an appropriate form for the situation: blanket, sprayed, loose-fill, or rigid foam. Blanket, or batt, insulation fits easily between studs and is relatively easy to install in accessible places. However, it can often leave unsealed gaps that allow for air infiltration. Loose fill insulation is suited to filling inaccessible or irregular spaces. It is not appropriate, however, for uses below grade. Sprayed or blown insulation is often used in retrofits. The insulation expands to fill gaps, sealing the building to prevent air and sometimes even water infiltration. Many, unfortunately are produced with HCFC blowing agents. Rigid foam insulation is used, among other places, below concrete slabs and on flat roofs. It is generally more expensive than other types of insulation, although this is partially offset by higher R-values per inch. Rigid foam is difficult to fit into irregular spaces. The increased efficiency of foam's higher R-values must be weighed against environmental drawbacks of its manufacture. Generally, rigid insulation is plastic foam, made of petrochemicals which involve high energy manufacturing and the use of non renewable materials like oil and natural gas. Rigid foam's manufacture is also associated with emissions of particulates, oils, phenols, heavy metals, and chemicals that cause acid rain. For these reasons, rigid foam and other synthetic insulators should be avoided when there is a viable alternative.

For a flat roof enhanced with rigid cellular insulation, use felt-backed insulation that is then finished with 2 further layers of felt or a high performance single membrane product.

Batt insulation

Loose fill insulation



Rigid insula-

Images from <http://oee.nrcan.gc.ca/keep_heat_in/chapter_2/chapter_2_1.cfm>

Blanket (Batt)

Option	Environmental Pros	Environmental Cons	Appropriateness
Fiberglass	• Fiber is more "green" than synthetics • Made from natural materials (often more than 40% recycled glass) • CFC, HCFC free	• Large amounts of energy consumed in production • Production releases a large amount of toxic chemicals • Health concerns for production workers • Non biodegradable	• Requires greater thickness than synthetics • Water proof, stable, non-combustible, vermin proof

Insulation (type)

Option	Environmental Pros	Environmental Cons	Appropriateness
CertainTeed	• Batt and blown-in fiberglass insulation with 30% recycled content, some from curbside recycling • Available in standard unfaced or faced		
Johns Manville	• Fiberglass blankets, batt, board and loose-fill with 20% to 30% recycled glass; formaldehyde-free, acrylic binder • R-11 to R-25 batt insulation		
Ottawa Fibre, Inc.	• Fiberglass insulation products from 100% recycled glass (overall recycled content 65%) • R-value is R-11 to R-38		
Mineral Wool (Rock Wool)	• Fiber is more "green" than synthetics	• May cause skin irritation • May degrade over time • Health concerns for production workers	• Requires greater thickness than synthetics • Vapor and air permeable
Roxul, Inc	• Mineral wool from basalt rock and recycled steel slag, available in batt and board forms • Naturally insect resistant, non-combustible, withstands 1832° F, and can act as fire barrier • Manufacturing plant has recycling facility to redirect waste back into manufacturing process, resulting in 50% water usage reductions and raw material consumption and energy usage reduction		
ThermaFiber LLC	• Loose-fill rock wool with 50% to 70% recycled content from iron ore slag. • Non-combustible: resists temperatures up to 2000° F; vermin proof		
Natural Fibers	• Renewable resources • Often made from recycled materials • Recyclable		• Lower R-value per inch than synthetics • Subject to moisture problems if not treated
Bonded Logic: Ultratouch	• 85% post-industrial recycled natural fibers (cotton and denim contents are 100% post-industrial); 3.5″ has R-value of 13; 5.5″ is 19 • Does not itch, easy to handle, no chemical irritants, no VOCs • Meets highest ASTM testing standards for fire and smoke ratings, fungi resistance and corrosiveness • Oversized widths to ensure a tight friction fit and fill capacity • Boron-based fire retardant also impedes growth of fungus, mold, and resists pests		
Inno-Therm	• Recycled cotton & denim fiber, 3.5″ has R-value of 13; 5.5″ is 19 • Fire-retardant • Rates 10% better than fiberglass in Sound Transmission (STC), sound absorption and complies with existing ASTM standards for batting insulation • Self supporting in stud wall applications		

Loose Fill

Option	Environmental Pros	Environmental Cons	Appropriateness
Fiberglass	• Fiber is more "green" than synthetics • Made from natural materials (often more than 40% recycled glass) • CFC, HCFC free	• Large amounts of energy consumed in production • Production releases toxic chemicals • Health concerns for production workers • Non biodegradable	• Water proof, stable, non-combustible, vermin proof • Works best in horizontal open spaces • R-value: 3/in

Insulation (type)

Option	Environmental Pros	Environmental Cons	Appropriateness
Johns Manville	• see batt section		
Mineral Wool (Rock Wool)	• Fiber is more "green" than synthetics	• May cause skin irritation • May degrade over time • Health concerns for production workers	• Requires greater thickness than synthetics • Vapor and air permeable, may degrade over time • Suitable for accessible attics, inaccessible areas like wood frame roof, walls, floors • Requires greater density in vertical areas • R-value: 3.2/in
Cellulose	• Fiber is more "green" than synthetics • High recycled content (no resource depletion) • Includes large percentage of wood-based cellulose from recycled newspapers • Uses borates as fire-retarder which are mined in the US • Low embodied energy		• R-value: 3.4/in • Small particle size allows it to fill around nails, electrical wires, etc. • Treated to be fire and vermin resistant
American Insulation, Inc.	• 100% recycled newsprint content in various sized bags and brands • Distribution limited to Midwest		
Applegate Insulation	• Loose-fill and blown cellulose insulation from 85% post-consumer recycled materials • Uses one-fifth the energy it takes to manufacture Fiberglass		
Modern Insulation, Inc.	• 80% of Weather Blanket brand from post-consumer recycled newsprint		
P.K. Insulation Manufacturing Co.	• Cellulose insulation made from post-consumer recycled newsprint for spray and loose-fill applications.		

Sprayed/Blown

Option	Environmental Pros	Environmental Cons	Appropriateness
Fiberglass	• Fiber is more "green" than synthetics • Made from natural materials (often more than 40% recycled glass) • CFC, HCFC free • seals building, preventing moisture and air infiltration	• May be sprayed with HCFC blowing agents • Large amounts of energy consumed in production • Production releases toxic chemicals • Health concerns for production workers • Non biodegradable	• Requires greater thickness than synthetics • Water proof, stable, non-combustible, vermin proof
CertainTeed	• See batt section		

Insulation (type)

Option	Environmental Pros	Environmental Cons	Appropriateness
Mineral Wool (Rock Wool)	• Fiber is more "green" than synthetics • Seals building, preventing moisture and air infiltration	• May be sprayed with HCFC blowing agents • May degrade over time • Health concerns for production workers	• Requires greater thickness than synthetics • Vapor and air permeable, may degrade over time
Cellulose	• Fiber is more "green" than synthetics • High recycled content (no resource depletion) • Includes large percentage of wood-based cellulose from recycled newspapers • Uses borates as fire-retarder which are mined in the US • Low embodied energy • Seals building, preventing moisture and air infiltration		• Requires greater thickness than synthetics • Can be blown into ceilings and walls or mixed with water or acrylic binder and sprayed into cavities • Can have moisture problems if it is not allowed to dry out properly before enclosure • May not be suitable in places where moisture can become trapped • Treated to be fire and vermin resistant
Applegate Insulation	• See loose-fill section		
P.K. Insulation Manufacturing Co.	• See loose-fill section		
Polyurethane foam	• seals building, preventing moisture and air infiltration	• May be sprayed with HCFC blowing agents • Synthetics are petroleum-based • Installers in danger of exposer to volatile polyisocyanates which can cause breathing difficulties • Health hazard in fire, releasing cyanide gas • Significant source of formaldehyde • Not recyclable	• R-value: 6/in • Should not be used in enclosed cavities
Icynene	• Water blown foam • No loss of R-value over time • Contains no CFCs, HCFCs, or HFAs • Organic by-product of petroleum distillation process • Seals building, preventing moisture and air infiltration	• Not recyclable	• R-value: 3.6/in • Suitable for wood frame structure • Insoluble in water • Combusts at 400˚; won't sustain combustion on its own • Can also be applied as loose fill through 1/2" drill holes
Soy	• Annually reproducible base product • No VOCs or CFCs, no formaldehyde • Polyurethane uses 2 part soybean oil • Seals building, preventing moisture and air infiltration		• Does not support mold growth • Resists pests—no food value • Class 1 fire rated • Open-cell, semi-rigid; behaves similar to petroleum based plastic foam
Insoylation	• See above		

Insulation (type)

Rigid

Option	Environmental Pros	Environmental Cons	Appropriateness
Extruded polystyrene foam (XPS)		• Extremely large amount of energy consumed in production • Depletes non-renewable resources • Production releases many toxic chemicals • Releases HFCs, HCFCs • Concerns with indoor air quality	• Waterproof • Check with manufacturer to see if HFCs (which cause global warming) are used in manufacturing.
Expanded polystyrene foam (EPS) "bead board"	• CFC, HCFC free • Better than extruded foam	• Extremely large amount of energy consumed in production • Depletes non-renewable resources • Production releases many toxic chemicals • Prevents health hazard in fire, releasing CO and CO_2	• Rigid, non-toxic • White styrofoam, used for cavity wall insulation
Polyurethane foam		• Extremely large amount of energy consumed in production • Depletes non-renewable resources • Production releases many toxic chemicals • Releases HFCs, HCFCs • Concerns with indoor air quality	
Polyisocyanurate foam		• Significant negative impact on air quality, water quality, and land quality in manufacture • Negative impact on worker health • No reusable or recyclable	

Ventilation

In a very tight building, ventilation must be deliberately planned to maintain a high indoor air quality. Whatever heating system is employed, ventilation must be provided to give adequate fresh air to the interior.

Fans should be placed in kitchen and bathrooms to remove humidity. These fans can be turned on by occupants or tied to humidistats or timers.

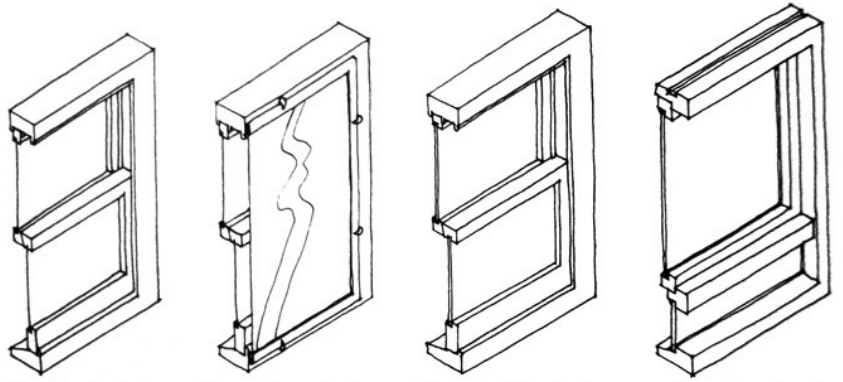
Windows can also be strategically placed to allow for cross-ventilation in appropriate weather. Making windows operable and equipping them with screens can improve the air quality of the indoor environment.

Option	Environmental Pros	Environmental Cons	Appropriateness
Bathroom fans	• Remove excessive humidity; prevent damage to structure	• Usually consumes grid-sourced electricity	• Should be used in areas of high humidity like bathrooms or kitchen • Can be operated by switch or tied to a humidistat or timer

Windows

With inappropriate or inadequate glazing, much of the work of creating a well-insulated building shell is lost. Although strategically placed windows can provide passive solar heating during the day, at night they will lose heat. At the same time shading devices should be considered to prevent unwanted heat gains during the cooling season. Decisions made about windows must be made in conjunction with decisions about insulation (especially moveable insulation), daylighting, ventilation, cooling, and passive heating. These concerns are addressed more specifically in other sections.

A single pane of glass provides a disappointingly high U-value (which indicates a low R-value). Simply adding a second pane, and thus trapping an insulating layer of air between, can significantly improve window performance. Ideally, this gap should be about 1/2″. At least two layers of glass should be used always. Special **low-e** coatings on the glass can increase its natural reflective ability, retaining longwave (heat) radiation. This improved U-value from low-e coatings is associated with reduced light transmission, and therefore may not always be appropriate if the windows are being used for daylighting.



Images from *Eco-Renovation*

Glass

Option	Environmental Pros	Environmental Cons	Appropriateness
Single glazing		• Huge energy loser, provides little insulation between indoor and outdoor environments	• U-value: 6 • Transfers 88% light
Double glazing	• Reduces condensation, noise, and downdrafts		•U-value: 3 • Transfers 80% light • Because downdrafts are reduced, radiators can be placed more freely.
–Secondary glazing	• See above		• A second pane, fixed or operable, is installed inside of the existing window, usually with its own frame
–Sealed units	• See above		• 2 panes are sealed at the factory; can sometimes replace panes of glass within sash or fixed widows • Vary from 1/2” to 1” thick
–Replacement double-glazed windows	• Most efficient way of improving performance of badly damaged old windows		• Can mimic historic appearance • May not be exact replica

Option	Environmental Pros	Environmental Cons	Appropriateness
Double glazing with low-e glass and argon gas	• Improved performance over regular double glazing		• U-value: 1.5 • Transfers 77% light
Triple glazing	• Improved performance over double glazed windows		• U-value: 2 • Transfers 72% light
Triple glazing with low-e glass and argon gas	• Improved performance over regular triple glazing		U-value: 1.2 Transfers 70% light
Double glazing with vacuum and low-e glass	• Vacuum provides best insulation between panes; attains highest performance	• Longevity studies have not been done to ensure that vacuum will last over long term	U-value: .5 Transfers 77% light

Frame

Option	Environmental Pros	Environmental Cons	Appropriateness
Metal		• May cause thermal bridging if there is not a thermal break • Consumes non-renewable resources	• U-value 3.6 with thermal barrier, 7 without thermal barrier • Inconsistent with historical appearance
Wooden frame–FSC certified	• Wood frame eliminates problems of thermal bridging • Wood harvested from a sustainably managed forest		• U-value 1.6 for over 80mm, 2 for 50-80mm, 2.8 for less than 50mm • Can match historical appearance • Design should seal end grains before assembly, rapidly shed water, avoid sharp edges and profiles, have weather seals at the back of casement, away from the wet area, avoid screws and dowels in external face
Wooden frame–non-FSC certified	• Wood frame eliminates problems of thermal bridging	• No guarantee that wood is harvested from a sustainably managed forest	•See above

Manufacturers

Option	Information
Anderson Windows	• Double hung windows, casement, awning windows, gliding windows, bay and bow windows, picture windows, skylights • Architectural series allows for some customizing • Specialize in wood framed windows • All windows include weatherstripping of vinyl-wrapped foam and compressible bulb weatherstrip • Available with low-e coatings, argon gas filled • Wood treated with unspecified preservative • Exterior outer frame members are covered with a preformed rigid vinyl PVC cladding • Sills constructed with a wood core and Fibrex® composite material exterior. Sill ends sealed with weather-resistant covers • Wood stops are made of treated, clear unfinished pine; on white prefinished interior units the stops are white foamed PVC • Insect screens available for all venting products • Gives preference to purchasing wood supplies that are FSC certified or "other equivalent systems"
Marvin Windows	• Can make windows and doors to order, by hand • Double hung, casement, awning, round top, magnum double hung, bay, bow, special shape, glider, ultimate insert double hung • Ult. double hung: 4 9/16" (116 mm) jambs, all wood brick mould casing, bare wood interior, screen, one-handed tilt • Ultimate insert double hung has all-wood exterior for historic look • Screens available with wood surround • Available with low-e glazing and argon gas filled, triple pane, and other reflective coatings • Available "bare wood" for staining, or "white-primed" for painting; for all-wood products, the wood exterior must be finished with an exterior paint. • Whenever possible, Marvin uses manufacturing waste wood to help fuel the company's 2 million square-foot (185,000 square meters) facility in Warroad • Approximately 6,000 tons of packaging and logging wood waste are recycled annually to fuel the plant's boiler; reduces the amount of solid waste to be landfilled while saving energy. • Recycles woodshavings • Seeks reliable raw lumber suppliers with sound forest management practices, which subscribe to the Sustainable Forest Initiative (SFI) promoting good forest stewardship (Note: not FSC)

Traditional Lumber

Wood has the potential to be one of the most environmentally friendly building materials. It is renewable and actually improves air quality. Compared to other building materials like concrete and steel, it has a radically lower embodied energy content, as most of the energy that contributes to the manufacture of wood is free, clean, renewable solar.

However, irresponsible harvesting and milling processes can reduce the environmental benefits of building with wood. Logging in the tropics and temperate zones has destroyed huge, irreplaceable old growth forests. Tropical hardwoods should be avoided if at all possible. Replanting plantation-style creates more trees, but lacks the biodiversity and full environmental benefits of a natural forest.

Some companies, though, are harvesting responsibly, managing forests to maintain their size and diversity. The Forest Stewardship Council is an international organization for certification of sustainably managed forests worldwide. Beware other certifications or claims of sustainability. There is little consistency or regulation in the certification world. Only trust FSC certification. If tropical hardwoods must be used, look for FSC certified greenheart from Guyana, Rubberwood from Malaysia, or Teak from Java, Thailand, or Burma. In many cases it is possible to use reclaimed wood, and thereby eliminate the need to harvest trees at all. Reclaimed wood was often originally harvested from old-growth forests which translates into higher quality than most conventional wood on the market today. Reclaimed wood bears the marks of its history with saw marks and nail holes, qualities to be appreciated rather than avoided.

Another environmental danger from wood is its treatment after being harvested. Milling wood requires a substantial amount of energy and kiln-firing much more. Ideally, wood will have its bark stripped, be soaked to remove sap sugar, and allowed to air dry over a long period. Air drying will not only save energy but may improve the quality of the wood, as kiln drying doesn't allow some woods enough time to stabilize which can lead to warping and shrinkage.

Many chemicals used to treat wood for resistance to insects, water, and fire have harmful health and environmental side-effects. Chromated copper arsenate (CCA) is one of the most commonly used and worst offending chemicals. Alternatives like ammoniacal copper quatenary (ACQ) are less environmentally malignant and are becoming more widely available. Borate-based treatments are typically the best, as they come from a natural source. Borate, however, is not suitable for all conditions. Whenever possible of course, it is best to leave wood untreated. The following domestic woods are known for having natural decay resistance:

> Cedar, Redwood, Bald Cypress (old growth), Catalpa, Black Cherry, Chestnut, Arizona Cypress, Juniper, Black Locust, Mesquite, Red Mulberry, Burr Oak, Chestnut Oak, Gambrel Oak, Oregon White Oak, Post Oak, White Oak, Osage Orange, Sassafrass, Black Walnut, Pacific Yew

Finally, depending on where wood is harvested and/or milled, there may be large transportation costs. Whenever possible it is best to get wood, like all other materials, from a local source.

Engineered Lumber

Glue laminated timbers are built up from smaller pieces of lumber. They can be used to span longer distances than non-engineered wood. Unfortunately, the manufacture of adhesives and preservatives used in glue lam timbers causes significant air and water pollution and

consumes non-renewable petroleum and natural gas. On the other hand, because engineered lumber uses smaller elements than would be required for a large beam or column, it reduces the need to harvest large old-growth trees. In general, engineered lumber should only be used where necessary.

Wood Products and Alternatives

Materials like chipboard, MDF, and hardboard, and plywood are all manufactured from small pieces of wood and adhesives or other bonding agents. Many of these adhesives and resins, such as those found in MDF are harmful. In some situations where wood or wood products are used, it may be appropriate to use another alternative product. Other products are on the market which can perform similarly but do not have the harmful environmental side effects. Often they make use of agricultural waste products that would otherwise be landfilled. In some cases, materials like cork or bamboo may be a positive alternative to us-

Type

Option	Environmental Pros	Environmental Cons	Appropriateness
Conventional lumber	• Renewable resource	• Likely to have been harvested irresponsibly • Likely to have been treated with environmentally harmful chemicals	
Air-dried timber	• Does not require the energy use of kiln-drying		• Appropriate anywhere wood is used • Takes a longer time to produce, thus less available than kiln-dried wood • Less chance of warping and shrinking than kiln-dried
FSC certified wood	• Renewable resource • Certification assures that wood comes from a sustainably managed forest		• Appropriate anywhere wood is used • Forest Management Certificate means the forest is certified • Chain of Custody Certificate means that the entire path of processing the timber is certified
Aacer Flooring LLC	• Flooring, hardwood • Northern hardwood, several species available: thicker than industry standards (25/32″), random length boards in standard widths: 1½″, 2¼″, 3¼″ • Peshtigo river plank, wide plank flooring: 3″, 4″, 5″ in several species		
Bennet Lumber	• Dimensional lumber and other wood products • Locations at Clarkston, Washington and Princeton, Idaho		
Brunkow Hardwood Corp.	• Nelson, WI • Lumber, kiln-dried; wide variety of species		
Cecco Trading, Inc.	• Milwaukee, WI • Naturally durable hardwoods: “Iron Woods”; appropriate for exterior • No chemicals used • Bridges, decking, flooring, lumber		

Option	Environmental Pros	Environmental Cons	Appropriateness
Certified Wood Products	• Minnetonka, MN • Paneling, siding, beams, posts, framing lumber (2x4s–2x12s; l=10–20 ft) in west coast hemlock fir, plywood (4′x8′x1/2″, 4′x8′x3/4″) in western fir		
Collins Co; CollinsWood	• H**ardwood flooring**: cherry, red oak, beech, red maple, ash. • **Dimensional softwood lumber** from California and Oregon (ponderosa pine, lodgepole pine, white fir, sugar pine, incense cedar) • **Lumber, logs, and dimensional hardwood lumber** from Pennsylvania (black cherry, red oak, white oak, ash, hard maple, red maple, beech, yellow poplar, basswood, birch) • **Particleboard** (CollinsWood) with high percentage of western pine; available FSC certified; manufactured from 100% post-industrial waste		
Hill Wood Products	• FSC certified lumber from Minnesota White Birch • 7/16″–11 1/2″ thick, 31 1/2″–53 1/4″ wide, 40″–48″ tall		
Living Forest Coop	• Wood harvested from northern WI • Flooring in hard maple, white ash, red maple, aspen, white birch; sold in random widths from 2 1/4″–5″ • Kiln dried lumber in aspen, hard maple, white birch, red maple • Can buy unfinished logs • Wood is harvested during freeze to minimize soil disturbance		
Midwest Hardwood Corp.	• Kiln dried Northern and Appalachian wood: alder, basswood, cherry, hard maple, red oak, soft maple, white ash, walnut, white oak, white pine, white birch, yellow birch, walnut, white oak, white pine, white birch, yellow birch		
Upper Mississippi Certified Group	• Aitkin, MN • Aspen, balsam fir, basswood, birch, black ash, pine, red oak, spruce, tamarack, larch • Flooring, furniture, logs, lumber (green or kiln-dried), millwork, mouldings, siding		
Wood Flooring International	• Engineered wood flooring product resembling solid wood plank. • 75% FSC certified wood, 25% postindustrial recycled wood content. • Wood sourced from around the globe (American Woods are the only FSC certified) • 9/16″ thick, with 1/8″ thick wear layer, widths of 3″ and 5″, random lengths 12″–84″ • May be nailed, glued or floated • Acrylic Urethane w/aluminum oxide finish		
Woodland Forest Products	• Oakdale, MN • Kiln dried lumber: ash, aspen, bass, white birch, yellow birch, butternut, cherry, hickory, hard maple, soft maple, red oak, white oak, ponderosa pine, northern white pine, yellow poplar, walnut		
Reclaimed timber	• Does not require any destruction or tampering with forests • Several options/companies within Minnesota • Reused and salvaged materials		• Wood often comes from old growth forests • Available in a range of sizes for floorboards and column and beam timber
A & B Disposal	• Runs a landfill site where you can take/buy salvaged wood. • Kingston, ON		

Option	Environmental Pros	Environmental Cons	Appropriateness
Duluth Timber	• All products salvaged from demolition of industrial structures • Custom sawn flooring and millwork • Kiln dried to 8-12% moisture • Timbers, planks, and floor: douglas fir and heart pine		
Elmwood Reclaimed Timber	• Reclaimed from pre 1930s buildings that are condemned, abandoned, or beyond repair • Wide plank flooring, solid wood beams, dimensional lumber, cabinet lumber, millwork		
Old Growth Woods	• Flooring, woodwork • Reclaimed wood originally harvested in early 1900s • Group of Midwest artisans dismantles old buildings that are beyond repair and helps preserve structures that can be saved • Large supply of 1″ and 2″ oak, call for availability of other species/sizes		
Manomin Resawn Timbers	• Wide plank flooring available in 4″, 5″, 8″, 10″ widths, some very rustic looking • Lumber for open-beam ceilings, custom-cut boards, fireplace mantels, and other custom woodworking. • Hugo, MN		
Glue laminated timber	• Uses small pieces of wood; doesn't require harvesting large old-growth trees	• Manufacture of adhesives and preservatives used in glue lam timbers cause significant air and water pollution and consume non-renewable petroleum and natural gas	• Can span longer distances than conventional lumber

Treatment

Option	Environmental Pros	Environmental Cons	Appropriateness
Creosote pressure-treated		• Dangerous chemicals • Among most dangerous preservatives	• Protects from insects, moisture, decay, fungi • Do not use in interior except for laminated beams or components in contact with ground or subject to decay/insects • If used on interior must be given 2 coats of sealer • Keep out of direct/indirect contact with drinking water • Appropriate sealers are: urethane, shellac, latex, epoxy, enamel, varnish
Pentalchlorophenol pressure-treated		• Dangerous chemicals	• Protects from insects, moisture, decay, fungi • Do not use in interior except for laminated beams or components in contact with ground or subject to decay/insects • If used on interior must be given 2 coats of sealer • Keep out of direct/indirect contact with drinking water • Appropriate sealers are: urethane, shellac, latex, epoxy, enamel, varnish

Option	Environmental Pros	Environmental Cons	Appropriateness
Inorganic arsenical pressure-treated		• Dangerous chemicals	• Protects from insects, moisture, decay, fungi
Copper napthenate, zinc napthenate, tributylin oxide		• Dangerous chemicals	• Applied onsite
Chromated copper arsenate (CCA)		• Dangerous chemicals • Harmful if burnt • Dust should not be inhaled • Among most damaging preservatives	• Most common • Sealer advisable on cut ends (but rarely done) • Must be kept away from food • Should not be used where it may be in direct or indirect contact with drinking water
Ammoniacal copper quatenary (ACQ)	• Less toxic than CCA • Among least damaging preservatives	• Some environmentally harmful chemicals	• Similar applications and performance as CCA
Chemical Specialties Inc	• has phased out use of CCA in favor of ACQ (check specific brand, some still rely on CCA); see Preserve Plus • TimberSaver treatment uses borate for protecting wood from decay and insects		
Naturewood: Osmose Wood Preserving, Inc	• Alternative to CCA; Copper-based preservative with a co-biocide (waterborne, alkaline copper quaternary; ACQ) • Durable and designed for outdoor construction • Appropriate for structural lumber, sill plates, outdoor furniture, playground products, patios, decks, garden edging, and landscaping structures • Use with hot-dip galvanized, stainless steel, or other recommended hardware		
Chromium copper boron (CCB), zinc copper fluoride (ZCF)	• Among least damaging preservatives		
Borate	• More environmentally friendly chemical than other treatment options • Among least damaging preservatives		• Not sufficiently water resistant for damp areas • Fungi and insect repellent, appropriate for dry areas
–Borate: impel rods	• See above		• Rod placed in drilled hole • Boric acid is absorbed by wood when the moisture exceeds 25% • Penetrates heartwood and sapwood, stopping decay • Inactive when wood is dry
–Borate: auro borax wood impregnation	• See above		• Site applied • Resists fungus and insects • Brush, spray, or dip applied • Corrosive in solution

Option	Environmental Pros	Environmental Cons	Appropriateness
–Borate: tim-bor	• See above		• Site applied • Powder applied to wet (>20%) lumber • Dipped or sprayed
–Borate: bora-care	• See above		• Liquid: dipped or sprayed • Includes glycol solution that helps diffusion
Advance Guard and Hi-Bor: Osmose Wood Preserving, Inc:	• Pressure treated with borate preservatives to protect against termites, carpenter ants, and fungal decay • For use in above ground weather protected structural framing; recommended for sill plate, furring strips, joists, studs, roof trusses, blocking, rafters, beams, and other framing applications • Also recommended for sill plate, furring strips, joists, studs, roof trusses, blocking, rafters, beams, and other framing applications • May be sawn, drilled, or routed with standard woodworking equipment. • Non-corrosive and may be placed in contact with aluminum • Should not be used for outdoor structures exposed to weathering • Field treatment of all end cuts and borings, including plumbing and electrical holes is required on all lumber and timbers over 2" in thickness • Check preservative brand; Osmose also makes CCA preservatives		
Lifetime Wood Treatment: Valhalla Wood Treatment	• Non-toxic: releases no harmful residue in soils and water; can be used in direct contact with garden soil without any toxic effect • Manufactured in Canada from naturally occurring plant and mineral substances; contains no solvents • Appropriate for decks, posts, log homes, sheds, doors, and posts and retaining walls that make contact with ground; also safe for indoors (recommended that fence posts be soaked in LifeTime for at least 2 days) • Available as powder concentrate in 1 and 5 gallon packages (1 gallon covers 160 sf); mix with water and apply to bare, untreated or pressure treated wood with brush, roller, spray, or by dipping • Can be applied in any weather; even 32˚ F • Powder concentrate is light and easy to ship with indefinite shelf life • Inexpensive		
Adhesives		• May contain harmful chemicals	• Frequently used on interior wood
Interior finishes	• Use wax, oils, eco-friendly varnish	• Chemicals may be carcinogenic in synthetic finishes	• Choose carefully to limit exposure to harmful chemicals
No treatment	• Requires no harmful chemicals	• Depending on application may decrease durability of wood	• May be possible with appropriate wood in dry and protected areas

Wood Products & Alternatives

Option	Environmental Pros	Environmental Cons	Appropriateness
Plywood, blockboard, chipboard		• Contain phenol and urea formaldehyde resins • Increase toxicity of indoor air	
Collins Co; CollinsWood	• **Particleboard** (CollinsWood) with high percentage of western pine; available FSC certified; manufactured from 100% post-industrial waste • See FSC certified wood, under **Type**		

Option	Environmental Pros	Environmental Cons	Appropriateness
PrimeBoard (Particleboard)	• Formaldehyde-free binder • Made from blend of agricultural residue fibers (wheat straw & sunflower hulls); may affect individuals allergic to grasses if surfaces remain exposed • Available in range of sizes, thicknesses and grades.		
MDF		• Even higher formaldehyde content (14%) than most engineered wood products	
SierraPine Ltd: Medex and Medite II	•Medex: no-added formaldehyde, moisture resistant MDF panel engineered for interior high moisture areas; use in place of sanded plywood and solid wood in non-structural applications • Medite II: no-added formaldehyde MDF panel engineered for non-structural applications; use in place of sanded plywood and solid wood. • Both use formaldehyde-free synthetic resin. (in Medex and Medite II panels are independently certified for no-added formaldehyde)		
DuraCane by Acadia Board	• Made from bagasse, the fibrous portion of sugar cane: leftovers after the juice is removed • Bagasse comes from nearby farmer-owned sugar cane coop • Bonded with MDI, formaldehyde-free resin		• Exceeds ANSI standards for particleboard • Appropriate wherever particleboard might be used
EcoPanel	• Panels made from fibrous agricultural waste products (sugar bagasse, water hyacinth, elephant grass, etc.) • Uses only non-toxic binding agents • 97% waste material, 3% binding agent		• Intended as alternative to softwoods, chipboards, MDF, and hardwood ply in some cases • Impact and tensile strengths comparable to particleboard • Superior water resistance to chipboard, not prone to distortion, not susceptible to infestation, fire-resistant • Can be sawed, nailed, glued, sanded
Cork (see flooring for more information)	• Renewable and benign (from bark of evergreen oak... stripping the bark doesn't harm the tree)		• Good for flooring, insulation, veneer • Lightweight, durable, nonflammable • Cells filled with air and can withstand high pressure
Bamboo (see flooring for more information)	• Rapidly renewable • Avoids harvest of forests	• Shipped from overseas • Does contain some formaldehyde	• Use in place of hardwood flooring • Similar strength to typical hardwood floor and often more dimensionally stable • Installation similar to hardwood: nailed, glued to subfloor, or installed as floating floor

Many traditional roofs employ environmentally harmful materials. Asphalt shingles are the most widely used residential roofing material in the U.S. Although they are durable and effectively waterproof, their manufacture is the source of much pollution. Alternatives should be explored.

Whenever possible, reuse old or salvaged materials. When that is not possible, it is best to use products produced from environmentally friendly materials or from waste products that would otherwise be headed for the landfill.

In addition to material concerns, the roof should be as durable and long-lasting as possible. The longer the roof lasts, the less waste will go to the landfill. Creating a durable roof not only means choosing materials than can handle the weather conditions of the site, but also careful installation to avoid problems with water infiltration etc.

Flat

Option	Environmental Pros	Environmental Cons	Appropriateness
Bitumen felt		• Felt doesn't always perform well	• Bitumen supported by felt matrix
Modified bitumen felt	• Longer lasting than blown bitumen	• Usually landfilled at end of life	• Fewer layers, better temperature stability, low temperature flexibility
Atactic polypropylene modified	• Resists UV radiation and high temperature	• Usually landfilled at end of life	• 70% bitumin, 30% APP • Often used in the south
Single ply EPDM (synthetic rubber)	• Best choice for flat roof • Relatively low impact compared to other options • High durability, reusable (50 year life expectancy) • Initial production has low embodied energy number • New solvent-free (no VOCs) available	• Usually landfilled at end of life	• Very important that installation/workmanship is of high quality • Made from ethylene, propylene, and a small amount of diene monomer • Good low temperature flexibility, doesn't become brittle • Resists cyclic fatigue • Resists hail damage • Available in white or black (white dyed with titanium dioxide, black with carbon black which absorbs more heat)
Water storage roof	• Collects rainwater for local use; lessens demand on water supply		• More complicated to design and install than conventional roof • Only appropriate for float roof
Planted roof	• Some insulation value • Increases green space and slows water run-off		• Must be carefully detailed and installed to prevent leaking and other problems • Heavy: requires adequate structure below

Sloped

Option	Environmental Pros	Environmental Cons	Appropriateness
Asphalt Shingles	• Some products include up to 25% recycled base material	• Open pit mining of raw materials • Consume petroleum in manufacture, releases harmful particulates • Landfilled at end of life	• Highly waterproof, can withstand structural movement • Life expectancy of 20-30 years (more frequent, thus expensive, than other options)
Natural slate tiles (local)	• Limited transportation costs • No harmful materials	• Consume nonrenewable resource	
Reclaimed tiles/slates	• Reused materials have lower environmental impact • Durable		• Can be used anywhere tiles or slates would be used
Durable Slate	• Specializes in historic restoration and repair • Buys salvaged slate and tile • Over 100,000 pieces of salvaged roofing slate and tile in stock.		
Clay/cement tiles	• Typically long lasting	• Concrete is energy intensive to manufacture	• Can be very heavy
Fiber-Cement tiles	• Some use waste paper and wood fiber	• Cement is energy intensive to manufacture	• Cost competitive with asphalt • Durable and long-lasting (warranties around 60 years)
Fiber Crete International, Inc	• Roof tiles made from a patented composite of organic refuse and Portland cement, fly ash and concrete epoxy. Fibrous waste material varies by plant location, but may include rice hulls, straw and other agricultural waste or recycled paper sludge; includes 40-50% fiber in composite.		
Cedar Shingles	• Theoretically a renewable resource	• Seldom come from a sustainably managed forest • Fireproofing treatments may be carcinogenic	• May be high maintenance • Expensive
Eco-Shake (Re-new Wood, Inc)	• Made from 100% recycled cellulose fiber and PVC (from hose manufacturing scrap)	• Contains PVC (although it's a waste product)	• Meant to resemble wood shingles • Class A fire-rating, 50 year warranty • Class 4 impact rating (highest), freeze-thaw resistant, UV protected, resists mold, mildew, and fungus • Maintenance-free • Available in random widths of 5, 7, and 12"; all 22" long • Should be nailed over solid decking with 30# felt applied directly to the roof deck
Enviro-Shake	• Mix of post industrial plastics, recycled rubber elastomers, and cellulose fibers	• Specific plastic content unknown	• Similar to Eco-Shake, meant to replicate look of cedar shingles • Hail resistant, 50 year warranty • Trimmable • Install like normal shingles

Roofs

Option	Environmental Pros	Environmental Cons	Appropriateness
Authentic Roof (Crowe Building Products Ltd.)	• Recycled materials used to make with Baljen TPO, an alloy made of Polyethylene, Polypropylene and EPDM rubber without the use of binding agents or plasticizers • TPO is recyclable • UV protected, hail resistant, 50 year limited warranty • Priced comparatively with high end roofing materials; installation costs slightly more than asphalt shingles, less than cedar shakes • For sloped roof with no less than 3/12 pitch		
Used tire treads *(Moore Enviro Systems and Tread Mill Inc.)*	• Reused materials	• Concerns with fire • Concern with off-gasing	• Limited information available

Cladding

Traditional wood siding has become increasingly rare in the construction industry as cheaper and easier to maintain alternatives have become available. Unfortunately, many of these alternatives have negative impacts both aesthetically and environmentally. Vinyl siding should be avoided. In general it fails to convincingly replicate the appearance of wood and its manufacture produces a number of harmful pollutants, including PVC. Fiber-cement siding provides a more attractive alternative, both in terms of appearance and environmental impact. Made of Portland cement and wood fiber, these products come closer to replicating the appearance of wood and are extremely durable. While their production is fairly energy intensive, it does not produce harmful pollutants and chemicals to the extent that vinyl siding does.

Of course, actual wood siding remains a viable option. If installed and maintained properly, it provides a durable building skin. Wood cladding should be acquired through a distributor of reclaimed or FSC certified wood. It must be treated on the exterior with an environmentally responsible finish keep it water-resistant.

Bark siding (as currently found on the Mill House) can come from a variety of trees, although some are more effective than others. For example, poplar bark outlasts chestnut. Currently poplar bark appears to be the only bark readily available, and only from North Carolina. Bark is harvested during a limited time in the summer with spuds that are used to peel it from felled trees. Because of the limited harvesting time some companies have a limited supply. Ideally the bark is harvested from trees already felled for lumber and the bark siding makes use of what would otherwise be a waste product. Before use the bark is kiln dried (to prevent later shrinking and cracking) and insect treated.

Traditionally, bark siding was placed in a single lap around the exterior of a building, as seen in the current Mill House. This practice is no longer acceptable as it does not provide adequate waterproofing. The currently accepted method is to lap bark shingles halfway to ensure water resistance. Still, bark is most effective when used in places out of harsh weather exposure. The bark is layered on a subsurface similar to that prepared for cedar shakes with screws rather than nails. Bark can meet fire codes when it is applied over a non-combustible fabric layer. According to manufacturers, bark siding can last 80-100 years if installed properly.

Option	Environmental Pros	Environmental Cons	Appropriateness
FSC Certified wood siding	• Harvested from sustainably managed forest • Renewable resource		• Requires regular maintenance • Historically authentic material
Certified Wood Products	• Minnetonka, MN • FSC certified siding and other wood products		
Fiber-Cement siding	• Durable	• Portland cement is energy intensive to produce	• Can be used in place of traditional wood siding

Cladding

Option	Environmental Pros	Environmental Cons	Appropriateness
James Hardie Bldg Products: Hardiplank, Hardi Shingleside, Hardipanel	• Durable (50 year limited warranty), long-lasting product resembles wood siding • Consists of Portland Cement, sand, clay, and wood fiber. • Resists rotting and cracking, water and hail damage, insects, shrinking and swelling • Non-combustible • Lap siding, shingle siding, individual shingles available • Can be painted • Installed over braced wood or steel studs spaced maximum of 24″ o.c. or directly to minimum 7/16″ thick OSB sheathing; can also be installed over foam insulation up to 1″ thick		
Vinyl siding		• Harmful pollution from manufacturing process, including PVC	• Inauthentic historical appearance • Less durable than other alternatives • Should not be used
Bark Siding	• Often harvested from already-felled lumber; would otherwise be a waste-product	• Transportation costs from NC	• Historically authentic
Highland Craftsmen	• No chemical additives • Bark comes from trees already felled for lumber; would otherwise be a waste product	• Transportation costs from NC • Unknown if wood comes from FSC forests	• poplar bark siding and large flat panels • Kiln dried • Resists infestation • See manufacturer index for more product information
Furniss Enterprises	• Bark hand removed before trees taken to mill	• Transportation costs from NC • Unknown if wood comes from FSC forests	• Poplar • Kiln dried • $6/ft^2
www.poplarbarksiding.com		• Transportation costs from NC • Unknown if wood comes from FSC forests	• harvested from poplar trees in Appalachian mtns. • dried and insect treated “with approved methods” • $5-$7/ft^2

Indoor Air Quality

The materials used in the construction, finish, and use of a building, as well as the type and quantity of ventilation contribute to the indoor air quality of a space. Many chemicals used in building materials release harmful toxins. Similarly, many finishes likes paint or carpet, or adhesives and varnishes used in woodwork or furniture can be hazardous to the health of occupants.

Formaldehyde is a common indoor toxin. Repeated exposure to it actually causes increased sensitivity. Formaldehyde in the air can irritate mucous membranes, skin, cause headaches and lethargy, sleep problems, irritability, paranoia, chest pain, heart problems, cold and flu symptoms, nosebleeds, nausea, menstrual problems and has been linked to cancer. Formaldehyde in indoor air can come from fiberboard, particleboard, urea-formaldehyde insulation, contemporary furniture, synthetic carpets, glues, drapes, oil-based paints, plastics, ceiling tiles, and incomplete combustion. Although Formaldehyde has been prohibited from paint manufacture, many companies still include elements known as formaldehyde precursors, even in low-VOC paint. These chemicals allow the paint to create formaldehyde as it cures, making it formaldehyde-free in the can, but not on the walls.

Products of incomplete combustion (which may come from gas stoves or boilers) include carbon monoxide, carbon dioxide, nitrogen oxide, nitrogen dioxide, and hydrocarbons.

Plants can effectively combat indoor air pollution, as they naturally clean pollutants from air and water. Research shows that many plants can even increase their ability to absorb pollutants with increased exposure to them. The common spider plant is especially good at removing formaldehyde from the air and can be quite helpful in a kitchen. Other helpful plants include:

* Dwark banana (muse cavendishii)
* Golden Pothos
* Chinese evergreens (aglaonema modestum)
* Peace-lily
* Genus Peperomia
* Snake Plant
* Goosefoot Plant
* Ivy Arum

In addition to the chemical benefits of plants, they can provide a positive visual and mental atmosphere. They can also be used to improve indoor air odor.

Many cleaning chemicals and soaps used in the home can contribute to negative indoor air quality. Search for cleaning products that are made of natural ingredients. These products also do not cause the environmental pollution that synthetic cleaners do.

The best way to ensure good indoor air quality is to create a structure that minimizes the opportunities for mold or mildew, provides adequate ventilation and fresh air, and eliminates the use of building materials that will release harmful chemicals.

Option	Environmental Pros	Environmental Cons	Appropriateness
BioShield Paint	• Manufactures a variety of natural household cleaners: laundry soap, chlorine-free bleach, organic plant-based hand soaps, vinegar cleaner, toilet cleaner, dishwashing soap, glass cleaner • All made of natural ingredients without formaldehyde, phosphates, petroleum, synthetic fragrances, dyes, or preservatives		
AFM Safecoat	• Several environmentally friendly all-purpose and carpet cleaning products • Contain no formaldehyde		

Flooring

Like other materials, an evaluation of a floor choice should include consideration of its durability, it manufacturing impact, and its affect on indoor air quality.

Wood floors are appropriate for the rehabilitation of the historic buildings at Arcola Mills. For more information about hardwood flooring and the environmental affects of different wood sources, see the Wood section (pg. 18) In some cases, materials like cork or bamboo may be a positive alternative to using wood. Cork and bamboo are especially appropriate for flooring. Cork is harvested from the bark of the cork tree and does not necessitate cutting down any trees. Bamboo, a grass, is rapidly renewable. To create flooring, bamboo poles are split lengthwise and then sent through a shaper to make them flat. The pieces are kiln-dried and laminated together with a hot-press and high-tech European glues. Cork and bamboo, however, generally require transportation over long distances as they are not produced locally.

Bamboo flooring is similar in appearance to hardwood flooring

For kitchens, bathrooms, and other areas that are subject to especially hard wear, a resilient floor is often more appropriate than wood. These floors are generally made of either linoleum or vinyl and come in a wide range of durability. Linoleum is made of linseed oil, pine resin, cork dust or sawdust, inert fillers, and pigments. Though there may be some off-gassing from linseed oil, it is not considered a health issue. Vinyl, on the other hand, is a largely synthetic product, with PVC as a primary constituent. PVC manufacture is not only energy intensive, but can be harmful to the health of workers and comes with serious negative environmental impacts, including the release of harmful dioxins. Whether using linoleum or vinyl, avoid over-ordering as this material will most likely be landfilled.

Linoleum, vinyl, and most other floors require adhesives. Many of these contain harmful chemicals and produce dangerous VOCs. Whenever possible choose adhesives made from rubber, cellulose, animal, or vegetable derivatives. If you must use synthetics, specify no VOC or low VOC and use the minimum amount necessary. In addition, choose an environmentally friendly underlayment for any floor that requires one.

Modern carpeting is usually made from synthetic materials including nylon, polyester, polypropylene, polyurethane, and acrylic. These materials contain VOCs and most of the dyes used are made from petrochemicals. Natural carpeting made of animal or vegetable fibers including wool, sisal, cotton etc. is less prevalent but a much better option environmentally as its manufacture is not responsible for nearly as much energy consumption and it does not have a negative impact on indoor air quality.

Option	Environmental Pros	Environmental Cons	Appropriateness
FSC certified wood	• Renewable resource • Certification assures that wood comes from a sustainably managed forest		• Appropriate anywhere wood is used • Forest Management Certificate: forest is certified • Chain of Custody Certificate: entire path of processing the timber is certified
Aacer Flooring LLC	• Flooring, hardwood • Northern hardwood, several species available: thicker than industry standards (25/32″), random length boards in standard widths: 1 1/2″, 2 1/4″, 3 1/4″ • Peshtigo river plank, wide plank flooring: 3″, 4″, 5″ in several species		

Flooring

Option	Environmental Pros	Environmental Cons	Appropriateness
Collins Co; CollinsWood	• Hardwood flooring: cherry, red oak, beech, red maple, ash.		
Living Forest Coop	• Flooring in hard maple, white ash, red maple, aspen, white birch; sold in random widths from 2¼″–5″ • Kiln dried lumber in aspen, hard maple, white birch, red maple • Can buy unfinished logs • Wood is harvested during freeze to minimize soil disturbance		
Upper Mississippi Certified Group	• Aspen, balsam fir, basswood, birch, black ash, pine, red oak, spruce, tamarack, larch • Flooring, furniture, logs, lumber (green or kiln-dried), millwork, mouldings, siding		
Wood Flooring International	• Engineered wood flooring product resembling solid wood plank. • 75% FSC certified wood, 25% postindustrial recycled wood content. • Wood sourced from around the globe (American Woods are the only FSC certified) • 9/16″ thick, with 1/8″ thick wear layer, widths of 3″ and 5″, random lengths 12″–84″ • May be nailed, glued or floated • Acrylic Urethane w/aluminum oxide finish		
Reclaimed timber	• Does not require any destruction or tampering with forests • Several local options/companies • Reused and salvaged materials		• Wood often comes from old growth forests • Available in a range of sizes for floorboards and column and beam timber
Duluth Timber	• All products salvaged from demolition of industrial structures, kiln dried to 8-12% moisture • Custom sawn flooring and millwork • Timbers, planks, and floor: douglas fir and heart pine		
EcoFriendly Flooring	• Reclaimed wood flooring: yellow heart pine and douglas fir from WI; $4.50-$11.50/sq. ft. • Provide installation services for Minnesota		
Elmwood Reclaimed Timber	• Reclaimed from pre 1930s buildings that are condemned, abandoned, or beyond repair • Wide plank flooring, solid wood beams, dimensional lumber, cabinet lumber, millwork		
Old Growth Woods	• Flooring, woodwork • Reclaimed wood originally harvested in early 1900s • Group of Midwest artisans dismantles old buildings that are beyond repair and helps preserve structures that can be saved • Large supply of 1″ and 2″ oak, call for availability of other species/sizes		
Manomin Resawn Timbers	• Wide plank flooring available in 4″, 5″, 8″, 10″ widths, some very rustic looking • Lumber for open-beam ceilings, custom-cut boards, fireplace mantels, and other custom woodworking. • Hugo, MN		

Flooring

Option	Environmental Pros	Environmental Cons	Appropriateness
Bamboo	• Rapidly renewable • Avoids harvest of forests	• Shipped from overseas • Does contain some formaldehyde	• Use in place of hardwood flooring • Similar strength to typical hardwood floor and often more dimensionally stable • Installation similar to hardwood: nailed, glued to sub-floor, or installed as floating floor
Amati Bambu Ltd.	• 3-ply, horizontally laminated with thin, vertically laminated strips in center ply; aluminum based polyurethane		
Bamboo hardwoods	• Uses the hardest species of bamboo ever discovered, available in 4 colors and several different styles • Option of engineered or solid floor • Engineered floors have maximum dimensional stability, floor is stable enough to "float", "nail-down" or glue-down; less likely to be affected by temperature and humidity changes • Solid floor is oriented in one direction, must be nailed to a healthy plywood substrate; less expensive than engineered floor • Pre-finished floors are finished with Aluminum-Oxide, a mineral resin, non-toxic, inert, it does not off-gas • Bamboo shipped from China and Indonesia		
D&M Bamboo Flooring Co.	• Pre-finished and unfinished solid flooring • Solid, engineered, and floating parquet floors		
EcoFriendly Flooring	• Bamboo flooring ($3.00-$6.00/sq. ft) • Provide installation services for Minnesota		
Smart House International	• Bamboo flooring: $5.50/sq ft		
Smith & Fong Plyboo Co.	• Available in two colors, natural and amber in various shades • Also produces 100% bamboo plywood: 4 x 8 Sheets-Standard, unfinished, compatible with Industrial finishes		
Linoleum	• Natural product • Biodegradable • Naturally antimicrobial, anti-static	• Not recyclable	• Keep dry from below to avoid mold
EcoFriendly Flooring	• Linoleum: durable, biodegradable material that is comfortable, warm and quiet; $5.00/sq.ft (volume discounts avail); many colors available • Provide installation services for Minnesota		
Marmoret: Armstrong World Industries	• Natural linoleum originally from Germany • Natural odor		
Marmoleum & Marmoleum Click: Forbo Linoleum, Inc	• Natural odor, no VOCs • 200 colors. • Marmoleum Click: on HDF with a cork layer in 36″ x 12″ panels or 12″ x 12″: $5.50 to $7.50 per square foot		

Flooring

Option	Environmental Pros	Environmental Cons	Appropriateness
Smart House International	• Linoleum: 3′x1′x7/16″ glueless floating floor planks; $5.50/sq.ft		
Vinyl	• Less durable than linoleum	• PVC is primary constituent, dioxins released in manufacture • Not recyclable • High embodied energy	• Keep dry from below to avoid mold • Naturally antibacterial
Tile	• Produces no fumes or gases • Does not support mold, mildew or bacterial growth • Can be maintained without the use of harsh chemicals	• Typically energy intensive to produce • Often applied with harmful adhesives	• Durable • Specify environmentally friendly adhesives and underlayment
GeoStone EcoCycle Tiles (Crossville Ceramics)	• 12″x12″ Glazed Porcelain Stone tile with unfired, reused material body; four of the five colors have a 50% reclaimed body and 50% base body, fifth color, Night Air, has a 100% reclaimed body—reclaimed, unfired raw material, including the dust particles collected from air-filtration and waste-water treatment facilities of the plant • All tiles made of naturally occurring clays and minerals mined in Tennessee and neighboring states. • 30% harder than granite, won't scratch, stain, or fade, suitable for floors, walls, counters • Most tiles are shipped in recyclable paper cartons. • Filtration process takes water used during manufacturing and returns it to the city of Crossville cleaner than when it entered the factory.		
Cork	• Renewable resource • Relatively benign in manufacture • Naturally antimicrobial	• Material often imported from far away	• Cork granules molded using a bonding agent • Floor requires protective coating
Dodge Cork Co.	• Unfinished, Waxed, Polyurethane Satin and Polyurethane Gloss cork tiles • Residential: 12" x 12" x 3/16", Commercial: 12" x 12" x 5/16"		
EcoFriendly Flooring	• Cork floors (ideal for comfort and high noise absorption); can be applied to any levelled surface including kitchens; starts at $3.50/sq. ft • Provide installation services for Minnesota		
Natural Cork Inc	• **Parquet:** solid cork glue-down tile; available in 7 standard colors and patterns; not recommended for use below grade or over in-floor radiant heating systems. • **Engineered floating floor**: 100% high density cork coated with U.V. cured acrylic finish (no VOCs), high-density fiberboard center core, low density cork underlayment; tongue & groove installation, no glue required; available in 18 patterns • Insect resistant		
Smart House International	• Floating cork floor: 3′x1′x7/16″ prefinished planks; $4–$5.50/sq.ft.		
Rubber	• Durable • Natural Rubber comes from renewable resource	• Usually mixed with synthetic materials	• Can be used anywhere durable, resilient flooring is desired

Flooring

Option	Environmental Pros	Environmental Cons	Appropriateness
Freudenberg Building Systems	• Tough and hard wearing, long life expectancy • Made of natural rubber supplemented by raw mineral materials extracted from natural deposits and by environmentally compatible color pigments. • Do not contain any PVC, plasticizers (phthalate) or halogens (e.g. chlorine) • Production scraps - such as die cut trim and sanding dust - reused in the production process to manufacture new products • Can usually be installed in rolls or tiles using solvent-free, environmentally friendly dispersion adhesives		
Recycled Rubber	• Recycled material	• May off-gas	• Durable
Synthetic Carpet		• Contain VOCs • Most fabric dyes made from petrochemicals • Nylon (often blended with wool) manufacture creates much Nitrogen Oxide, toxic when burned	• Includes nylon, polyester, polypropylene, polyurethane, acrylic
Spring Planting Line: Interface-FLOR (modular flooring)	• Modular floor/carpet tile for the home • Face material made from Ingeo® PLA, a corn-derived material, which takes less energy to produce and is recyclable (only applies to Spring Planting line of tiles) • 19.5″ square; $10.99 per tile		
Natural Carpet	• Do not contain harmful VOC producing chemicals • Less embodied energy in manufacture		• Includes animal or vegetable fibers: wool, sisal, seagrass, coir, cotton, hessian on natural backings (jute, latex) • Choose undyed, unbleached, without insecticides
Earth Weave Carpet Mills, Inc.	• Broadloom or area rugs • Biodegradable: face fiber of 100% natural wool, no moth proofing or stain protections, naturally pigmented, natural primary of hemp and cotton (primary is the material that the tufting machine places the wool yarn into and holds it in place); hemp is durable, strong, and mold and mildew resistant • Adhesive is 100% natural and bio-degradable: made of natural rubber; the secondary (back of carpet) is jute, a hardy earth friendly fiber producing plant. • Natural carpet padding available: blend of coarse naturally pigmented wools mechanically needled (not glued) into a cotton scrim; free from dyes, fire retardant, glues, moth proofing or adhesives; can be recycled in garden where it will safely biodegrade while serving as a weed barrier and mulch—will completely degrade in 2-3 seasons • Rug Gripper available: 100% natural rubber non-skid rug pad for area rugs		
Carousel Carpet	• Sheet carpets made from wool and cotton fibers, with jute and natural latex backing (May aggravate wool allergies.) • Custom carpets and rugs.		

Underlayment

Option	Environmental Pros	Environmental Cons	Appropriateness
WoodStalk: Dow BioProducts Ltd.	• Underlayment made from up to 93% wheat straw fiber (may affect allergies if surface exposed) • Formaldehyde-free polyurethane binder • Install under vinyl, carpet, hardwood and laminate flooring; 50% harder than most plywood underlayments • 1/4″ & 3/8″. Thicker (1/2″, 5/8″, 3/4″) to level floors. • Manufactured in Manitoba, Canada		
Homasote	• High-density board made from 100% recycled wastepaper and formaldehyde-fee paraffin binder • Designed for sound control • Flooring underlayment and in wall assemblies, roof decking • Variety of sizes and thicknesses. • All water in production process is recycled in closed loop system • Shipped from NJ		

Adhesives

Option	Environmental Pros	Environmental Cons	Appropriateness
Water-Based, Plant Derived Adhesive	• Best adhesive choice • Made of renewable resources		• If not available choose a water baed, low solvent synthetic • check carefully with installation instructions to make sure the adhesive will work
Hot Melt Adhesive	• Fewer solvents than traditional	• Still releases VOCs	• check carefully with installation instructions to make sure the adhesive will work
Synthetic Adhesive		• VOCs • Harmful manufacturing process • consumes nonrenewable resources	• Avoid • check carefully with installation instructions to make sure the adhesive will work
AFM Safe Coat	• Low VOC flooring adhesive for ceramic, parquet, formica, and slate tiles; lightweight wall tiles, carpet		
Titebond Solvent Free: Franklin International	• Solvent-free, nonflammable construction adhesive contains 6.6 g/l VOCs. • Performance equivalent to conventional adhesives. • Complies w/APA, AFG-01 test for subfloors.		
Natural Adhesive	• Better choice than synthetic • often made of renewable resources		• May include methyl cellulose, natural latex, balm turpentine, boric acid, rosemary oil, eucalyptus oil, silicate clay, milk casein, borax, water • check carefully with installation instructions to make sure the adhesive will work
BioShield Paint Co.	• 98% of ingredients in their products are natural materials • Floor Adhesive: elastic, water-based glue for cork, natural carpeting, and linoleum with jute backing		

Walls

Interior walls may contain or be finished with materials that create an unhealthy indoor environment. The materials should be chosen carefully.

Fortunately, some of the most common wall construction materials have few negative environmental associations. Gypsum and plaster are among most benign building materials. While they do not release VOCs after their initial installation, both can absorb VOCs from other sources and release them slowly over time. Also, the joint compound used with drywall often releases VOCs.

When choosing drywall look for flue-gas (recovered) gypsum. Many plants are now using this manufacturing process that uses the waste product from stack scrubbers of coal-fired power plants. In addition, seek out drywall with high recycled content. Finally, specify low VOC joint compound and good ventilation during installation and minimize sanding the joint compound

Paint

Indoor finishes should be evaluated in terms of the effect of their manufacture, their effect on building use and performance, and their effect on indoor air quality.

Paint consists of three parts: pigment, binder, and solvent. The solvent is typically the portion of the paint that is environmentally harmful. Most solvents abound in VOCs. Solvents from the petrochemical industry are the most toxic. On the other hand, natural resin emulsions are solvent free and biodegradable. Traditional paint systems consist of powder with water added just before application. They contain no harmful chemicals and are washable after curing

Environmentally, the best paints are those from natural sources. First choice should be linseed oil based paints, which are totally renewable, though they do contain some natural VOCs. The second best choices are wood or vegetable resin paints which are renewable but solvent borne with VOCs, or distemper, mineral paints, and limewash which have no VOCs but contain nonrenewable resources.

All synthetic paints are harmful in terms of manufacturing impact. However, if natural paints are not a viable option, there are some things to keep in mind. The best conventional paints are zero VOC 100% acrylics which have good durability and a marginally lower manufacturing impact, though they are more expensive than other synthetics. If this is not possible look for paint with the lowest VOC content available. Still beware of synthetic paints that are advertised for having a low VOC content. They often still contain many toxins like acetone, ammonia, and crystalline silica that are irritating to those with chemical sensitivities. They may also contain formaldehyde precursors that allow the paint to create formaldehyde as it cures, making it formaldehyde-free in the can, but not on the walls.

Avoid oil based or vinyl emulsions if at all possible. In any case apply paint with a brush; do not spray.

Other Wall Treatments

Vinyl wallpaper should be avoided. Instead, use natural paper wallcoverings. Also consider a durable wall material (wood, tiles, etc.) that does not need any treatment.

Walls

Option	Environmental Pros	Environmental Cons	Appropriateness
Gypsum drywall	• Gypsum is plentiful • Paper facing is generally 100% recycled • Long life expectancy as long as water damage is avoided	• May be initial VOC off-gassing from drywall and joint compound (but inert after installation) • Drywall can absorb VOCs from other sources and release them over time • Create a lot of waste, typically 10% of material • Landfilled at end of life	• Look for high recycled content • Specify low-VOC joint compound (unless it requires shipping over long distance) and good ventilation during installation • Specify dry-mix joint compound which have fewer additives instead of ready-mix products • Use paper, not fiberglass joint tape
Plaster-and-lath	• Plentiful resources • Little negative impact on installer's health • Long life expectance	• May be initial VOC off-gassing from plaster (but inert after installation) • Create a lot of waste • Landfilled at end of life	
Veneer Plaster	• Gypsum is plentiful • Paper facing is generally 100% recycled	• May be initial VOC off-gassing from drywall and joint compound (but inert after installation) • Create a lot of waste, typically 10% of material • Landfilled at end of life	• Look for high recycled content • Specify low-VOC joint compound and good ventilation during installation • Specify dry-mix joint compound which have fewer additives instead of ready-mix products • Use paper, not fiberglass joint tape

Paints

Option	Environmental Pros	Environmental Cons	Appropriateness
Synthetic Paints		• **Negative manufacturing impacts**	
–Zero VOC 100% acrylic	• Best option within synthetic paint category • Good durability • Marginally lower manufacturing impact		• More expensive than other synthetics • If not available, look for lowest VOC content available
AFM Safe Coat	• Primers, interior and exterior low VOC • No formaldehyde • Interior Paint contains zero VOCs; no formaldehyde, ammonia, crystalline silica, or ethylene glycol		
Benjamin Moore Low VOC paints	• Primer, sealer, flat, eggshell, and semigloss low VOC paints available • Low odor, low VOC, 100% latex paints: Pristine® Eco Spec® Interior Latex Flat 219, Pristine® Eco Spec® Interior Latex Eggshell Enamel 223, Pristine® Eco Spec® Latex Semi-Gloss 224		
Genesis Odor-Free (low VOC): Duron Paints	• Interior acrylic latex paint, low-VOC content • Available in flat, low-lustre and semi-gloss		

OPTION	ENVIRONMENTAL PROS	ENVIRONMENTAL CONS	APPROPRIATENESS
Harmony Coatings (low VOC): Sherwin-Williams	• Durable, low-odor, low VOC, anti-microbial, interior paint formulated without silica. • Flat, eggshell, gloss, and primer available • Meets or exceed the criteria set forth by LEED as defined in GreenSeal's GS-11, 2002.		
Lifemaster 2000: ICI Paints	• Interior eggshell, semi-gloss, and primer/sealer • 100% acrylic; no VOCs (1 gram per liter), low odor; solvent-free		
–Oil-based/Vinyl Emulsion Paints		• VOCs • Vinyl contains PVC • Use nonrenewable resources • Harmful manufacturing impact	• Avoid if at all possible
–*Recycled Paint*	• Reuses paint that would otherwise end up in landfill and pollute ground and water • No added manufacturing effects from reused material	• Paint is unlikely to have low VOC content	• May have limited color palette • For use anywhere conventional paint is used
Green Paint Co.	• Recycled paint (90% post-consumer)		
Natural Paints	• **Generally limited VOCs** • **Far fewer negative manufacturing costs**		
–Linseed Oil-Based Paint	• Best paint option from environmental perspective • Totally renewable	• Some natural VOCs	
BioShield Paint Co.	• 98% of chemicals in their products are naturally derived from plants and minerals • Wall Paint: solvent free, zero VOC in matte or satin finish; available with ultra low VOC tints; 1 gal=$29, 5 gal=$125; pigments sold separately; shipping is about an extra 10% • Casein Milk Paint: comes as dry powder (add water) to make an off-white base that can be tinted; suitable for drywall, plaster, wood • Wall glaze: water-based, transparent concentrate made of natural ingredients		
–Wood/Veg. Resin Paints	• 2nd best choice • Renewable	• Contains solvents, therefore VOCs	
–Limewash	• Other 2nd best choice • No VOCs	• Nonrenewable resource	• Lime, water, and 10% tallow, casein, or pulverized fuel ash • Often used in historic restoration projects • Applied by brush in several coats; more labor intensive than traditional paint
–Distemper (Milk Paint)	• Other 2nd best choice • No VOCs	• Nonrenewable resource	• Perishable once mixed • Often used in historic restoration projects • More labor intensive than traditional paint

Option	Environmental Pros	Environmental Cons	Appropriateness
Old Fashioned Milk Paint	• Recommended for restoration projects • Consists of milk protein, lime, and earth pigments; sold in powder, add water • Good for those with allergies and promotes good indoor air quality • Comes in 16 colors, base, primer (mix with white to get correct shade)		

Other Wall Treatments

Option	Environmental Pros	Environmental Cons	Appropriateness
Exposed wood	• avoid the need for paint or other finish	• avoid synthetic sealers which can release VOCs and entail a harmful manufacturing process	• especially appropriate for several of the cabins • Finish with natural oils, waxes, or sealers
AFM Safe Coat	• AFM Naturals include penetrating oil and oil wax made of natural ingredients • Low VOC stains and sealers; no formaldehyde • Safecoat Polyureseal BP: very low VOC content, comparable to conventional urethanes in performance for use on wood, metal, concrete, furniture, etc.		
BioShield Paint Co.	• 98% of chemicals in their products are naturally derived from plants and minerals • Aqua Resin Stain Finish: solvent free, zero VOC, water based interior and exterior wood stain; available in natural wood and accent colors • Aqua Resin Trim Enamel: solvent free, zero VOC, water based weather resistant satin finish for interior or exterior • Resin & Oil Stain Finish: colorize and preserve interior and exterior woodwork, provides UV protection • Wood Impregnation Stain & Sealer: exterior wood preservative, made of linseed oil and other natural ingredients • Citrus Thinner: low-odor solvent for clean-up of oil based products • Penetrating Oils & Sealers: made from linseed oil, plants and other non-petroleum based materials; breathable, elastic, water-resistant coating for interior or exterior • Floor & Furniture Finishes: oil based resin finishes and natural waxes		
Aqua ZAR: United Gilsonite Laboratories (UGL)	• Clear wood finish, water-based polyurethane • Low-odor, non-yellowing, fast drying, and resists most abrasions.		
Vinyl Wallpaper		• Contains PVC (see vinyl flooring)	• Should be avoided
Natural Wallpaper	• Made of natural and renewable materials		• May requires more intensive installation
EnVision Portfolio Collection: Duron Paints & Wallcoverings	Nonwoven textural, natural fiber, breathable, water-based inks, No PVCs or harmful substances Low sheen with pearlescent overprint, or metallic background with opaque overprint, 54″ x 30 yd bolts Class A fire-rated		
Paperez: Eisenhart Wallcoverings Co.	Nonwoven, water-based inks 100% strippable on properly prepared walls Class A fire rating		

OPTION	ENVIRONMENTAL PROS	ENVIRONMENTAL CONS	APPROPRIATENESS
InnVironments: Innovations in Wallcoverings	• Wide variety of wallcoverings made from cork, sisal, cellulose, and other natural, renewable and/or recyclable materials. • No solvents or heavy metals		
Muraspec Walls Natural Environments	**Grasscloth** papers handcrafted of natural farmgrown fibers and water-based inks; 36″x 8 yds **Treviso** non-woven cellulose and polyester with 100% cotton scrim; 54” width **Abaca** non-woven from wood pulp/polyester fibers/nylon; water-based inks; no heavy metals; pulp from managed forests; 54” x 30 yd bolts; **Agave** non-woven wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 56” x 30 yd bolts; **Fusama** non-woven wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 56” x 30 yd bolts; **Kamiko** non-woven mulberry bark/wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 42” x 30 yd bolts; All have class A fire-rating Shipped from Europe		
Ceramic Tiles	• Durable • Porcelain tile does not off-gas • Does not support mold, mildew or bacterial growth	• High embodied energy	• Choose an adhesive with little or no solvent
Recycled/Reused Glass Tiles	• Durable • Reused material, avoid landfill and manufacturing effects		• Choose an adhesive with little or no solvent
Amdec	• Made from 100% recycled post-consumer and post-industrial bottle glass • Use anywhere ceramic tile would be used: counter tops, back splashes, fireplace hearths, showers, walls, pools, spas and floors in light traffic areas • Exceed ANSI specifications for breaking strength. • Translucent, opaque, semi-gloss, matte; individually handcrafted		
EcoFriendly Flooring	• Glass tile: made from 100% recycled glass from post-consumer or post-industrial sources; appropriate for countertops, backsplashes, showers, and landscaping; 2″, 4″, and 6″ square; many colors/finishes available		
Quarry Tile Co: Eco-Tile	• Ceramic Tile • Contains a combination of post-consumer recycled glass, post-industrial grinding paste from the computer industry, and post-industrial mining waste from the sand and gravel industry		
Sandhill Industries	• 100% recycled glass; each tile takes less than one-half of the energy to produce than ceramic tile, and less than one-fourth of the energy it takes to produce a cast-glass tile • Used for interior and exterior installations on both horizontal and vertical surfaces • Manufacturing facility in Boise, Idaho • Available 36 colors, glossy or matte finish • Available as field (loose) tile or mosaic mounted on front faced film		
Smart House International	• Glass tile: some with 100% recycled content (not all sizes)		

Thermal Comfort

Conventionally, buildings are designed to create an indoor thermal environment that falls within a narrow temperature range, hovering around 70˚ F. However, the human comfort range far exceeds the conventional comfort window on both ends, depending on the activity and amount of clothing worn, as shown in the chart below. It is estimated that for every 1˚ C (1.8˚ F) we raise indoor temperature, 10% more fuel is burned. With this in mind, it is clear that simply adjusting clothing levels is the more economically and environmentally responsible choice. Little or no heat at all is needed during sleep.

Clothing value	Walk	Stand	Sit	Rest
0.0: Nude	70˚	81˚	82˚	86˚
0.5: Light clothes	59˚	73˚	77˚	81˚
1.0: Normal clothes	46˚	66˚	70˚	75˚
1.5: Heavy clothes	32˚	57˚	64˚	70˚
2.0: Very heavy clothes		50˚	57˚	64˚

Before considering the type of heating system to use, it is important to ensure that the house is well sealed and insulated. Once that issue is addressed there is a wide range of heating options.

Water Based Heating

Steam and hot-water systems make use of the thermal properties of water for heating. All of these systems require a boiler either as the sole energy source or as a back-up for solar heated water. For water-based heating, gas boilers are generally the most efficient. Condensing gas boilers are about 20% more efficient than conventional gas boilers. In a condensing boiler, the steam that results from gas combustion is cooled by the return water from the heating the system. As the steam condenses it releases latent heat which is used by the boiler.

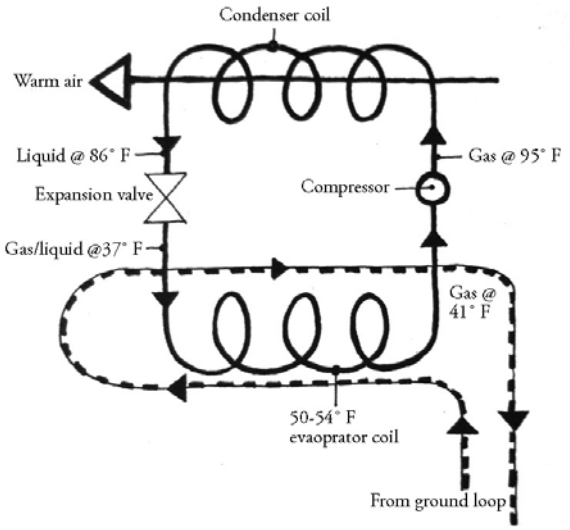
In-floor radiant heat operates on the principle that the experience of heat is equal to the average of radiant temperature of surrounding objects and the air in a room. In-floor concrete radiant systems are slow to respond to changes and are therefore not appropriate for rooms with large south-facing windows.

Radiators with low capacity are preferable to larger models, as they are able to respond to changes in demand quickly. Old radiators can be replaced by ones with small-bore flow and return pipes (15-22mm) or even microbore pipes (12 or 6mm). Water is pumped under pressure through each radiator individually and back to a common manifold. (In old systems, the water travelled through all radiators before returning). This not only maximizes efficiency but isolates radiators for easier repair. Choose thermostats instead of simple on/off valves on radiators. Positioning radiators along interior walls rather than beneath windows will slow heat loss through windows. If radiators are beneath windows, be sure that curtains fall behind them so that hot air is not pulled behind the curtain. Place a shelf above a radiator to throw heat back into the room. An insulated reflector between the radiator and external wall will also direct heat into the living space. More extensive information on boilers and solar water heat can be found in the water heat section.

Geothermal

Geothermal pumps draw heat from the ground. They have two main elements. One is a high density polyethylene pipe filled with water and antifreeze that is buried in the ground as a heat transporter. Pipe is laid either horizontally or vertically. The other element is the heat pump with an evaporator coil, compressor, condenser coil, and expansion

valve. A liquid refrigerant is forced through an expansion valve. As the liquid leaves it loses pressure and thus evaporates and removes heat from water in the ground loop pipes that are wrapped around the evaporator coil. Water leaving the evaporator casing is cooled and ready to move heat from the ground. The refrigerant is now a gas that goes through the compressor. High pressure makes the refrigerant vapor condense at a fairly high temperature and release heat to the heat condenser coil at 65˚C. A reverse valve allows the system to be used for cooling in the summer. A heat pump delivers cooler air than a conventional HVAC system. Thus more air needs to be delivered, either through larger ducts or a faster blower (i.e. AC speed).



Geothermal heating; image from *Eco-Refurbishment*

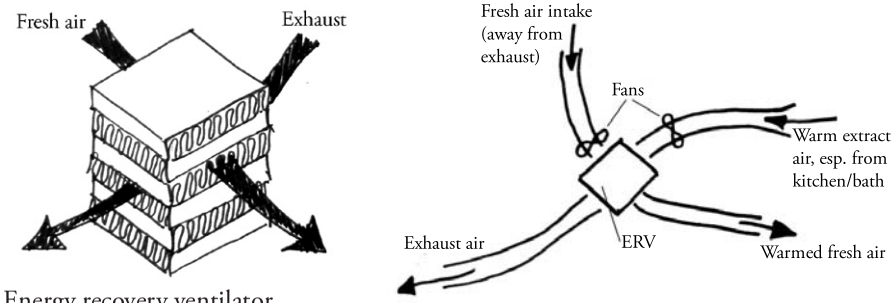
Open loop systems use ground water from an aquifer that is piped directly from the well to the building. After the water leaves the building, the water is either drained at the surface (to a stream, pond, river, etc), sent to a properly sized drainfield below the surface, or pumped back into the same aquifer. Poor water quality, however, can cause serious problems as it may cause mineral deposit to build up in the heat pump heat exchanger. Water from springs, ponds, rivers etc. are not recommended. A closed loop system is more common and better suited to cold climates like Minnesota.

Stirling Engine

The Stirling Engine was invented in 1816. An "external combustion engine," heat is applied to the exterior of the unit to heat gas within a closed cylinder. The engine contains a fixed amount of helium or nitrogen gas in the cylinder. The heat is applied only to one end; the temperature difference between this end and the cool one drives a piston inside. Heat can be drawn off of the cool end to provide space heating for forced air or wet heating systems or for domestic hot water. In addition to heat, Stirling engines create some DC electricity. Because Stirling engines do not involve explosive combustion, they are very quiet. They can operate on natural gas, diesel, or oil and are 90% efficient (a conventional boiler is only 60% efficient) and can be adapted to provide cooling. A Stirling Engine uses external combustion to efficiently produce heat and some DC energy. The engine operates on natural gas, diesel, or domestic fuel oil.

Energy recovery ventilator

An energy recovery ventilator is a heat exchanger combined with a ventilation system for controlled ventilation. It can be a significant source of energy savings in larger buildings, as it captures heat energy



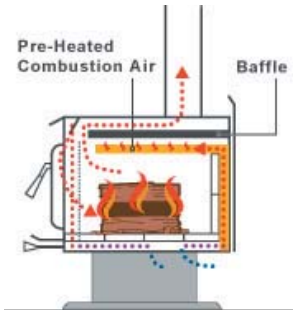
Energy recovery ventilator

that would otherwise be lost, lightening the energy load on the heating system. An ERV with humidity regulation includes a way to increase or decrease the humidity of ventilated air. The ERV brings in fresh air to tightly sealed buildings and preheats it with heat from the exhaust air. These systems can be costly (over $1000). ERVs can be wall mounted or duct-connected and require two small fans.

Wood-burning stoves

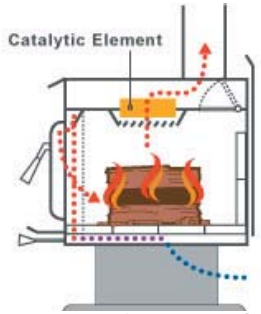
Although older wood-burning stoves were inefficient at heating and were often sources of pollution both within and outside the home (releasing between 30–80g of particulates per hour), highly efficient modern stoves are available that eliminate these problems (releasing less than 6g/hr). Improved stoves include a grate to ensure regulated air supply, a refractory lining in the combustions chamber to minimize surface heat loss, and a fuel door to minimize open flame heat loss. Wood pellets and manufactured fire logs are available that burn more cleanly than regular firewood. Choose stoves that have received EPA certification for efficiency (Ideally up to 80% efficient).

Stoves are available in non-catalytic and catalytic types. New recirculating non-catalytic stoves have firebox insulation, a large baffle (to produce longer, hotter gas flow) and pre-heated combustion air brought in above the fuel in the firebox to ensure a good environment for complete combustion. Non-catalytic stoves do not produce heat as evenly as catalytic stoves, though they are more popular and a bit simpler to operate.



Non-catalytic stove; from <*www.epa.gov/air progmoar/woodstoves/technical.html*>

Catalytic stoves decrease the normal burn temperature for a slow, controlled fire with the fewest emissions. The exhaust enters a ceramic honeycomb where all incompletely combusted material burns. All of these types of stoves have a lever to move the bypass damper during starting and reloading. The durability of the ceramic honeycomb is dependent on proper care of the stove. If used properly, it will last over six heating seasons. For this type, choose a cast iron or plate steel body (1/4″).

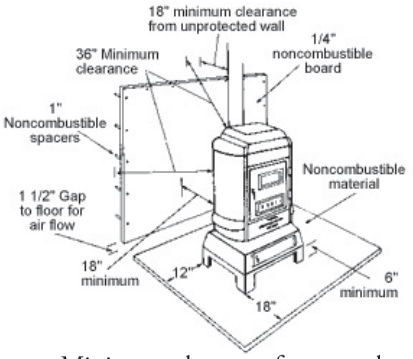


Catalytic stove; from <*www.epa.gov/air progmoar/woodstoves/technical.html*>

Pellet-burning stoves are the cleanest and most efficient option. They use a motorized fan to distibute space heat. Pellets are made from renewable biomass, often recycled wood water. This redirects waste from landfills and converts it into usable energy. Pellet stoves look similar to wood stoves but are generally automated and require less regular attendance. The user adds pellets to a hopper and sets the desired heat output. The user must provide regular maintenance and clean the ash tray. Many pellet stoves are available that do not require a complicated chimney. Instead, they vent directly outdoors.

Care must be taken to install a wood-burning stove safely. It should have appropriate clearance from all combustible surfaces, including wall, floors, and furniture.

The size of the chimney should be close to (never less than) the diameter of the stove's flue outlet. If the stove is burning properly, the only visible exhaust should be white transparent steam, with darker and opaque smoke only slightly visible.



Minimum clearance from combustible surfaces; from <*www.epa.gov/air-progm/oar/woodstoves/technical.html*>

The latter is a sign of particulates and volatile gases, the products of incomplete combustion. Manufacturer instructions should be consulted to determine the necessary chimney capacity, height, and location. Ideally a chimney will be located in the center of the house where most of it is inside of the building.

At Arcola Mills the stone chimneys are quite old and have been out of use for some time. If they are to be re-adapted for wood stoves they must be inspected for safety. They should have a tile lining or a stainless steel stovepipe on the interior. Before use, a professional building inspector should check the installation.

In addition to installing an efficient and clean-burning stove, it is important to operate it properly. If conventional firewood is used it should be adequately air dried in order to extract the maximum amount of energy from the wood. Green wood produces about 60% less energy than dry. To avoid smoke, first preheat the chimney. Remove all but the thinnest layer of ashes and put 5-6 pieces of crumpled newspaper and fire kindling in the stove. Open the dampers and ignite the paper on all sides. Keep adding kindling until the chimney is preheated. The fire should burn with lots of fast flame during startup. To reload, put finely split pieces on the charcoal bed and fully open the air supply. The chimney is adequately preheated when large pieces burn vigorously without any loss of intensity. During the warmer season, the heat should be controlled by the amount of fuel, not by limiting the air supply. Small hot fires (which require regular attendance) are the most efficient. That said, extremely hot fires (often the result of burning trash, lots of paper etc.) should be avoided as they can damage the stove or start a chimney fire. Ash should be removed from the stove in a non-combustible container and kept away from combustible materials. Ash can be disposed by spreading it in gardens or compost piles.

Chimneys and vents must be checked annually. Chimneys should also be cleaned anually to remove built-up creoste. Stove pipes should be checked regularly for corrosion. A chimney temperature gauge can be installed to display the temperature of exiting gases. It can be used to monitor the stove's use and prevent excessive production of harmful creosote. A sufficiently sized fire extinguisher should be available near the stove.

For more information on wood burning stoves see: http://hpba.org/communications/FactSheets/answers.shtml.

Ducts

In blown air systems, the ducts can have a significant impact on energy efficiency. Duct leakage is a major source of energy loss and poor indoor air quality. Faulty ducts also allow for depressurization (from closed interior doors that block air from return plenum) and overpressurization within the building. To allow the ducts to function properly, doors must be sufficiently undercut for air to pass between rooms.

Ducts should be insulated to at least R-6 with a reflective outer surface. They must also be fully sealed. All ducts should first be mechanically fastened with screws, rivets, or metal bands for flex ducts. Duct mastic is the preferred flexible sealant. It can move with expansion, contraction, and vibration. If a gap is more than 1/4″, reinforce the mastic with fiberglass mesh tape (similar to drywall fiberglass tape, but wider and treated to reduce smoke development). Do not use duct tape except to seal joints on access doors. The area to be joined should be wiped clean with a dry rag, the mastic applied with a trowel or brush and spread 1″ beyond the joint. Gaps over 1/2″ need a rigid metal covering. All connections must be sealed. Seal penetrations into the plenum. Flex duct inner and outer linings should be sealed—do not extend duct liner through the wall of the plenum to the interior of the plenum. Seal the air handler closet and the handler itself. Line the return plenum with

duct board (foil face in) and seal. The support platform should be sealed on all sides. Seal all penetrations into the plenum. Seal return grills at the point of penetration to the walls. Seal all structural cavities (duct board—cut to fit—placed on all 4 sides, foil sides in, and sealed).

Overall concerns

A heating system (via the thermostat) should be able to respond to quick changes. This is easiest with radiators of low capacity. Full central heating may be unnecessary for small, well-insulated houses or if activities are concentrated in one or two rooms. Generally, in a small two-story house, the upper floors can be heated by heat sources on the first floor due to the stack effect.

Whatever system is used, a programmable thermostat can save energy. The temperature should be set significantly lower overnight. A winter temperature setback can save 16-30% on energy. The thermostat should be located away from extreme temperature areas. When choosing a thermostat look for features such as a sensor for outdoor conditions so that recovery from a setback setting occurs at a good time, manual override, a back-up battery in case of power outage, different scheduling ability for weekdays/weekends, and a low-battery indicator.

Water Based Heating

Option	Environmental Pros	Environmental Cons	Appropriateness
Gas Boilers	• Condensing boilers reclaim heat from exhaust gases	• Energy inefficient if boiler is sized too large	• Gas, condensing boiler should be used • Choose electric ignition (gas pilot light is wasteful)
Gasification Wood Boilers	• Efficient combustion (90%), emission levels similar to natural gas • Uses renewable resource	• Appropriateness of wood for burning depends on source	• Can be loaded for up to 24 hours
Radiators	• Choose radiators with low capacity for quick responsivity • Small or microbore pipes increase efficiency		
Radiant Heat	• Necessary water temperature change to change room temperature is relatively small • Boiler can be set at lower temperature		• Uses a low-temperature boiler • Reduced needed amount of mechanical ventilation • Hydronic radiant heat can be as cool as 85˚-90˚ • Can be slow to react to temperature changes
–Radiant Floor (Core System)	• Water circulates through plastic tubes embedded in a concrete slab • Slow to respond; not appropriate for rooms with large south-facing windows		
–Panel System	• Aluminum panels with metal tubes connected • Minimal thermal mass, so system has a quick response time • Often used with suspended ceilings		
–Capillary System	• A fine grid of small-bore plastic tubes placed under a wall or ceiling, or imbedded in gypsum board. • Appropriate for a retrofit • Takes up a whole plane of a room		

Geothermal Heat

Option	Environmental Pros	Environmental Cons	Appropriateness
Geothermal Pump	• Uses 50% less electricity than a conventional electric heating/cooling system • Cuts overall energy consumption • Can provide hot water as well	• Uses electricity to power system • Uses more electricity than fossil-fuel based systems	• Can be very invasive to the landscape • Requires adequate draw area in ground so that ground isn't frozen by process • Delivers cooler air than conventional HVAC; requires larger ducts or faster blower
–Open Loop	• May be used if ground water is plentiful • Simplest to install		
–Closed Loop	• Most common and appropriate for most situations • May be installed horizontally or vertically		
Econar	• 50 year warranty • Can be incorporated into forced air and radiant heat systems • Can also be used for domestic hot water •Typical home of 2000 sf costs between $10,000-$15,000 (about double cost of conventional heating, cooling, and hot water system)		

Stirling Engine

Option	Environmental Pros	Environmental Cons	Appropriateness
Stirling Engine	• Significantly more efficient than conventional gas boiler • Produces supplemental electric current	• Does consume some non-renewable resources	• Operates on natural gas *Whispertech, Sunpower USA*
WhisperGen; WhisperTech	• Gas-powered Stirling engine produces residential heat and supplemental electricity • Not currently available in the United States		

Heat Recovery Ventilator

Option	Environmental Pros	Environmental Cons	Appropriateness
Energy (Heat) Recovery Ventilator	• Ventilation can improve indoor air quality • Recovers energy (heat) from exhaust air that would otherwise be wasted • Reduces heating load and thus energy consumption		• Most crucial for highly air-tight buildings, those where heating/cooking equipment is not adequately vented, of if there are high radon or formaldehyde levels • Installed in attic or storage area • Requires 2 connections to outside for intake and exhaust—ideally on different sides of house • Supply outletshould not blow directly on people • Exhaust can be hooked to bathroom fan

Space Heating

Option	Environmental Pros	Environmental Cons	Appropriateness
Wood Burning Stove	• Pellets and manufactured logs burn more cleanly • Catalytic stoves create the fewest emissions	• Potential hazardous emissions from incomplete combustion	• Only effective if it is a super-efficient model
Jotul wood stoves	• All models made of 100% recycled cast-iron • Several small options available • Non-catalytic combustion, EPA approved, efficiency around 68% combustion, emissions for smaller models range from 2.4 g/hr–5.2g/hr • Functional cookplates		
Lennox Hearth Products (wood & pellet stoves)	• Wood burning stoves: cast iron non-catalytic, EPA approved, emissions range 2.72 g/h–4.42 g/hr • Pellet Stove: 1 load proved up to 36 hr. fuel; achieves nearly 100% combustion, 0.9 g/hr emission, self-igniter button starts fire		
Marine Stoves (wood burning)	• Small models appropriate for boat or cabins • EPA Certification • Non-catalytic, efficiency and emissions unknown		
Thelin Stoves (wood & pellet)	• Pellet heaters equipped with battery back-up in case of power outage, efficiency ranges 78.5%–94% • Wood stoves all surpass EPA standards, 3.62 g/hr emissions; efficiency unknown		
Electric Space Heater		• Most inefficient form of heat; uses worst energy source in terms of pollution, resource consumption	• Use should be strictly limited

Solar Heat (passive)

Passive solar heat can significantly reduce heating loads when employed properly at a favorable site. Solar energy is free, pollution-free, and renewable, making it an attractive source of heat both economically and environmentally. It does, however, require careful planning and an appropriate site.

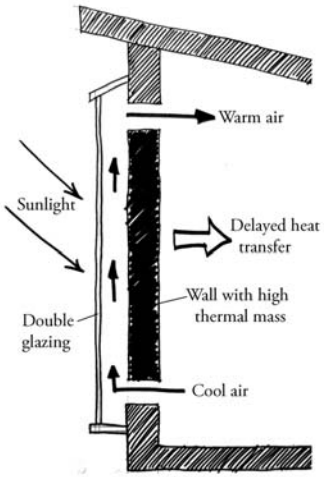
In general, for a cold climate like Minnesota, a building elongated on the east/west axis is the most efficient. This orientation provides the greatest southern exposure in the winter and minimizes east and west exposure in the summer. For northern latitudes, the northern exposure should also be minimized. East and west windows can often cause overheating and should be kept to a minimum. Ideally, south facing windows should receive sunlight between 9am and 3pm during the heating season. Significantly less exposure may turn a passive solar heating system into a net heat loser. The three main approaches to passive solar heating are direct, indirect, and isolated gain.

Direct Gain

In direct gain, the living space itself is a solar collector, absorber, and distributor. The thermal mass of walls and floors absorb heat during the day and radiate at night. Therefore the thermal mass materials should be kept as bare as possible. Floors should have a medium dark color. Lightweight walls should have a light color to reflect light onto the mass materials. Thermal mass walls can be any color. For about every square foot of south-facing glass, about 150 pounds of masonry or 4 gallons of water should be used. The surface area of the mass exposed to direct light should be about nine times the glazing area. Direct gain systems can actually be net energy losers if night moveable insulation is not used.

Indirect Gain

For indirect gain systems, thermal mass is located between glazing and the living space. Operable vents at the top and bottom of the wall allow heat to convect from between the wall and the glass. These vents must be closed at night. The exterior mass wall should be dark. The space between the glass and the wall should be at least 4 inches. A well insulated house requires about two square feet of thermal mass per square foot of floor area. A thermal wall should be about 10″-14″ thick for brick, 12″-18″ for concrete, and 8″-12″ for adobe or other earth material.



Indirect gain; trombe wall

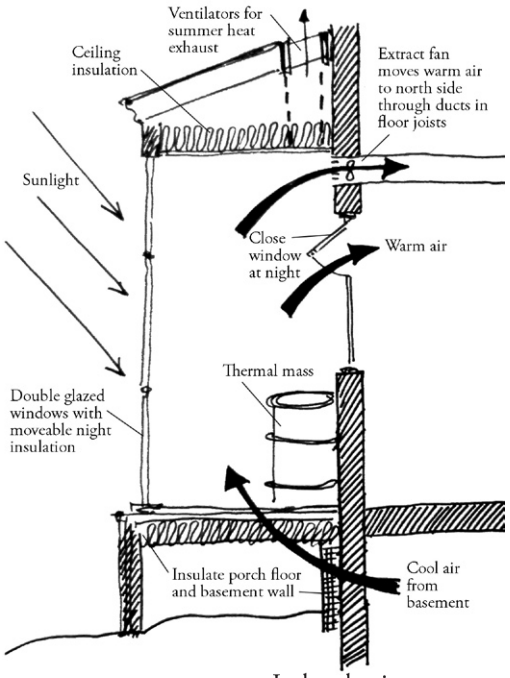
Isolated Gain

A sunroom is an example of an isolated gain system which creates a convective heat loop. Heat energy is retained in the mass and air of the sunspace and brought into the home through conduction of the mass wall or through vents. Again, the thermal wall should have a dark color with similar thickness as prescribed for the other systems. Water can also be used for thermal mass. It makes excellent thermal storage since its quantity is adjustable.

A ventilation system is necessary to allow the heat to escape in the summer. Overhead glazing is not recommended for this system, as it can easily cause overheating of the space, and introduces complications into the building process. Clear glass (not low-e) will let the most solar

energy into the sunspace. Warm air can enter the house through high windows or vents, with return air drawn from the basement or bottom of the window. The warm air can passively vent into the adjoining space or a variety of simple methods can be employed to route the warm air to other areas of the house. An extract fan can take heated air to the north side via ducts between floor joists. The fan should be wired to a thermostat so that it automatically turns on when the temperature in the sunspace is at the desired level. The fan can also blow hot air outside when it is no longer the heating season.

A sunspace also acts like a buffer zone, even in the absence of direct solar gain. An ideally spaced and sized sunroom can provide 70%-80% of the heat needed in this part of the country. Night insulation is necessary for a functional sunspace. It can be a quilted fiberglass pop-in, a pool cover or a number of other options (See Insulation (placement), pg. 5). Don't use rigid foam if the sunspace is going to be a fire exit as it will release toxic fumes when burned. A location's solar window can be determined with a solar plotter.



Isolated gain; sunspace

Option	Environmental Pros	Environmental Cons	Appropriateness
Direct Gain	• Free, renewable, non-polluting energy source	• Depends on materials and construction techniques of structure • Can be a net energy loser if night insulation is not used	• Requires appropriate exposure and building materials
Indirect Gain	• Free, renewable, non-polluting energy source	• Depends on materials and construction techniques of structure	• Requires appropriate exposure and building materials
Isolated Gain	• Free, renewable, non-polluting energy source • Can be used for growing plants • Acts as buffer zone, regardless of solar gain • Can provide significant portion of necessary heat	• Depends on materials and construction techniques of structure	• Requires appropriate exposure and building materials • Must be sealed from the living space except when conditions are favorable for solar gain • All unglazed spaces should be well insulated • Fan and thermostat necessary for appropriate distribution of heat • Requires moveable insulation for night, and overcast days

Solar Heat (active)

While passive systems are always the most environmentally benign, active solar systems are still desirable from an environmental standpoint since they use a renewable non-polluting energy source. These systems can be used for hot water and additional space heat. Active domestic water systems consist of a collector, circulation, storage, backup, and control system.

Collector

There are a number of different collector types available: flat plate, integral collector/storage (ICS), and evacuated tube collector.

Flat plate systems are the most common. In these systems an absorber plate is placed under a clear layer of glazing.

In an ICS system, one or more black tanks or tubes are placed in an insulated glazed box. Cold water passes through (preheats) and continues to conventional backup water heater. Because this system involves water exposed to outdoor temperatures, this system is not appropriate for Minnesota.

Evacuated tube systems consist of parallel rows of glass tubes with a metal absorber tube inside, attached to a fin.

An air collector appears similar to water collector. A black metal absorber is in an insulated glazed box. Air from inside the box is drawn by a fan into a series of channels in a space behind the absorber where it is heated by an absorber plate. Air enters the home directly or a storage medium (rocks) holds the heat for use during the night. A controller fan turns the system on or off, using sensors in the collector to activate when it is hotter. Air collectors can be mounted vertically on a south wall if used for space heating only. (A well designed overhang can prevent overheating in the summer.) For year-round use, an air-to-water heat exchanger is necessary. This system is not as efficient as fluid-circulating systems.

Solar collectors typically have a high initial cost and a low operating cost. They are most effective if loads are minimized and the building is well-insulated. The water heater thermostat should be lowered to 120˚. To be efficient, collectors require full sun from 9am to 3pm in the heating season. The collectors should be tilted (usually at latitude +15˚) so that they are perpendicular to the sun during the heating season. Collectors ought to be placed as close as possible to due south, though they will still function within 30 degrees of south. Collectors and storage tanks should be placed close to the backup and distribution system to avoid pipe loss and, of course, pipes should be well insulated.

To determine the number of collectors that are needed to meet heating needs, the average heat load should be divided by the collector rated heat output (available from the manufacturer). For each square foot of collector, about 1.5 gallons of hot water storage is needed. To ensure that you get a good product, select systems tested and certified by the Solar Rating and Certificate Corp (SRCC).

Circulation

Solar water heating systems can use direct or indirect circulation. Direct circulation systems pump household water through collectors and into the home. These systems are not appropriate for cold climates like Minnesota. In an indirect circulation system, pumps circulate a non-freezing, heat transfer fluid (like antifreeze) through the collectors and heat the exchanger. Although these systems are more complicated, they are necessary for cold climates where water might freeze.

Solar Heat (active)

Storage, Backup, Controls

Active solar heating can tie into any heating distribution system that uses heated fluids as a heat source. It is appropriate for systems that use hydronic radiators, floor coils, or forced air. Even in an ideally sited system, an auxiliary heating system is necessary.

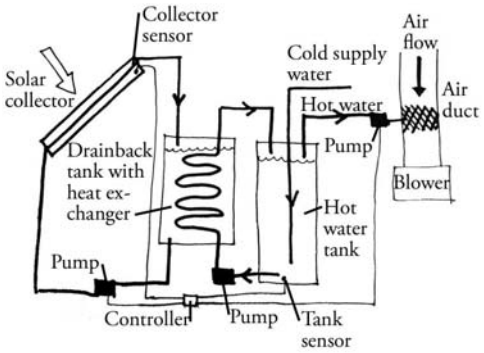
A controller allows fluid/water to be pumped from the collectors when it is above a minimum temperature. The auxiliary heater can add heat to solar storage when necessary, or the solar system may simply lighten the load of a conventional furnace. If the solar system is used with hydronic radiators, the heated water from the collectors circulates along with a boiler into the radiators, reducing the boiler's energy use. If the solar system is used with hydronic in-slab heat, water from the solar system is pumped through piping in the floor. Water temperatures in an in-slab system are lower than others (not over 80˚). In this case the auxiliary heat system is connected to heated output water or connected to the solar tank.

Option	Environmental Pros	Environmental Cons	Appropriateness
Flat Plate Collector	• Utilize free, pollution-free, renewable energy source		• 10-15 sf of collector per person; storage tank of 20-30 gal per person
Air Collector	• Utilize free, pollution-free, renewable energy source		
ICS	• Utilize free, pollution-free, renewable energy source		• Not appropriate for MN climate
Vacuum Tube Collector	• Utilize free, pollution-free, renewable energy source • Most efficient collector type available		
Direct Circulation System	• Utilize free, pollution-free, renewable energy source		• Not appropriate for MN climate
Indirect Circulation System	• Utilize free, pollution-free, renewable energy source		• Uses non-freezing heat transfer fluid–appropriate for MN climate • Require regular inspection (about every 2 years) of the antifreeze; not required if using oil or refrigerant fluids which are more expensive

Water Heat (general)

Gas water heaters are the best choice among conventional heating options (excluding solar).

Some systems combine water and space heating in one system. Obviously, this can be done with hydronic heating systems, but it can be done with forced air heat as well. In the latter, circulating hot water from the water heater moves through the heat exchanger into the air handler. The blower moves the hot air through the regular duct system. To size a combined system, an air handler and coil should be selected that are greater than the heat loss of the design. The water heater output should be rated greater than the output of the coil and handler. A minimum 40 gallon storage tank is necessary. Any water heater sized to meet space hating requirements will meet domestic hot water needs.



Water-based forced air system supplemented with solar energy; image based on one from <*www.greenbuilder.com*>

The simplest way to reduce energy consumed for hot water, is to limit hot water use. This can be done by keeping showers short, and installing low-flow fixtures on taps.

The bathroom and shower should be insulated to prevent water heat loss during use.

Option	Environmental Pros	Environmental Cons	Appropriateness
Solar	• Non-polluting and renewable energy source		• Requires unshaded south facing location for collector
Gas	• High-efficiency models available • No electricity required	• Uses a non-renewable resource	• Can be combined with a space heating system • Takes less space than 2 separate systems

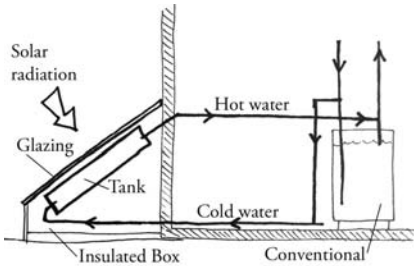
Water Heat (solar)

Solar water heat systems require a backup water heat system. It is unlikely, even in the best conditions, that a reasonably sized solar system will be able to produce all of the needed hot water during the heating season.

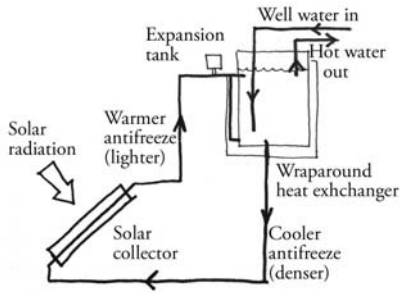
Passive Systems

Passive systems use natural convection or household water pressure to circulate water through the solar collector to the storage tank or point of use. They are less efficient than active systems, but simple and economical.

There are two basic types of passive systems: batch and thermosyphon. The batch system is the simplest. One or more metal water tanks are painted black and placed in an insulated box with a glazed cover. Existing house water pressure moves the water. When a tap is opened, heated water from the tank is removed and new water is added. This system requires highly insulated piping. Polybutylene piping is often used to avoid freezing pipes. The mass of the batch heater prevents its freezing. An insulating cover should be placed on the heater at night. Manufactured batch heaters have a "selective surface" that readily absorbs heat but permits little heat loss.



Batch water heating



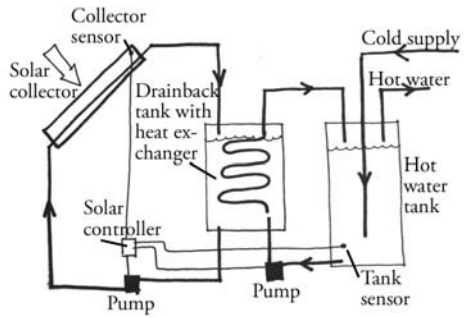
Thermosyphon water heating

Images based on those from <*www.greenbuilder.com*>

Thermosyphons consist of a flat plate collector and a separate storage tank located higher than the collector. The collector is similar to those used in active systems. Water from the top of the collector enters the top of the storage tank. Cooler water from the bottom of the tank is drawn to the lower entry of the collector. This system may or may not use a heat exchanger. Thermosyphon systems are more expensive than batch systems.

Active Systems

Active systems tend to be more versatile than passive systems and therefore more appropriate in most situations. In an active system, a collector heats water; sensors and a controller activate a pump to circulate the fluid in the collector, which can be potable water from the storage tank or food-grade antifreeze for freezing climates. The fluid is drawn from the bottom of the storage tank and circulated back to top. This system can function as a preheater for a conventional system. There are three types of collectors for active systems: unglazed, flat plate, and evacuated tube.



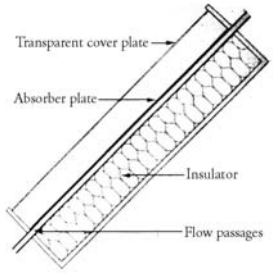
Active solar water heating system; image based on one from <*www.greenbuilder.com*>

In an unglazed system solar energy heats a black plastic or metal pipe through which the fluid flows.

Flat plate systems are the most common, in which an absorber plate is placed under a clear layer of glazing.

Evacuated tube systems consist of parallel rows of glass tubes with a metal absorber tube inside. The absorber transfers heat energy to the

Water Heat (solar)



Flat plate collector; image from *Eco-Refurbishment*

Vacuum tube collector; image from *<www.viessmann-us.com>*

heat transfer liquid.

Solar collectors typically have a high initial cost and a low operating cost. They are most effective if loads are minimized. The water heater thermostat should be lowered to 120˚. To be efficient, collectors require full sun from 9am to 3pm in the heating season. The collectors should be tilted (usually at the degree of latitude) so that they are roughly perpendicular to the sun. Collectors ought to be placed as close as possible to due south, though they will still function within 30˚ of south. Collectors and storage tanks should be placed close to the backup system to avoid pipe loss and, of course, pipes should be well insulated. Where the total amount of solar heat collection is small, the most successful method is to use solar energy to preheat the water in a hot water cylinder so that less energy is used bringing the water up to the required temperature in a conventional boiler.

Each person requires approximately 10-15 square feet of collector area with a storage tank of 20-30 gallons per person. The optimum panel size for an average house is usually around 30 square feet. To ensure that you get a good product, select systems tested and certified by the Solar Rating and Certificate Corp (SRCC). Collectors and insulated pipes can last the lifetime of a house. The circulating pump, antifreeze, and a few minor components are subject to wear and will need replacement periodically. The system should be checked every 5-10 years by a technician. Average annual maintenance for an active system is about $25. A typical 2-panel system costs about $5000-$6000.

Passive Systems

Option	Environmental Pros	Environmental Cons	Appropriateness
Batch	• Non-polluting and renewable energy source	• Back-up system needed	• Requires unshaded south facing location for collector • Most appropriate if hot water is used mostly in the afternoon and evening. • Storage tank/collector combined or very close; requires a very strong roof as it can way 300 lbs. or more
Thermosyphon	• Non-polluting and renewable energy source	• Back-up system needed	• Requires unshaded south facing location for collector • Requires way to support storage tank at elevation higher than collector • Storage tank/collector combined or very close; requires a very strong roof as it can way 300 lbs. or more

Water Heat (solar)

Active Systems

Option	Environmental Pros	Environmental Cons	Appropriateness
Unglazed collector	• Non-polluting and renewable energy source	• Some energy required for operation	• Requires unshaded south facing location for collector • Simple and cheap but only raised the water temperature about 20˚ C above air temperature
Flat Plate Collector	• Non-polluting and renewable energy source	• Some energy required for operation	• Requires unshaded south facing location for collector • Raises temperature up to 70˚ C
Evacuated Tube Collector	• Most efficient collector type	• Some energy required for operation	• Requires unshaded south facing location for collector • Raises temperature 100˚ C
Vitosol 300	• Applicable for flat or sloped roofs • Can utilize diffused radiation • Dry connection of the collector tubes allows for individual tubes to be mounted and disassembled without having to drain the solar heating system • Integrated solar system package available including collectors, storage tank, pump, control unit, etc.		

Water Heat (gas and electric)

Gas (or in rare instances, electric) water heating is a sensible choice for areas where solar water heating is not feasible or for use as an auxiliary water heating system. For gas powered water heat it is possible to integrate water and space heating (see pg. 42). High efficiency models are available that allow venting of water heaters through the wall instead of a chimney to aid in space heating.

Water heaters are available as demand or storage units. Demand systems do not store any hot water, but heat it on demand near the point of use. They are a good choice if hot water use is limited. Although they are a less efficient method of heating water, the system can save energy overall because no energy is spent maintaining the heat of stored water. A typical medium sized unit will raise water temperature 60˚ at 3.5 gal/min. Some systems can sense incoming water temperature and will not turn on if the water is already hot enough (making the system appropriate for solar interconnections or circulating systems). Demand systems are available in gas and electric models. Gas systems consist of multipoint heaters and combination boilers that can do space heating as well. Electric systems provide water for showers and mini units for handwashing at remote locations.

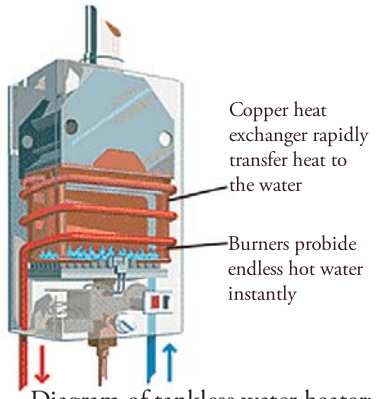


Diagram of tankless water heater; image from <*www.protankless.com*>

Storage tank systems are more common than demand heaters, and usually cheaper. The highest efficiency tanks have recovery efficiencies of about 85%. Insulation is very important in a storage system. It is often a good idea to add more insulation around a storage tank yourself. A hot water cylinder thermostat prevents scalding water and reduces overconsumption. The boiler should be turned off for extended periods of non-use.

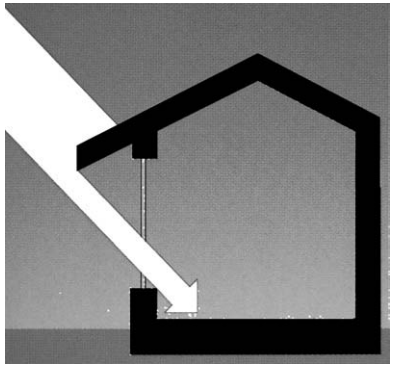
Option	Environmental Pros	Environmental Cons	Appropriateness
Demand (Gas)	• Can save energy compared to storage system when hot water use is limited	• Uses non renewable resource	• Useful for areas with limited space • Not appropriate for multiple draws for hot water • Minimum 15-20 psi • Wall mounted with vertical venting • For 1 or 2 people • Limited number of hot water locations • Most demand is for small quantities • System is used infrequently • Gas usually most appropriate for a small house
Demand (Electric)	• Can save energy compared to storage system when hot water use is limited	• Requires electricity	• See above for appropriateness of a demand system • Mini unit only makes sense at the end of a very long pipe run
ProTankless	• Transportation from Vermont • Efficiency rating: 87%, can supply 2 showers at once, 6 gal/min • Available in gas and electric units		

Water Heat (gas and electric)

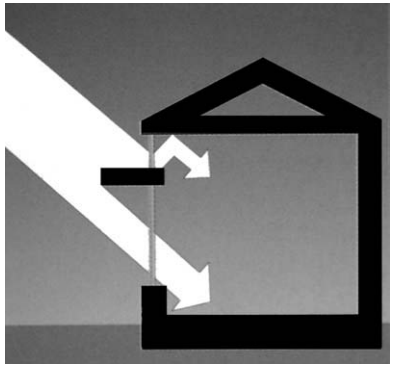
Option	Environmental Pros	Environmental Cons	Appropriateness
Storage	• Choose high efficiency, condensing gas boiler with electric pilot light for maximum energy savings	• Uses non renewable resource	• Multiple demands at a time • Most demand is for large quantities • Should be highly insulated • Very heavy: needs a sturdy structure and proper support along base

Conventional air conditioning systems are large energy consumers and should be avoided as much as possible. Luckily, there are a number of passive and active systems that can significantly improve indoor comfort during the cooling season that use much less energy.

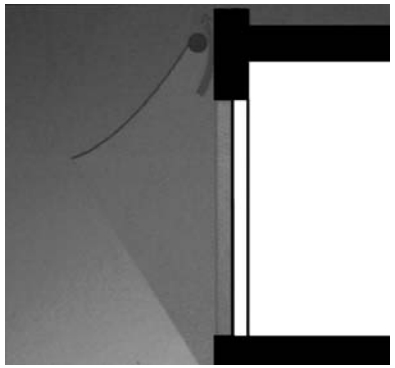
The simplest systems consist of shading the interior from direct sunlight. This can be achieved with permanent architectural features, trees, or blinds, shutters, louvers, etc. The closer such systems are to the outside, the more effective they are because the heat energy is not trapped by glass.



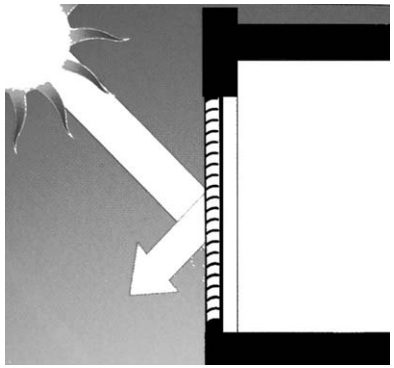
Overhang



Light shelf

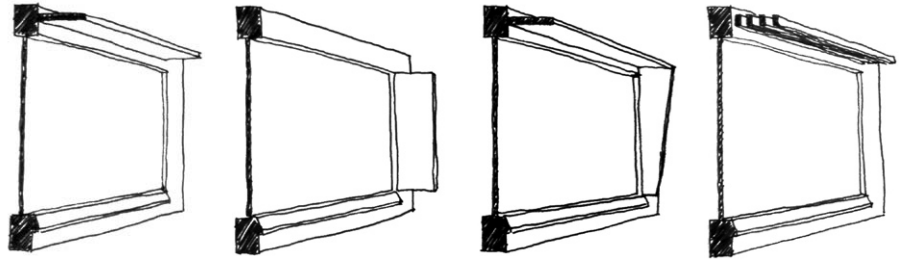


Awning



Reflective blinds

Images from *Green Vitruvius*



Fixed external shading devices; images based on those from *Green Vitruvius*

Ceiling fans can make a higher temperature comfortable by increasing air circulation and skin evaporation. A ceiling fan operating 10 hours a day costs less than $3/month in electricity costs. During the heating season, these fans can bring warmer air at the ceiling down into living space (at a low speed that won't cause a breeze). In general, blade material does not affect performance, but select a fan with a good warranty (indicates good durability). Metal motor housings may need annual oiling, but will probably last longer than plastic. Match fan size to room size for maximum efficiency.

Finally, just as we can adjust to cold conditions by wearing more clothing and staying active, we can tolerate warmer conditions by wearing light clothing and avoiding activity. In addition, appliances (TVs, stoves, computers) and lights give off a great deal of heat. Minimizing their use can keep the indoor environment cool.

Passive

Option	Environmental Pros	Environmental Cons	Appropriateness
Internal shade	• Passive system, no operation energy		• More user-friendly than external devices

Cooling

Option	Environmental Pros	Environmental Cons	Appropriateness
External shade	• Passive system, no operation energy • More effective than internal shades		• Requires more effort to use, or device for operating from within the building
Horizontal louvers			• Must be completely closed to block sun on east and west facades
Vertical Louvers			• Can be left partially open on east and west facades to block direct light but allow in diffused light
Passive Ventilation			• During summer vent through high windows, skylights, and passive thermal chimneys

Active

Option	Environmental Pros	Environmental Cons	Appropriateness
Fans	• Enhance natural ventilation • Provide cooling without air conditioning	• Consumes electricity	
Ceiling fans	• Enhance natural ventilation • Provide cooling without air conditioning • Comfortable temperature increases 4-6˚ F	• Consumes electricity (comparable to a 100 watt incandescent bulb)	• Can be helpful for both heating and cooling

Electricity (general)

Buildings account for about 2/5 of the world's energy consumption. Electricity production is responsible for some of the world's worst pollution, usually relying on coal burning which requires harmful mining processes and significant air pollution. Nuclear power is cleaner in the short-term but bears the hazard of catastrophic malfunction and produces radioactive waste that will be with us for millennia. Although some energy companies are beginning to investigate the use of renewable energy sources (solar, wind), this remains a minute proportion of total electric production. In addition, centrally produced electricity is terribly inefficient due to the large energy losses through wires during transmission from plant to home.

Alternative energy sources should be used when available, especially locally generated renewable sources. The best strategy, though, is simply to limit consumption. This can provide significant economic benefit as well, with 25% of a typical building's operation cost going toward the energy bill.

Large-scale hydropower has been responsible for much environmental damage due to its dramatic influence on natural ecosystems. Small-scale, local hydropower, however, is minimally invasive and an environmentally positive source of electricity. Small hydropower is considered anything producing less than 10 MW, mini hydropower produces between 100 kW and 1 MW, and microhydropower produces less than 100kW. The quantity of power potential is determined by the quantity of water flow and head height.

An elevated head is created when water is diverted through a pipe into a turbine couple to a generator that converts kinetic energy into electricity. Water is finally discharged at a lower level. The theoretical power of a system is equal to the volume of water multiplied by the height of the head. Some new technology is available that does not require an elevation drop at all.

Electro-Magnetic Fields are created by all electrical devices and may cause health risks. There is little agreement about what the extent of the health risk is or why it exists, but some studies have linked EMFs to an increased risk of cancer. Although total elimination is unreasonable, "prudent avoidance" is encouraged.

EMFs diminish rapidly with distance from the source, although they are not hindered by objects, including walls. Electric meters and subpanels are powerful EMF emitters and should be kept remote from living areas. Keep HVAC blowers away from high use areas. Use only Romex wire. Do not place fluorescent light fixtures directly below high-use second floor areas. Remove as much wiring from living areas as possible. Put kitchen appliances on walls away from high use areas.

Option	Environmental Pros	Environmental Cons	Appropriateness	$
Hydropower	• Renewable, non-polluting energy source • On small scale, little or no environmental damage is caused by hydropower		• Requires constant supply of water of sufficient quantity and head • Turbine and required pipe may interfere with visual quality of place	
Grid Power		• Non-renewable fuels burned in manufacture • Extremely inefficient source of energy	• Easiest connection if site is already wired	
Solar Electricity	• see next section for more information			

Electricity (photovoltaics)

Photovoltaic (PV) panels are not yet an efficient choice for electricity production from a purely economic viewpoint. The efficiency of most PV cells today is about 13%. The cost of a PV system in areas with grid access continues to outweigh its financial benefits over the long-term. Still, PV technology is significantly more efficient than it was even a few years ago and it is believed that future technological developments will make it a viable economic contender. Still, PV systems are presently a desirable option when environmental costs are factored into the evaluation and where finances and site conditions allow.

In a photovoltaic panel, electrons in certain crystals are freed by solar energy and then travel through an electric current. These panels should be placed at at an angle equal to the site's latitude plus 15˚, to maximize shorter winter light. There are three options for mounting panels: fixed, adjustable fixed, and trackers. Fixed panels, as their name implies, are installed and remain stationary on the roof. The angle of adjustable fixed panels is manually adjustable, allowing the panels to take advantage of the most sunlight according to the season. Trackers are freon activated to track the sun from the east to west. The energy drawn from the PVs to do this is minimal (about 1 watt while drastically increasing output). Most gains are during long summer days.

A simple grid-connected panel system costs between $8000-$9000 per kW installed for a roof-mounted system. Installation comprises a large chunk of the expense.

A number of companies manufacture solar shingles, which are much lighter than other PV systems. They are made from active silicon on an unbreakable stainless steel sheet (for stiffness) The shingle is encapsulated in UV stabilized polymers, framed in anodized aluminum and uses no glass. Solar shingles are wind and water tight, allowing them to take the place of conventional roofing material. Triple junction shingles are three semi-conductor junctions stacked on top of each other. The bottom cells absorb red light, the middle green, and the top blue. This spectrum splitting makes the shingles more efficient than typical PVs. Bypass diodes allow solar shingles continue to work in low-light conditions. For information on power expectations for various shingle systems, see www.clean-power.com/unisolar.

The first step in making photovoltaic electricity a reasonable choice is reducing the electric load of the building through high-efficiency lighting and other appliances.

To estimate the electric load of a building, list all of the electricity consumers (i.e. refrigerator, television, lamps, etc.) and mark those that will operate on direct current (DC). Enter the quantity of appliances, estimate the hours of daily use, their wattage and multiply these factors to find the total daily watt usage. For those that are not DC multiply by 1.1. Finally, add these totals to find the average daily energy use. If batteries are to be used, multiply this total by 1.25 to account for energy loss.

The rated output wattage of a system is the number of watts each panel will create in one hour of direct sun. Multiply the rated wattage by the number of viable operating hours to estimate what you can produce. The average daily solar radiation per month in Minnesota is about 3-4 KWh/m^2/day. This assumes full solar access and does not show the true range across the seasons. Production will be significantly lower during the winter months.

PV systems can be broken down into two main categories: grid interface and stand alone systems. In a grid interface system, surplus electricity is "sold" back to the utility. When inadequate electricity is being produced by the PV system, it is taken from the grid. In many areas, special meters charge the homeowner for the net electricity taken from the grid.

A stand alone system can be used in a house that is or is not connected to the grid. If the house is off the grid, batteries are needed to store surplus electricity from the PV system. To determine battery size

divide daily energy use by the battery voltage (usually 12) to determine amp-hours. Multiply amp-hours by the number of days the battery should be able to store power. Batteries should not be discharged excessively (no more than 50%), so multiply this product by 2. Do not use car batteries to store PV electricity as they cannot handle deep discharges. "RV" or "marine" batteries can be used for beginning systems, but will last only 2–3 years. The best battery choice is a deep cycle battery (available for Golf Carts, include Industrial Chloride Batteries) which can be charged up to 80% and lasts 3-5 years. Some larger capacity deep cycle batteries can last 7-10 years. Industrial Chloride batteries last 15-20 years. Non-lead batteries (nickel-cadmium) batteries are more expensive but can last a long time if they are not overly discharged. However it is difficult to measure the depth of discharge from these types of batteries since they do not slow down over time, but simply cut off when out of power). Batteries present some environmental problems. They can release harmful chemicals into the natural environment when they are landfilled. The environmental cons of batteries should be weighed against the environmental benefits of the individual photovoltaic system.

PVs create DC electricity. However, most appliances operate on alternating current (AC). Therefore an inverter is necessary and can be a major cost of the installation (over $1000). When wiring, consider that some DC may be desirable. DC appliances are initially more expensive, but use less power. If DC is used, heavier wiring is necessary. #10 wire is best for DC, but larger wire may be necessary for long runs.

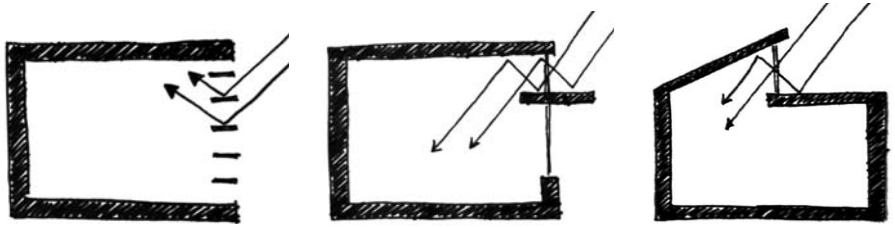
Charge controllers regulate voltage entering batteries to avoid overcharging and to prevent power loss through the panels at night.

Option	Environmental Pros	Environmental Cons	Appropriateness
Stand-Alone System		• Requires either batteries or back-up electricity from grid	
Grid-Interface System	• Eliminates need for batteries		• Requires compliance with a number of regulations. May not be possible in some areas.
Fixed Panels			• Cheapest, lowest producers • Metal frame is best as PV panels will outlive a wooden rack
Fixed with Adjustable Tilt Angles and Manual Tracking Mounts	• Capture more energy than static fixed panels		• Require manually changing angles either several times a day or seasonally
Tracker panels	• Increases output from fixed panels from 40-50%		• Must be without east/west obstacles
Solar Shingles	• Take place of regular shingles		• Textured, meant to blend in with conventional asphalt shingles • Cannot be cut

Electricity (photovoltaics)

Option	Environmental Pros	Environmental Cons	Appropriateness
OKSolar Shingles	• Bypass diodes mean that system continues to work, even in part shade or cloudy conditions • 12" x 86.5" (exposure is 5" x 85.4") • Nailed in place on roof decking over 30 lb. felt sheeting • Electric lead wires (#18AWG) extend 12" from underside through roof decking for connections on the interior • Roof build like normal, then a template from manufacturer shows where to drill holes for wiring • An electrician does the wiring under the roof to a combiner box		
Uni-Solar	• See above • Mounted 35" up from eave to ensure adequate wiring space • VersaShield underlayment goes on wood decking and is extended 12" around perimeter of shingle installation • Slope 15º-60º. Ideal is the latitude plus 15º for maximum winter gain		

Daylighting provides the most environmentally friendly source of light. Overhangs can be designed to prevent direct light except when desired. To determine appropriate overhang distance for summer shade, divide the wall height (window height plus wall above) by 4 for south-facing windows. Light can be reflected into the room with the aid of light shelves, louvered window coverings, venetian blinds with reflective coating on slat tops, and a light colored ceiling. Whenever possible,

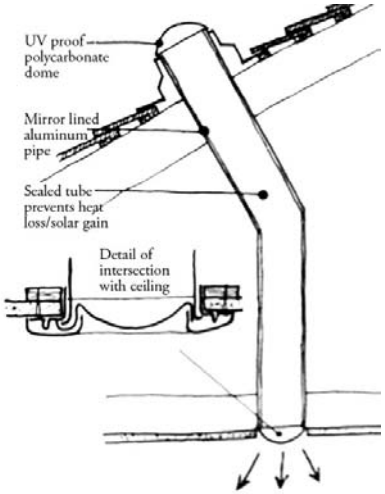


Reflective blinds Light shelf Clerestory

Images based on those from *Green Vitruvius*

background lighting should be from a reflected source. In general, high windows provide more daylight and penetrate deeper into the space. Daylight coming through a regular window at the middle of the day can equal the light output of five to thirty 100w bulbs.

Light colored interiors reflect light and therefore reduce the amount of artificial lighting needed. Avoid dark colored furnishings. Paint outdoor window frames white. Mirrors in strategic locations also help to reflect light. Light pipes are passive systems for lighting interior rooms like bathrooms. Daylight enters a small domed skylight and travels down a mirrored tube to illuminate the space.



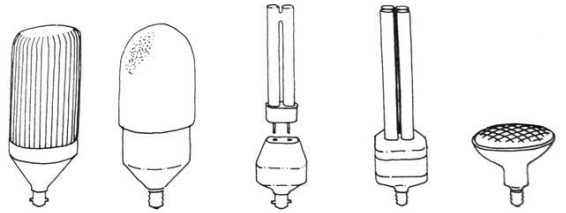
Light pipe; image from *Eco-Refurbishment*

Light distribution is another important factor to be considered. Where there is a big difference between the light level at the window and at the far wall, people tend to turn on lights there, even when they are not functionally necessary. Light shelves and similar devices can send daylight farther into a room.

Task-appropriate light should be chosen to avoid over-consumption of electricity. Limit the number of light fixtures tied to a single switch. Minimize the light needed for background and safety. Outside, use photocells and possibly movement detectors for safety and entry lights.

A typical incandescent bulb converts 95% of the electricity it uses to heat and only 5% into light. Incandescent bulbs are available with reduced voltage and 15% more efficiency. Using lamps with reflectors is better and ellipsoidal reflector lamps are the best.

Fluorescent bulbs are by far the most energy efficient and are now available in color ranges similar to the warm glow of incandescents. New fluorescent lamps oscillate too fast to be perceived and thus avoid the sickness associated with old fluorescent tubes. A 15 watt compact fluorescent lamp (CFL) is comparable to a 60 watt incandescent bulb. The higher initial cost of CFLs is quickly offset by longer life and lower operation cost. Electric high frequency ballasts (not magnetic) improve the efficacy of the lamp and cause a smoother start, extending the life of the bulb and reducing flicker.



Electromagnetic ballast Electronic ballast Halogen floordlight

Images from *Eco-Renovation*

High Intensity Discharge (HID) lamps look similar to incandescents but operate more like fluorescent. They are best for outdoor and security lighting. Mercury Vapor HIDs are the least efficient. Metal

Halide is 50% better with better color as well. Sodium HIDs are even better. High pressure versions have high initial cost and poor color rendition. Low pressure types are more efficient but also have poor color, making them a good choice for security lighting.

Passive

Option	Environmental Pros	Environmental Cons	Appropriateness
Daylighting	• Zero operational energy	• May cause unwanted heat gain or loss • Admits UV rays	• Indirect light is usually best as direct light can cause unwanted glare • East and west windows are not recommended unless shaded by trees
Light colored walls	• Increases brightness of space without operational energy	• Depends on material used to achieve light color	
Light Pipe			• Mirrored tube directs light from domed rooflight • Good for windowless spaces, like bathrooms.

Active

Option	Environmental Pros	Environmental Cons	Appropriateness
Cove Lighting	• Use low wattage fluorescent or low voltage lights behind a valance on the upper 1/3rd of wall • Minimizes energy used in necessary background light		• Consists of ledges, valances, horizontal recesses that distribute light over ceiling and upper walls • Good for background light and safety light in corridors etc.
Daylight responsive lighting	• Avoids over-consumption when daylighting is sufficient		• Consists of a fluorescent lamp with a daylighting "ballast" that varies its output in response to need
Photocells	• Use solar energy		• Good for overnight outdoor safety lights
Occupancy Sensors	• Only use light when someone is there		• Connect to background light and use infrared or ultrasonic sensors
Dimmers	• Can save energy if	• Only save energy when used consistently	• For background lighting
Timers	• Avoid overuse by forgetting to turn of unnecessary lights		• Turn lights on and off at preset times

Option	Environmental Pros	Environmental Cons	Appropriateness
Fluorescent Bulbs	• 4 times as much energy converted to light as an incandescent bulb • Efficacy is about 50-75 • Efficacy of triphosper is 80-100		• Select lights with a mid-range temperature (3500-5000K) (a warm tone can be found from 2700-3000K) and a CRI (color rendering index) close to 100. • Select bulbs with an electronic ballast • When possible for compact fluorescents, get ballast separate from bulb, which it will outlast • Select longest rated life • Triphosphers or multiphosphers give off most light (sometimes called "deluxe")
HID (High Intensity Discharge) Lamps	• Efficacy is 70-90		• Outdoor/security lighting
Incandescent		• Highly inefficient energy usage • Efficacy is about 10-15	• Should be avoided and replaced with CFLs

Buildings account for 1/6 of the world's freshwater withdrawals. A primary goal in making buildings more green is to reduce water consumption.

Choose water conservation products with standardized, replaceable parts. Stop cocks should be placed on all appliances so the whole system doesn't have to be drained if one item has a problem. The water heater should be placed as close as possible to the site of use to prevent wasting water while waiting for hot water.

Most areas divert rainwater to sewers and any sewage overflow can go directly into streams without treatment. To prevent this, it is best to ensure that most rainwater follows natural drainage patterns as closely as possible.

Rainwater harvesting

Rainwater harvesting systems collect rainwater for a variety of uses in and around the house, reducing the demand on public water facilities. A system consists of a catchment area (the roof), a conveyance system, filtration, storage, and distribution. New systems designed to supplement homes already hooked up to a water supply can be costly. To determine the water harvesting capacity needed to supply all water needs, multiply the number of people by the gallons of daily use by the number of days of the longest draught.

If the water is to be used for drinking, the **roof** should be metal, clay or cementitious material (not asphalt or any other material that could release harmful chemicals into the water supply).

The conveyance system for rainwater harvesting consists of gutters, downspouts, and piping. The front of the gutter should be 1/2″ lower than the back with a slope of at least 1/16″ per foot. Place gutter hangers at 3′ o.c. Downspouts should have one square inch of opening for every 100 square feet of roof area. The maximum gutter run for one downspout is 50′. Conveyance piping from gutter to cistern should be schedule 40 PVC or comparable piping, in a 4″ diameter. Keep angle bends in horizontal pipes less than 45°, sloping 1/4″ per foot.

Water can be stored above or below ground in a concrete, steel, ferro-cement, or fiberglass storage unit. The cistern should be durable and watertight with a smooth, clean interior. It must be covered to prevent mosquito breeding and algae growth.

Keep a leaf screen over gutters and downspouts. A roofwasher system (commercially available) can be devised to reject the first wash of water that falls on the roof, and then direct the rest to the cistern. A roofwasher is not necessary if the water is only to be used for irrigation.

If the cistern is high enough, gravity can be used to distribute the water. If it is not, a pump is necessary. Usually water needs to be pumped into a pressure vessel. A screened 1.25″ foot valve inside the tank is connected to a 1.25″ outlet from the cistern about 1′ above the bottom.

Harvested water can be used to flush toilets, wash clothes, and irrigate plants. More extensive filtering is necessary if it is to be used for drinking.

Greywater treatment

Greywater is the wastewater from sinks, showers, and washing machines. It can be treated for re-use for flushing toilets, washing clothes, and irrigating gardens. Compared to blackwater (wastewater from toilets and kitchen sinks), greywater has less nitrogen, fewer pathogens, and decomposes faster. However, if it is left untreated for several days it acts like blackwater, becoming malodorous as anaerobic activity begins and bacteria thrive. There are several types of greywater treatment options

which result in different potential uses for the treated water.

Aerobic pre-treatment provides water suitable for showers, hand washing, and laundry treatment, but not suitable for contact with food. The process first removes large particles and fibers to prevent later clogging in the system. Then water is transferred quickly to a biologically active aerobic soil zone.

An evapotranspiration system creates a more refined end product. In anaerobic to aerobic pre-treatment a three stage septic tank is used to separate sludge and grease. Sludge will be removed from the tank much less frequently than in a conventional septic tank system (about once every 4 years instead of twice a year). The outgoing effluent is anaerobic. A sandfilter is used to restore aerobic conditions. Finally the water is treated in a planter bed. This method is not the cheapest, but it is one of the most effective and easy to maintain on-site treatment systems.

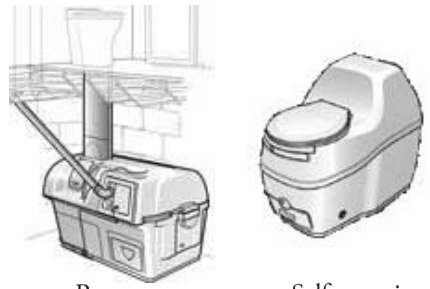
The planter soilbox must be well drained to prevent a water-logged zone. The bottom layer consists of polyethylene "actifill" or pea gravel. Next a plastic mosquito netting is used to prevent sand from falling through. Coarse sand is placed above, then concrete-mix sand. The top 2 feet consists of humus-rich top soil (no clay).

Pressure infiltration pipes allow for even distribution to landscaping and are easy to clean. They are placed on the soil surface after planting and then covered with 2–4″ of mulch. In colder climates, a deeper infiltration system with an automatic switchover is used. Either way, the distribution is achieved with two concentric pipes. The inner one has holes pointing up and the outer one expands slightly with water pressure when on. When the water is off, the sleeve closes and prevents bugs and roots from entering and clogging the pipes.

Composting Toilets

Up to 40% of a home's water is used to flush toilets. Overflow or leaks from septic tanks pollute natural waterways, creating large algal blooms and reducing oxygen levels in the water. These are some of the reasons why a composting toilet may be an appropriate choice for a given site. Composting toilets require little or no water for flushing and reduce the need for treating wastewater. They can compost nearly all organic waste including cotton tampons (not plastic ones or applicators) and kitchen scraps.

Initially the composting chamber is "charged" with wood shavings, peat moss, and water. During normal use, a bulking agent is regularly added such as wood shaving or sawdust to achieve an ideal moisture content between 40–50% (organic waste moisture is closer to 70%). If the pile becomes too dry it can be sprayed with water. Maximum decomposition requires somewhere between a ratio of 25:1 and 30:1 of carbon to nitrogen. Therefore the carbon rich material of the bulking material helps to achieve the desired ratio. Most waste converts to carbon dioxide and water vapor. In most models, an electric fan and vent pipe at the top of the tank pull fresh air into the tank and remove gases and odors. The bulking agent has the added benefit of creating voids that aid the fan in evaporation. Well composted matter is dark gray, crumbly, earthy smelling and bears no resemblance to fecal matter. Decomposition slows in the cold and practically stops below 40° F.



Remote composting toilet — Self-contained composting toilet

Images from <*www.sun-mar.com/products/selectpage.php*>

Batch or continual process versions of composting toilets are

available. In a batch system, one container is completely filled and then replaced with an empty one while the first container completes decomposing. Some report batch systems to compost more thoroughly due to better aeration. They also have an expandable capacity, whereas continuous systems are fixed. Batch systems often require less mixing or raking. They are advertised as reducing the risk of disease organisms in the finished product.

Composting toilets must be sited well and properly maintained to ensure satisfactory performance. Undersized, poorly located, or unmaintained toilets often have high coliform content. A study of composting toilets in national parks found that the most common problems were the incorrect amount of bulking material, a lack of mixing, standing liquid, dry conditions, spiders and rodents in the basement, and clogged vents. Easy access to the hatch (if it is located on a lower level) with adequate room for turning and waste removal is crucial to successful operation. The basement where the digester is located must be waterproofed.

Option	Environmental Pros	Environmental Cons	Appropriateness
Low flush toilet	• Likely consumes less water than older toilets	• Does not exceed most codes for new installation	• 1.6/gal per flush is considered low flow, a requirement of all new toilets
Dual flush toilet	• Can reduce flush volumes by up to 68%		
Keralor USA	• .8/1.6 gal flush options		
Caroma	• 4" trapway to prevent blockage • ADA models available • Several MN distributors available		
Composting toilet	• Reduce or eliminate creation of blackwater • Can also be used to compost kitchen waste, weeds, dust, etc. • Increases feasibility of greywater treatment system • Decentralized system means that a malfunction causes minimal damage compared to significant damage by malfunction in large scale sewer system	• Undersized, poorly located, or unmaintained toilets often have a high coliform content and may cause unpleasant odors.	• Wide range in cost from $1000-$10,000 • Requires regular maintenance (turning, adding bulking agent) • Optimal decomposition temperature is 65º • Should be placed in a at least nominally conditioned space as continuous cold will prevent proper functioning. Minimum ambient temperature should be 65º F. • Self-contained units may be more appropriate for winter use since they don't require a conditioned zone below • Should not have any unpleasant odor if properly maintained
Biolet	• self-contained composting toilets • $1000-$1600		
Clivus Multrum	• Largest model • Problem that sometimes newer waste overflows older waste and is then removed before it has had time to fully decompose (according to Phoenix website) • Advertises that is appropriate for any climate • Large size meant to contain several years contents for "enclosed long-term composting;" theoretically can be sized to go 30 years without emptying		

Option	Environmental Pros	Environmental Cons	Appropriateness
Envirolet	• Available in self-contained or centralized systems • Manual basin trap (so you don't have to be sitting for it to open)		
Phoenix	• Periodically manually rotated (weekly); requires significant effort • Decomposed waste falls to bottom and is removed about once a year (varies depending of frequency of use) • Small light can be added to attract fruit flies which are then ejected from the composter • Liquids are manually resprayed onto the top of the pile or can be drained to a conventional septic tank or peat infiltration bed • Cost ranges from $3500-$6000 • Tank made of molded, crosslinked polyethylene and foamed linear polyethylene		
Sun-Mar	• only self-contained system certified by NSF • Self-contained and remote units available • 3 self-contained areas: Rotating self-contained composting drum, evaporation chamber for excess liquid, and finishing drawer where compost finishes decomposing free from fresh material		
Spray Tap	• Reduces water consumption		• For basins, sinks showers
Lever Faucet	• Allows quicker temperature control and encourages less water consumption		
Rainwater Harvesting	• limits or eliminates consumption of freshwater supply • avoids excess run-off		• Can be costly if you're already hooked up to water
Greywater Treatment	• Reduces freshwater consumption		• A greywater distribution system is similar to the cost of a down-sized septic system.
Reactor Dynamics: Dyno2	• Advertised for having a simple installation (1 day), durable, low-maintenance, and minimal landscape disruption • Bacteria-filled effluent from septic tank filtered through wetland plant system that removes harmful bacteria and releases clean water into dispersal area • Pre-assembled, 7′ x 12′, pre-stressed concrete unit drops into place like a septic tank • Forced Bed Aeration™ accelerates treatment from the bacteria and plants in the vertical flow wetland system. • Plants rooted in peat used for insulation and odor control; septic wastewater enters at the root zone and trickles down; wastewater is aerated as it re-circulates through the system. • Removes 70% of the total nitrogen of effluent. • Functions year-round • Requires electricity		

Landscaping

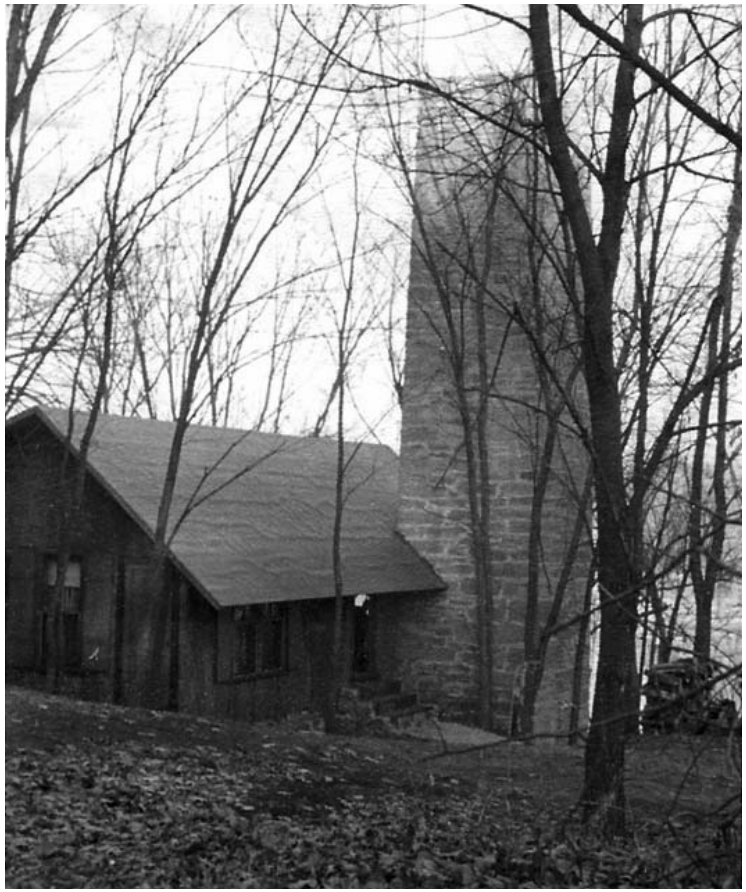
Indigenous landscaping is nearly always the most environmentally appropriate choice for a site. Choosing vegetation that naturally grows in an area limits or eliminates the need for watering or other maintenance. The Arcola Mills Center is fortunate to have a site rich with native vegetation. The indigenous plants of the area do much more than provide a scenic background. They are an active system that ensures the longterm stability of the place as it encourages biodiversity, groundwater recharge, regenerates the soil, and improves the quality of the air. The natural space surrounding Arcola Mills provides shade and moderates climatic extremes. Meanwhile, it does not require the resource and energy consumption of maintaining an artificial landscape.

Trees can remove up to 75% of the dust, lead, and other particulates in the air. They lower the summer air temperature and increase temperature in the winter as they slow wind and reduce ground radiation to the night sky. The environmental, mental, and physical benefit of these natural surroundings is clearly beneficial to Arcola's strength as a retreat and education center. Rehabilitating structures on the site with an effort to maximize environmental responsibility promotes the health of the natural landscape locally and beyond.

Option	Environmental Pros	Environmental Cons	Appropriateness
Indigenous landscaping	• Doesn't require watering • Provides clean air, shade, water purification, rich soil • Tempers extreme temperatures		• Already present at Arcola • Should be preserved and restored
Perforated paving blocks	• Moderates negative run-off conditions, allowing rainwater to drain into the soil more naturally		• Parking areas, outdoor patio spaces etc.
Uni Eco-Stone: Borgert Products, Inc	• Cement Pavers designed to reduce surface water pollution and sewage treatment plant loads • Designed to facilitate rainwater infiltration.		

Recommendations

Recommendations: Mill House



Historic photo of the Mill House, late 1930s

Overview

The Mill House cabin is on the site of the original saw mill at Arcola Mills. Although the mill itself is gone, the chimney remains as a distinctive feature of the Mill House cabin. Much of the interior wood of the house, in fact, was sawn at the mill, as apparent by the distinctive saw marks still left. The Mill house is on the National Register of Historic Places. Therefore its rehabilitation will require careful decision-making to ensure that its historic appearance is preserved. The rehabilitated Mill House will have three bedrooms (two on the main floor, and one in the loft space), and a large living space. The space below will function as an outdoor patio when weather and water levels permit.

In keeping with its history, the thematic emphasis of the Mill House will be on the use of wood. Features of the original structure as well as elements of the rehabilitation process will provide educational opportunities for highlighting the responsible use of this valuable resource.

Current Status

Much of the Mill House's current structure is in need of repair or replacement. Many structural and cladding materials are badly damaged from rot; in other areas, the structure is compromised by inadequate structural elements.

Current roof rafters and support

The current roof rafters are 2x4s placed 24″ o.c., which is not sufficient to support the roof. At present there is no ridge beam. This has led to a significant sag along the ridge of the roof, clearly visible from the exterior. The rafters have been reinforced through a piecemeal approach over the years, with a number of horizontal ties added at about the top third of the rafters. While this system has kept the roof from completely collaps-

ing, it is not a satisfactory long-term solution.

The loft balcony rests on a beam which runs the entire span of the building without intermediate support except for a log post which appears to have been put in as an afterthought at some point. This structure is too precariously engineered and will require redesign. The current stairs to the loft are supported in the center of the stair treads, creating an unstable structure. In addition, there is no landing at the top of the stairs, which creates a dangerous situation for entering and exiting the loft.


Loft Balcony


Balcony stairs

The north wall of the loft is pieced together with wood pieces and has a number of significant gaps, open to the bedroom below.

The current windows have wooden frames with a single pane of glass. Some of the glass has been broken by vandals. The large window expanse on the east and north sides of the central living area are a significant cause of heat loss during the winter. Structural racking makes window operation difficult.


Single-pane windows

Much of the interior woodwork remains in relatively good condition. However, there is a significant amount of visible mold in the north bedroom. The rest of the Mill House should be carefully inspected for signs of rot and mold.


Mold and rot in north bedroom

The porch and kitchen area below the entry level are located within the flood plain and have endured significant floods. They are not appropriate places for permanent living spaces.


Inadequate support below living space

The north side of the building is inadequately supported on the lower level by a number of undersized, warped posts. There is no foundation other than the chimney's stone foundation on the south side.

The floor joists of the living space, which are exposed to the lower porch below are insufficient for holding their load.

First Priorities

The first priority of rehabilitating the Mill House must be to ensure its structural integrity. This will entail replacing those elements that are badly damaged by rot or mold or those that are inadequately sized for their function. In some cases, reinforcement may be an acceptable alternative to replacement. A structural engineer or experienced contrac-

tor should be consulted for all structural and construction decisions. A full analysis of what is necessary structurally is beyond the scope of this report. What follows is a basic outline of items that need to be addressed and recommendations for dealing with those issues in an environmentally responsible way. Contractors, architects, or engineers involved in the project should be apprised of the environmental concerns of the Arcola Mills center, and these suggestions shared with them.

Much of the roof structure will need to be replaced, in a manner in keeping with its historic appearance. A ridge beam should be added to supplement the rafters and provide rigidity and prevent the slumping that is currently seen in the roof line. Rafters should be replaced to provide a more reasonable structure, likely with horizontal elements similar in appearance to those there presently, but more deliberate in their installation and function. A structural engineer and/or contractor should be consulted to determine the specific details of the roof structure.

A significant increase of structural support should be provided on the underside of the main living space. Because this area is sure to flood at times, lumber used in this area must be treated and detailed to prevent water damage and rot. A foundation is needed for posts on the north side of the building. This may be achieved with concrete piers. A structural engineer should be consulted to determine the least invasive but still sufficient and feasible solution.


Current gap between wall and fireplace

Tuck pointing will be necessary on the fireplace and chimney to ensure its longevity. Gaps between the chimney and walls need to be carefully and completely sealed.

The floor joists of the main living area are inadequate. They must be replaced or enhanced to create a more stable and level floor. Engineered lumber may be required for the joists to achieve the span between the middle columns and the limestone chimney wall. The main beam on the underside of the floor should be replaced.

The span of the loft balcony is too long for the current wood beam to easily broach. Since a staircase will punctuate the space anyway, it is suggested that the additional support for the balcony be provided by placing a wood post column on either side of the stairs. These posts can also be incorporated into a handrail for the stair.

A new structure for the stairs is necessary that will support the treads along their full length rather than only in the middle. The orientation of the stairs also need to be reconsidered to provide adequate landing space and an appropriate rise to run ratio. This may be achieved by turning the stairs 90 degrees, extending the stairs further into the living space, or by pushing the wall separating the balcony and loft bedroom to the west. The redesigned stairs will require a handrail on either side for safety.

The current balcony rail poses a potential hazard, as it does not provide an adequate barrier from slipping through. A new balcony rail should be designed that incorporates the character of the old (made of unfinished branches) but provides adequate protection.

Any interior wood that shows sign of rot or mold will need to be replaced. This includes sections of the north bedroom's wall and roof and any other areas that are discovered through the process of rehabilitation.

Obviously, much of the structural repair of the Mill House will use wood, the cabin's thematic focus. Wood has the potential to be one of the most environmentally friendly building materials. Compared to other widely used building materials like steel or concrete, wood requires dramatically less energy to manufacture. In fact, most of the energy that goes into the production of wood is solar: clean, free, renewable. How-

ever, educational materials within the cabin should inform guests that irresponsible harvesting practices throughout the world have destroyed vast areas of old growth forests. Although many logging companies advertise that they replant as much as they harvest, plantation-style forests lack the biodiversity and health of natural forests. Despite these detractions, the rehabilitated Mill House will highlight responsible ways of using wood.

For all rehabilitation that requires the replacement of wood there are several things to keep in mind. First, wherever possible, wood should be salvaged and reused. This applies to everything from doors, to floorboards, to structural elements. Items that are reused should be highlighted in educational displays. Reusing wood eliminates the need to harvest new trees, and requires no added energy costs for processing or transportation.

For items that require replacing, the first priority should be to use reclaimed wood from another source. Using salvaged wood avoids the need to harvest from living forests. It also prevents old wood from being sent to the landfill. As an additional benefit, much salvaged wood was originally harvested from old-growth forests and is of a higher quality than what is harvested from newer forests today. Many companies in Minnesota specialize in reclaimed timber for use as floorboards, dimensional lumber, and heavy timber. The use of salvaged wood should also be highlighted in educational displays, its environmental benefits and historical richness explained. It might be noted that the original builders of the Mill House used many salvaged wood elements, environmentalists ahead of their time.

If appropriate reclaimed timber is not available for some reason every effort should be made to purchase new wood products from a sustainable source, namely products that are certified by the Forest Stewardship Council (FSC). Forests that are FSC certified are managed sustainably to maintain the size and biodiversity of the natural environment. Again, the importance of using FSC certified wood should be articulated to guests.

Some areas of the Mill House will require treated wood, to deal with moist exterior environments and to avoid problems with insects. This provides an opportunity to educate guests about the dangers associated with the most common chemicals used for wood preservation. These chemicals create a myriad of health and environmental hazards. Seek out the least environmentally harmful treatments possible. For areas where the concern is limited to insect infiltration and not water resistance, choose a borate based treatment. Borate is naturally derived and does not pose the same environmental threat as the other chemicals typically used. If moisture resistance is necessary, choose Ammoniacal copper quatenary (ACQ) treated wood over Chromated copper arsenate (CCA) treated wood. Although ACQ is not without its environmental woes, it does not match the toxicity of CCA. Even better, consider a natural alternative such as *Lifetime Wood Treatment* which is a non-toxic product and is safer for the environment as well. The manufacturer advertises that this natural alternative is appropriate for any application where CCA or ACQ would traditionally be used.

Although its use will likely be minimal in the Mill House, anywhere particleboard or plywood is used, an alternative product should be considered instead. Traditional plywood involves the use of harmful adhesives and preservatives that are a significant source of air and water pollution. Many products such as *DuraCane, EcoPanel,* and *PrimeBoard* are manufactured from agricultural waste with similar properties.

Recommendations: Mill House

First Priorities Checklist:

- ☐ Roof
  - • Ridge beam
  - • New rafters and horizontal supports
- ☐ Foundation and Support
  - • North foundation
  - • Support columns below living space
  - • Floor joists and beams
- ☐ Chimney
  - • Tuck pointing
  - • Gaps between chimney and wall
- ☐ Balcony
  - • Beam and supports
  - • Stairs
    - –Landing
    - –Handrail
    - –Support
  - • Railing
- ☐ Replace any wood with rot or mold

Environmental priorities:

- • Wood Source
  - 1–Reuse
  - 2–Salvaged/Reclaimed wood
  - 3–FSC certified wood
- • Wood Treatment
  - 1–Untreated
  - 2–Borate
  - 3–*Lifetime Wood Treatment* or ACQ
- • Wood alternatives (*DuraCane, EcoPanel, and PrimeBoard*)

General Rehabilitation

Insulation

To make the building efficient (and habitable) in the winter, the Mill House must be thoroughly insulated. Insulation should be installed for the roof, the floor, exterior walls, and bathroom walls. To make a super-insulated building, R-value goals should be R-50 for the roof, and R-30 for exterior walls and floors. This may be beyond what is feasible given the limits of historic appearance. Still, in all cases, the minimum R-value prescribed by code should be exceeded.

Wherever possible, cellulose (or soy, if it is available) spray insulation should be used. Cellulose has a low embodied energy and a high recycled content (from newspapers), reducing resource depletion. Cellulose insulation typically uses borate as a fire-retarder, one of the least environmentally offensive chemicals used for that purpose. Applying it as a spray helps to minimize air infiltration. Educational displays should point out that using cellulose (a recycled wood product) saves energy and resources in its manufacture, minimizing pollution and resource depletion.

To maintain the historic appearance of the wood stud walls on the interior, the exterior walls can be insulated from the exterior. Happily, the deep roof overhangs of the original structure should easily accommodate this added wall thickness with little change to the building's exterior appearance. To avoid thermal bridging, be sure that insulation is detailed to cover window and door reveals. The design of this detail should be made in conjunction with sizing new windows.

Since the historic character of the building is tied to its interior exposed roof structure, it is recommended that the roof be insulated on the exterior. This will also serve the beneficial function of keeping the

roof structure itself insulated and warm. Placing insulation above the rafters of the roof involves the redesign of the eaves to allow for added thickness. In this situation, unfortunately, cellulose insulation is unlikely to be appropriate. Instead, rigid board insulation should be used. Compare manufacturers to find a product with the lowest CFC and HCFC content. Although this insulation has a much more harmful and energy-intensive manufacturing process than cellulose, it will save energy in the building's operation. The old roof needs to be stripped, insulation board placed on the rafters with a water vapor barrier in between and a layer of building board or roofing lath above to attach to the finished roof surface.

For the main living area, the floor is accessible from below. After stabilizing the structure (replacing or repairing floor joists and beams where necessary), insulation can be applied there from below. Spray cellulose insulation should be used here, so long as the desired R-value can be achieved (ideally R-30). If the necessary R-value cannot be achieved with cellulose, an alternative such as Icynene or rigid foam will have to be considered. Although these materials have a negative manufacturing impact, this must be considered in balance with the energy and resources that will be saved in heating a well insulated structure. The insulation and floor structure will then need to be appropriately weather-proofed and sealed.

On the west side of the Mill House, in any areas where the floor is not accessible from below, the floor boards will have to be removed in order to adequately insulate. At this opportunity, the structure should be inspected for rot in these areas and measures taken to ensure that the structure is adequately positioned above ground level and waterproofed. Once these issues are resolved, insulation can be placed in between floor joists (ideal R-value: R-20). Cellulose loose-fill or spray insulation should be used. Do not use cellulose if this area is likely to retain moisture; use a synthetic instead.

Moveable insulation should be considered for the large window expanses of the Mill House. Currently, there are shutters along the exterior of the building, though they are either inoperable or extremely difficult to operate. These shutters should be replaced or repaired as necessary. However, without significantly changing the exterior appearance of the Mill House the shutters will be much more effective at blocking sunlight than insulating. Interior night insulation (or for use when the building is unoccupied) is a reasonable solution. While window quilts or thermal blinds may be effective, they are not in keeping with the interior historical aesthetic. Removable pop-in panels are more appropriate and provide a much higher R-value (about R-4 per in of foam thickness). They can be handmade (and even embellished by a local craftsperson or quilter—look for volunteers). Pop-in panels are made of rigid lightweight insulation like polystyrene or polyurethane (purchase at Home Depot or similar retailer). They can be covered in decorative fabric on the interior side. A vapor retarder on the warm size of the insulation will minimize the possibility of condensation on the window and frame. Care should be taken so that the panels fit snugly in the window frame with minimal air infiltration. Guests should be instructed on how, when, and why to use moveable insulation.

In addition to adding insulation to the Mill House, it must be draft-proofed. The first priority should be sealing the fireplace. The process of cleaning the chimney and providing the equipment to make it both operable and efficient is likely to be prohibitive. Assuming that the chimney and fireplace will not be used, it should be tightly sealed. Exterior doors (which should be salvaged and repaired if at all possible) should be equipped with weatherstripping. It is also important to ensure that there is a tight seal between wall and floor to prevent drafts. This can be achieved with baseboard secured on a compressible strip or by carefully caulking the space where floor meets wall.

In conjunction with insulating and draft-proofing the building

must be strategically ventilated. This may include ridge vents in the attic spaces. A bathroom extract fan should be used to remove humid air from the living space and vent it to the exterior. If attached to a switch, guests should be explicitly encouraged to use it whenever the bathroom is used, especially during and after showers.

Windows

While every effort should be made to maintain the historic appearance of the windows, for the sake of energy efficiency they should be replaced by double paned windows. Seek windows with wood frames of FSC certified wood. Be sure that windows are operable and come with screens to allow for cooling ventilation in warmer months. Both *Anderson* and *Marvin windows (Ultimate double hung)* advertise wood framed windows and promote their ability to mimic the historic appearance of multi-paned double hung windows; *Marvin Windows* especially advertises their ability to custom-make windows according to specific design guidelines. If is financially reasonable, consider low-e and/or argon filled windows which inhibit heat from escaping through windows.

Roof

As can be seen by comparing current photographs with older ones, the Mill House's present roof is not reflective of the original. Therefore, there is no historical need to replicate the appearance of the current shingles with new asphalt shingles. It is not clear from photographs exactly what the original roofing material of the Mill House was. A wood-alternative shake roofing shingle is recommended. There are a few different manufacturers that produce roof shingles made from a combination of environmentally friendly and recycled waste products. These products are more durable than traditional cedar shakes but are applied in a similarly straightforward way. Eco-Shake and Enviro-Shake shingles both contain recycled cellulose fibers and should blend into the roof unobtrusively. A dark color should be chosen that mimics the shade shown in historic photographs. Asphalt roof shingles should not be used.


Current roof condition

Although these alternative materials are not made of wood, they are still appropriate for the cabin's theme. Because these products are more durable and require less maintenance than a traditional wood roof, they avoid unnecessary harvesting of forests and minimize the amount of material which is eventually landfilled.

Bark Siding

The bark siding of the Mill House is one of its most distinctive exterior features. Unfortunately, the current siding has been damaged by moisture and is a haven for insects and vermin. It does little as a weather barrier. The old bark siding must be stripped. This will provide an opportunity to insulate the exterior. After insulation is complete, new bark siding can be installed in accordance with the manufacturer's guidelines; the required subsurface is similar to that needed for cedar shakes. The bark should be installed with screws, each shingle lapped halfway over the previous to ensure water resistance. The bark available as cladding today has been treated to be insect-resistance.

Bark should be purchased from a supplier that harvests bark from trees already felled for lumber. Information provided to guests can emphasize the fact that bark is usually treated as a waste product, and

if not harvested, it is generally removed during milling and landfilled. Using bark for siding maximizes the use of harvested trees and limits the amount of waste sent to the landfill. If possible, ensure that the bark is sourced from an FSC certified forest.

Flooring

As much of the interior wood flooring should be preserved as possible. Although the floor is badly slanted in the main space, this will improve when the structure is fixed. Some floorboards will need to be replaced. This should be done with reclaimed timber. Many companies offer wideplank flooring which is in keeping with what is currently present. If new wood must be used, it should be from a FSC certified source. The final floor should be cleaned and sealed with either a penetrating oil or wax made of natural ingredients (as available from *BioShield Paint* or *AFM SafeCoat*). The *BioShield* catalog includes a description of the differences between oil and wax finishes. Avoid synthetic products that can release VOCs and other harmful indoor toxins. Synthetics also produce harmful pollution and are energy intensive in their manufacture.

The floor of the bathroom should be rehabilitated with a more resilient flooring, one that can cope with the moist environment. This will ensure the durability of the space and a high indoor air quality. Linoleum is a sensible choice. It is made of natural materials, biodegradable, and naturally anti-microbial. Vinyl flooring should be avoided.

Area rugs in the living spaces and bedrooms can keep the floor warmer in the winter and also protect the wood floor. If new rugs are purchased, they should be made of natural materials on a natural backing. Several manufacturers of such products are listed in the appendix. Avoid synthetic carpets, as they have negative environmental effects and contribute to poor indoor air quality.

Interior Walls & Finishes

Original interior wood paneling

The interior walls of the Mill House should be preserved as much as possible, both to conserve resources and to retain their unique historic appearance. The wood should be cleaned and sealed with natural products in order to ensure its durability. These materials must be chosen carefully as otherwise they can release harmful VOCs and detract from indoor air quality. *BioShield Paint* (and others) manufactures a range of wood finishing and preserving products made from natural ingredients. Guests should be reminded of how using wood as an interior finish (assuming it is responsibly cared for) is an environmentally positive option, as it obviates the need for any potentially harmful finish like paint or wallpaper and does not require frequent replacement over the life of the building.

If any areas are painted, refer to the Interior Finish part of the Information section (pg. 37) to determine the most environmentally sound choice.

Exposed wood in the bathroom should be sealed with a water-resistant finish (again, see natural options from *BioShield Paints* or A*FM Safecoat*). Areas that are currently tiled should be restored with new material. Although ceramic and glass tiles are energy intensive in their manufacture, their durability can make them an environmentally sound choice. Better yet, choose reused tiles if they can be found or those that are made from 100% recycled materials (several options listed in appendix).

Recommendations: Mill House

Heat & Water Systems

Choosing the best systems for any building is a complicated decision-making processes. Because efficient systems are interdependent, a change in one element can have repercussions for others. That is, what is a good choice in the context of specific other choices may no longer be the best option if other elements change. This should be kept in mind when considering the recommendations in this section. Use the Information section of this report to gain a familiarity with the different options available, their appropriate uses, and the general pros and cons of each to guide decision-making. Unanticipated conditions may require departing from the recommendations outlined here, and as one element changes, others may need to be adjusted accordingly.

Because of its shaded location, solar power (for heat, hot water, or electricity) is not a reasonable choice for the Mill House. Gas-powered radiators are recommended for heating the cabin. They should be placed in the main living space, the two lower bedrooms, and the bathroom. Because the Mill House is a small building, the natural movement of air should provide adequate heat for the loft space, especially if it is primarily used as a sleeping space. Choose radiators with low capacity and small- or micro-bore pipes which increase efficiency. Radiators should be individually adjustable with thermostats rather than simple on/off switches. All pipes running from the boiler to the radiators should, of course, be well insulated to avoid heat loss.

A high efficiency condensing gas boiler is the most efficient choice for water-based heating. They are about 20% more efficient than conventional gas boilers. Check manufacturer's information to compare their efficiency rating. In a condensing boiler, the steam which results from gas combustion is cooled by the return water from the heating the system. As the steam condenses it releases latent heat which is used by the boiler. Be sure the boiler is adequately insulated. If space allows, add more (batt) insulation to the storage tank's exterior.

A programmable thermostat is worth the expense. This will allow temperature settings to fluctuate during the day (and even in weekly cycles) to match the building's use. Temperatures should be set significantly lower overnight. Guests should be reminded of the energy and pollution savings created by lowering the thermostat even just a couple of degrees, and be encouraged to add more blankets rather than bumping up the thermostat. Position the thermostat away from extreme temperatures (i.e. exterior walls, windows, doorways, radiators). The thermostat should also be equipped with a manual override to accommodate changes in routine use.

Since a hot water storage tank will already be present for space heating, it makes sense to use it for domestic hot water as well. Energy can be saved by using one system in place of two. Any water storage system with enough capacity to heat the space should provide adequate hot water. Do not oversize the water boiler, as it wastes energy.

Cooling

The Mill House is nicely situated to remain cool in the summer, shaded by deep roof overhangs and trees. The southern side, which typically has the most potential for solar gain, is especially shaded. Conventional air conditioning is not necessary. Natural ventilation can provide a comfortable environment for all but the very hottest days. Those few days when the temperature does slightly exceed the comfort range do not warrant the expense or energy consumption of conventional air conditioning.

As mentioned previously, all new windows should be fitted with screens so that they can be opened in warmer weather and encourage ventilation. While ceiling fans can provide significant cooling benefits,

they are not in keeping with the historic appearance of the building. Removable window fans should be available instead to facilitate cooling ventilation when necessary. To be sure that air moves freely throughout the Mill House guests should be encouraged to leave interior doors open whenever possible.

Guests should be asked to use manual shading devices to maintain a comfortable interior environment during warmer months. Rehabilitating the exterior shutters and providing an easy method for closing them from the interior will provide dramatic cooling effects when windows are exposed to direct sunlight. These will be especially effective on the east windows during the first half of the day in the summer. Interior devices are less effective because they still allow the sunlight to radiate through the glass; the heat is then trapped on the interior. However, to ensure that moveable shading is easily accessible to guests, it is recommended that reflective shades are installed over the windows, especially those in the main living space.

Electricity & Lighting

There is not a reasonable alternative for producing electric current at the Mill House other than acquiring it from the grid. Therefore, the best way to be environmentally responsible is to limit its use. In large part this is done by avoiding water or space heating systems that use electricity as a power source. Secondly, this is accomplished by minimizing the number of electric appliances.

Every room in the Mill House already has a window, which allows daylighting to be the primary source of interior illumination. The main room, with large windows on the north and east sides, should be well illuminated with daylight for the first half of the day.

Light fixtures should be kept to a minimum. Assuming that the Mill House will perform primarily as a retreat and lodging space, there is no need for overall bright lights, nor would they be historically appropriate. Lights in the Mill House can be limited to small areas of task lighting in the living space and bedrooms. No more than one light source should be attached to one switch to avoid unnecessary use. Guests should be encouraged and reminded to turn off lights when they are unnecessary. Guests who have chosen Arcola Mills as a nature focused site for retreat may easily be encouraged to organize their activities to the cycle of daylight, using the daily cycle to determine sleep schedules and daytime activities.

The exposed wood of the Mill House provides a fairly dark interior, one not well suited to reflecting light. To provide more reflection and thus maintain a brighter interior (which will discourage unnecessary use of electric lighting) rugs, bed linens, and other furnishings should be chosen in light colors. Similarly, light colored paint, tile, and floor in the bathroom will minimize the need for artificial lighting as well as provide an inviting interior.

With compact fluorescent lights now available (CFLs) in tones that mimic the warm glow of incandescents, there is no need to use the latter. CFLs are dramatically more efficient and last much longer. The reduced energy cost and long lifetime easily pay for their more expensive initial cost. Choose CFLs with electric high frequency ballasts (rather than magnetic) as they further reduce the oscillating associated with older fluorescent lights and do not pause when switched on.

If security lighting is necessary outside, choose a HID bulb which is among the most efficient available. This can be outfitted with a light sensor so that it automatically turns on at night and off when it is light again. Because of their unappealing color tones, HID bulbs are not appropriate for interior lighting.

Recommendations: Mill House

Water

Water for the Mill House will likely come from a well (yet to be drilled) sourced out of the basement of the Bungalow. Like electricity, the best way to be environmentally responsible with water is to limit its use.

In a residence like the Mill House which will have minimal kitchen needs, no laundry facilities, and no need for landscape irrigation, the toilet will consume the vast majority of water. While composting toilets do not need any water to function, the small size of the bathroom and siting near a flood plain does not make the Mill House a good candidate. Instead, the best choice is a dual flush toilet which allows users to choose a half flush or full (still low) flush depending on necessity. If used properly a dual flush toilet can be a significant source of water savings.

Other points of water use in the Mill House should be equipped to minimize consumption. Low flow fixtures on the sink, and especially on the shower should be used. A lever tap on the sink (rather than dials) reduces water use because it minimizes water wasted while re-finding the desired water temperature.

Because of the proximity of the Mill House to the St. Croix River, wastewater must be handled carefully to avoid any harmful pollution of ground or river water. Traditional septic tanks are the typical solution to homes located away from an urban sewer system. Unfortunately, septic systems are prone to malfunction, releasing effluent which is not only offensive to smell, but to the surrounding environment as well. If time and finances permit, a greywater recycling system should be considered. This would recirculate water from the sink and shower for flushing the toilet. However, wastewater from the toilet (blackwater) still requires a septic tank. A pre-treatment system, however, can minimize the negative environmental effect of such a system. The *Dyno2* system which is planned for the Mansion at Arcola Mills, provides wastewater pretreatment before it percolates into the ground. This system should be used to prevent water contamination from a regular septic tank. Consult with the manufacturer to determine whether the Mill House should have its own system or wastewater treatment should be shared with one or more other cabins.

Landscaping

The landscape around the Mill House has grown up considerably since its original construction and even since a couple of decades ago when a lawn was carefully maintained. Although some of the low growing vegetation will have to be cut back to re-establish a clear path to the main door (on the south side), the natural landscape should be left as undisturbed as possible. The closely cropped lawn of the 1980s in not in keeping with the historical or natural aspects of the site, nor is it an environmentally advantageous approach.

Mill House and lawn, 1980s

Mill House and vegetation today

Recommendations: Mill House

General Rehabilitation Checklist

- ☐ Insulation (cellulose or insoylation where possible)
  - Roof—from exterior; ideally R-50
  - Exterior Walls—from exterior; ideally R-30
  - Floors—from below; ideally R-30
  - Interior bathroom walls
  - Moveable pop-in panels for windows
- ☐ Draft-proof
  - Seal fireplace
  - Weatherstrip exterior doors and windows
  - Baseboard on compressible strip or caulk between wall and floor
- ☐ Ventilation
  - Attic
  - Bathroom fans
- ☐ Windows
  - Double paned, low-e, wood frame, screens
- ☐ Roof
  - *Eco-Shake* or *Enviro-Shake* shingles
- ☐ New bark siding
- ☐ Flooring
  - Reclaimed timber where replacement is necessary
  - Linoleum in bathroom
  - Use *Homasote* or *WoodStalk* underlayment with natural adhesive
  - Natural light-colored rugs
- ☐ Walls & Finishes
  - Repaired (replaced with reclaimed timber where needed)
  - Sealed with natural sealer or wax
  - Natural, zero-VOC paint
  - Recycled glass tile in bathroom
- ☐ Space Heat
  - Small or micro bore radiators in first floor rooms
  - High efficiency, condensing gas boiler (extra insulation)
  - Programmable thermostat
- ☐ Hot Water
  - Integrated with space heating system
- ☐ Cooling
  - Repair shutters
  - Interior blinds
  - Temporary window fans
- ☐ Lighting
  - Task lighting (no permanent light fixtures)
  - CFL bulbs with electronic ballasts for interior
  - HID bulb for exterior security, attached to light sensor
  - Light colored furniture, rugs, linens
- ☐ Water
  - Sourced from well via Bungalow
  - Dual-flush toilet
  - Low-flow fixtures
  - Greywater recycling system (to flush toilet)
  - Wastewater treated with *Dyno2* system
- ☐ Landscape left as natural as possible
  - Path to front (south) door reestablished

Recommendations: Bungalow

Historic photo of the Bungalow, late 1930s

Overview

The original structure of the Bungalow was reportedly a restaurant located nearby that was later transported to its current site. Over the early years of its placement along the St. Croix River, a screen portch was added to the east side and other additions for bedrooms and a kitchen along the west and southsides. The Bungalow is not currently registered as a historic building. It is strongly recommended that any effort to register the building not be undertaken until *after* rehabilitation is complete.

Because different parts of the building were built at different times, there is some flexibility about what is retained and what elements are discarded. Additional spaces may be built between the west side of the building and the path to create more bedrooms for guests. There are currently two bedrooms, but this number could be increased to three or four. The east porch may or may not be kept. The same is true for the small kitchen to the south. A foundation and basement will be added to the Bungalow to elevate the wood frame above the ground and to provide a site for mechanical equipment.

Bungalow's current east screen porch

The thematic emphasis of the Bungalow will be on energy. This will include educational information on everything from energy production to consumption, both in the operation of the building and in the materials required to build it. Guests should have the opportunity to learn about the environmental costs of various energy sources (electricity, natural gas, solar, etc). The Bungalow also provides an excellent opportunity to introduce guests to the concept of embodied energy. Embodied energy refers to all of the energy consumed in the manufacture and installation of an item, from natural resource extraction, to manufacturing, to transportation to its final site. Of course, the goal of rehabilitating the Bungalow is to make it as energy efficient as possible and its successes should be highlighted in educational displays.

Current Status

None of the current Bungalow cabin is supported by a functional foundation. This has caused the structure at the ground to rot and sag in many areas. Much of the interior structure is likewise plagued by mold

and rot. A collection of CMU blocks and wood shims have been placed below the porch and other areas in an attempt to prevent localized collapse. However, this is not a satisfactory solution to the situation.


Inadequate foundation support

A large portion of the roof of the porch and the kitchen have fallen in. The floor of the kitchen is also severely slanted.

The roof is supported by 2x4s, 24″ o.c. which is inadequate for its load. This, coupled with the shifting of the building itself, has caused the roof lines in some areas to droop, as is clearly seen from the exterior.


Porch roof has caved in

The primary problems of the Bungalow as it currently stands are its lack of foundation and the extensive rot throughout, which makes much of the structure unsalvageable. Rot and mold plague the interior and have begun to destroy the structure itself. Much of the interior floor, wall, and ceiling structure has been irreparably damaged by water and mold. Some floorboards and millwork may be salvageable however, as is some of the exterior wooden siding.

First Priorities

As with the Mill House, the first priority of rehabilitating the Bungalow is to ensure its structural integrity. This will entail replacing those elements that are badly damaged by rot or mold or those that are inadequately sized for their function. In the case of the Bungalow, this work will be extensive. A full analysis of what is necessary structurally is beyond the scope of this report. What follows is a basic outline of items that need to be addressed and recommendations for dealing with those issues in an environmentally responsible way. Contractors, architects, or engineers involved in the project should be apprised of the environmental concerns of the Arcola Mills center and the recommendations of this report.

A concrete foundation wall (creating a crawl space and partial basement) should be a first priority for the structure. This will provide a structurally sound base for the building as well as elevate it above the ground to prevent future water damage. Local building codes can be consulted to determine the minimum distance that the wood-clad portion of the building must be held above ground level. The partial basement should be designed to provide an area for mechanical equipment, including a well for all three cabins. Design of the basement must include an easily accessible staircase for maintenance although this space should be restricted from guests. A structural engineer and/or architect should be consulted to determine a satisfactory solution for the basement and foundation.

Most of the floor joist are too badly damaged to be saved. Any that can be salvaged should be reused; the rest will need replacement. The same applies to floor boards. The addition of a foundation and basement will likely require some redesign of how the floor is supported. A professional should be consulted. Any other interior wood that shows sign of rot or mold will need to be replaced.

Much of the roof structure will need to be replaced. Rafters should be replaced to provide a more reasonable structure. A structural engineer and/or contractor should be consulted to determine the specific details of the roof structure. Because the roof structure is not exposed, it is not important that the new structure reflect the appearance of the original.

Recommendations: Bungalow

The process of repairing the roof structure should be undertaken in conjunction with the design of any western addition. This may change the overall design of the roof.

The exterior of the chimney should be checked for excessive wear. Where necessary it should be tuck pointed to ensure its longevity.

For all rehabilitation that requires the replacement of wood there are several things to keep in mind. First, wherever possible, wood should be salvaged and reused. This applies to everything from doors and floorboards to structural elements. For items that require replacing, the first priority should be to use reclaimed wood from another source. Using salvaged wood avoids the need to harvest from living forests and saves the energy of doing so. It also prevents old wood from being sent to the landfill. As an additional benefit, much salvaged wood was originally harvested from old-growth forests and is of a higher quality that what is harvested from newer forests today. Many companies in Minnesota specialize in reclaimed timber for use in floorboards, dimensional lumber, and heavy timber. Buying locally reduces the energy consumed in transportation.

If this is not possible for some reason, every effort should be made to purchase new wood products from a sustainable source, namely products that are FSC certified. Refer to the Wood section (pg. 18) for an explanation on the importance and benefit of specifying wood from an FSC certified source.

If there are any areas that require the use of treated wood (in water-exposed areas or to prevent insect invasions), seek out the least environmentally harmful treatments possible. In areas where the concern is limited to insect infiltration and not water resistance, choose a borate based treatment. If moisture resistance is necessary, choose ACQ treated wood over CCA treated wood, or, even better, consider a natural alternative such as *Lifetime Wood Treatment* which is a non-toxic product and is safer for the environment as well.

Anywhere particleboard or plywood is used (walls, ceiling, roof, etc.), an alternative product should be considered instead. Many products such as *DuraCane*, *EcoPanel*, and *PrimeBoard* are manufactured from agricultural waste and have similar properties to particleboard, plywood, hardboard, or MDF.

There are several trees growing up against the structure on its south and west sides. These should be removed as they have the potential to disrupt the structure and hold moisture against the building, promoting rot. The trees themselves can be chopped for firewood or mulched for landscaping uses at Arcola Mills.

Trees crowd Bungalow's structure

First Priorities Checklist:

- ☐ Foundation and Basement
  - • Provide accessible space below
  - • Elevate building
- ☐ Floor, Walls
  - • Replacement of rotted joists, beams and boards
  - • Replacement of any rotted studs, millwork
- ☐ Roof
  - • Rafter and decking replacement
  - • Redesign in conjunction with addition
- ☐ Chimney
  - • Tuck pointing where necessary
- ☐ Tree Removal near house

Environmental priorities:

- Wood Source
  - 1–Reuse
  - 2–Salvaged/Reclaimed wood
  - 3–FSC certified wood
- Wood Treatment
  - 1–Untreated
  - 2–Borate
  - 3–ACQ or *Lifetime Wood Treatment*
- Wood alternatives (*DuraCane, EcoPanel, and PrimeBoard*)
- Salvage chopped trees for firewood or mulch

General Rehabilitation

Insulation

As an exemplar for responsible energy use, and since much of the Bungalow will have to be replaced, it makes sense to make it a super-insulated building. This requires insulation levels for the roof, floor and exterior walls significantly higher than code requires. To make a super-insulated building, R-value goals should be R-50 for the roof, and R-30 for exterior walls and floors. Basement walls should be insulated to R-20. These high R-values will provide a dramatic energy savings in terms of heating the building. The added expense of more insulation will be more than compensated for by the energy savings in heating the building. Guests should be informed about the importance of insulation as an energy-saving strategy, especially for cold, northern climates.

Wherever it is feasible, cellulose (or soy, if it is available) spray insulation should be used. Cellulose has a high recycled content (from newspapers), reducing resource depletion. Compared to other insulation materials, cellulose has a much lower embodied energy. Cellulose insulation typically use borates as a fire-retarder, one of the least environmentally offensive chemicals used for that purpose. Applying it as a spray helps to minimize air infiltration and increase the efficiency of the building. This should be appropriate for wall cavities and beneath roof rafters since they will not be exposed in the final building. Care should be taken in the details to avoid any thermal bridging.

The floor should be thoroughly insulated between any unconditioned basement or crawlspaces and the living space. Ideally this can be accomplished with blown cellulose insulation, assuming moisture levels can be kept reliably low. Basement walls should also be insulated. The type and placement of basement insulation is a decision that should be integrated with the design of the basement and foundation walls. This may require the use of synthetic rigid foam insulation, depending on the construction technique used.

Moveable insulation will maximize the Bungalow's energy efficiency. Although windows can provide valuable solar heat when exposed to direct sunlight, they can be net heat losers if they are not insulated overnight or during cloudy conditions. During the heating season, all windows in the Bungalow should be fitted with either nighttime pop-in insulated panels or thermal window quilts. The efficacy of either strategy depends on a tight seal between the insulating material and the window frame. Because pop-in panels use rigid foam insulation they have a higher R-value than window quilts. However, pop-in panels require a storage area during the day. For this reason, window quilts may be a more reasonable option for most of the Bungalow's windows. Manufactured window quilts are recommended over home-made versions, as they include a vapor barrier as well as insulating batting. If a different appearance is preferred than the available options, the interior surface of the window quilts can be covered with other fabric or other drapes can be

placed over them. Ensure that the window quilts are tightly sealed when pulled over the windows.

For additions to the Bungalow, a more efficient and integrated system can be implemented for moveable insulation. Insulated (with a rigid foam core) shutters can be designed that fold or slide into the wall and cover the window at night. Edge seals will ensure a tight seal between the window frame and the insulating element.

In addition to adding insulation to the Bungalow, it must be draft-proofed. If a new pellet-burning stove is installed as recommended (see Heat section pg. 42), the current chimney may not be necessary. If the chimney is not used it should be sealed. All exterior doors (which should be salvaged and repaired wherever possible) must be equipped with weatherstripping. Baseboard should be used in all rooms and installed on a compressible strip to eliminate air infiltrations.

The east porch and small south kitchen should be retained as thermal buffer zones and used as seasonal porches. Entry porches can significantly reduce drafts and thereby save energy. The porches may be enclosed with screens or glass windows (Glass windows should have removable screens to be used during warm weather). It is important that these areas not be considered interior. The wall behind the porch must be fully insulated and the porch should not be heated for this strategy to work efficiently. Windows and doors between porches and the interior should be kept tightly closed during the heating season.


East porch to be kept and repaired as thermal buffer zone

In conjunction with insulating and draft-proofing, the building requires strategic ventilation. This may include ridge vents in the attic spaces. A bathroom extract fan should be used to remove humid air from the living space and vent it to the exterior. If attached to a switch, guests should be explicitly encouraged to use it whenever the bathroom is used, especially during and after showers. Also consider attaching the bathroom fan to an occupancy sensor so that it tuns on automatically.

Windows

The current windows in the Bungalow have only a single pane of glass, which provides a scant R-1 insulating value. In order to realize the efficiency benefits of a super-insulated building, the windows of the Bungalow must have at least a double pane of glass. Low-e glazing, which also hinders heat loss is recommended for windows, especially those on north, east, and west elevations.

Wood frames will maintain the historic character of the building. Seek windows with wood frames of FSC certified wood. Be sure that windows are operable and come with screens to allow for cooling ventilation in warmer months. Both *Marvin* and *Anderson Windows* manufacture wood framed double-hung windows that can meet the above recommendations.

Roof

If an addition is built on the west side of the current building, the roof design of the Bungalow is likely to change. Any changes should remedy problems with the current roof design which funnels water into valleys in some areas where it can lead to leaks. An architect should be consulted to determine an appropriate design for the roof structure. More details about rehabilitation of the roof structure can be found in

the First Priorities section (pg. 87).

Asphalt shingles, which are by far the most widely used roofing material for sloped roofs, should not be used. Their manufacture is a source of significant energy consumption and pollution. Instead, a shingle alternative product is recommended. Both *Eco-Shake* and *Enviro-Shake* manufacture roofing shingles that imitate the appearance of cedar shingles. Unlike cedar though, they require no tree harvesting, are much more durable, and do not require the intensive maintenance associated with wood shingles. Both products are made of cellulose (recycled paper) and post-industrial plastics which would otherwise end up in a landfill. These shingles are advertised for their durability and weather-resistance and are available in dark, natural shades that should easily blend in with the building. Because these products make use of post-industrial recycled materials, they require less energy to manufacture. In addition, their durability minimizes the frequency of replacing the roof, further saving energy.

Cladding

Some of the Bungalow's siding is salvageable. Of course, reusing materials always saves more energy than replacing those materials with new elements. All paint should be carefully stripped from the old siding that is to be reused. For the addition, or for areas where the siding is not reusable, choose siding made from reclaimed timber. A number of companies specializing in reclaimed timber are listed in the manufacturers section. Several should be able to provide wood siding to mimic the present siding. If appropriate reclaimed wood cannot be found, use wood siding sourced from FSC certified forests.

Eastern facade with salvageable siding

To ensure the durability of the building's exterior, the wood siding will require proper sealing and regular maintenance with paint or other exterior sealant. Historic photos show the Bungalow painted white; currently it is dark brown. Whatever color is chosen for the rehabilitation, choose an environmentally responsible paint or sealer for the job. The first choice should be a natural products. Synthetics consume more non-renewable resources, are generally more energy intensive to produce, and release toxins in their manufacture and at the site of application. *BioShield Paints* offers both water-based and oil-based exterior wood stains in a variety of colors made from natural ingredients. *AFM Safecoat* manufactures a low-VOC exterior paint without any formaldehyde precursors (unlike other paints advertised as low-VOC). Refer to the Information section for details about formaldehyde precursors (pg. 30).

Flooring

As much of the interior wood flooring should be preserved as possible. However, most floorboards will need to be replaced. These should be sourced from reclaimed timber which is available in a great variety of stains and widths. If new wood must be used, it should be from a FSC certified source.

The floor of the bathroom should be rehabilitated with a more resilient flooring, one that can cope with the moist environment. This will ensure the durability of the space and a high indoor air quality. Linoleum is a sensible choice. It is made of natural materials, biodegradable, and naturally anti-microbial. Alternatively, a tile of recycled material can be used. Vinyl flooring should be strictly avoided.

Area rugs in the living spaces and bedrooms can keep the floor warmer in the winter and also protect the wood floor. If new carpet is purchased, it should be made of natural materials on a natural backing. Several manufacturers of such products are listed in the appendix. Avoid synthetic carpets, as they have negative environmental effects and contribute to poor indoor air quality.

Interior Walls & Finishes

Many of the interior walls will need replacement. Reclaimed dimensional lumber or FSC certified wood should be used for any replacement framing. Gypsum board walls are appropriate for the building. Choose a manufacturer with a high recycled content for both the gypsum and paper covering. Use paper joint tape rather than fiberglass. Specify a low VOC joint compound and use it sparingly. Dry mix joint compound typically has fewer additives than ready-mix products. Careful application will reduce the need for sanding, which can release harmful particulates into the air.

Walls may be painted or covered, depending on the desired appearance. If painted, a natural, water-based zero-VOC paint is recommended (available from *BioShield Paints*). If choosing wallpaper, avoid vinyl. Instead choose a natural wallcovering and a natural adhesive. Leave interior woodwork unpainted and seal it with a natural wax or finish. Avoid any petroleum-based or solvent-borne synthetic materials which are harmful both in their manufacture and in their affects on indoor air quality.

A significant portion of the bathroom should be tiled. Although ceramic and glass tiles are energy intensive in their manufacture, their durability can make them an environmentally sound choice. Choose reused tiles if they can be found or those that are made from 100% recycled materials (several options listed in appendix). Painted areas of the bathroom should follow the same guidelines listed above.

Heat & Water Systems

Choosing the best systems for any building is a complicated decision-making processes. Because efficient systems are interdependent, a change in one element can have repercussions for others. That is, what is a good choice in the context of specific other choices may no longer be the best option if other elements change. This should be kept in mind when considering the recommendations in this section. Use the Information section of this report to gain a familiarity with the different options available, their appropriate use, and general pros and cons of each and use that knowledge to guide decision-making. Unanticipated conditions may require departing from the recommendations outlined here, and as one element changes, others may need to be adjusted accordingly.

Ideally, the Bungalow would be able to make full use of solar energy for heating and even some electricity needs. Unlike other cabins at Arcola Mills, the Bungalow has a clearing to its south side, which allows much more direct sunlight to reach the building. This, of course, is necessary for any system dependent on solar energy. Unfortunately, with the site as is, it does not seem that the building will receive a significant amount of sunlight each day during the winter when heating is most needed.


Clearing on south side of Bungalow

In general, an effective solar-based system requires direct sunlight

on the southern side of the building (the "solar window") for about six hours each day. Preliminary estimates (made over the summer) suggest that this will not be achieved during a substantial part of the winter with the trees as tall and as close as they are*.

A gas-powered, water-based heating system is recommended for the Bungalow. After solar, wind, or water energy, natural gas is the cleanest and most efficient source for heat. Electricity-based heaters are extremely inefficient and rely on one of the most polluting energy sources (most electricity plants get their energy from coal burning). The heating system of the Bungalow may consist of actual radiators in the space or, since much of the floor will have to be removed anyway, in-floor radiant heating. Cost of installation and use should be compared and evaluated to determine which option best suits the Bungalow.

If radiators are used, they should be placed in each room. Choose radiators with low capacity and small- or micro-bore pipes which increase efficiency. Radiators should be individually adjustable with thermostats rather than simple on/off switches. All pipes running from the boiler to the radiators should, of course, be well insulated to avoid heat loss.

A high efficiency condensing gas boiler is the most efficient choice for water-based heating. They are about 20 % more efficient than conventional gas boilers. Check manufacturer's information to compare their efficiency rating. In a condensing boiler, the steam which results from gas combustion is cooled by the return water from the heating the system. As the steam condenses it releases latent heat which is used by the boiler. The energy-saving benefits of this type of boiler should be explained to guests. The water storage tank should be well-insulated. If space allows, add extra batt insulation to the outside of the tank.

A programmable thermostat is worth the expense. This will allow temperature settings to fluctuate during the day (and even in weekly cycles) to match the building's use. Temperatures should be set significantly lower overnight. Guests should be reminded of the energy and pollution savings created by lowering the thermostat even just a couple of degrees, and be encouraged to add more blankets rather than bumping up the thermostat. Position the thermostat away from extreme temperatures (i.e exterior walls, windows, doorways, radiators). The thermostat should also be equipped with a manual override to accommodate changes in routine use.

There is currently a make-shift stove in the living room of the Bungalow. This is clearly not the original fireplace nor does it appear safe. Still a space-heating stove will provide an educational opportunity to showcase alternative heating methods. In recent decades, the EPA has set guidelines for efficiency and emissions for wood-burning stoves which require them to be vastly cleaner and more efficient than their predecessors.

Among stove options, pellet-burning stoves are by far the most efficient and cleanest. Although they lack some of the rustic charm of loading the stove with cordwood, they provide a much more even flow of heat and are semi-automated, making their operation much simpler. This is ideal if guests are to use the stove. A pellet-burning wood stove is therefore recommended for the Bungalow. The user simply adds pellets to a hopper and sets the desired heat output. An ash tray is periodically emptied and cleaned. The ash can be disposed by spreading it in a garden or on a compost pile. Pellets for the stove are made from renewable biomass, often recycled wood waste; thus matter that would have been

*A more accurate prediction of the winter solar window can be found using a solar plotter. A solar plotter can accurately determine where shadows will fall on a given site throughout the year based on a site's latitude. If results from the solar plotter or a change in the immediate site (i.e. trees cut down around southern perimeter) reveal that solar energy is a viable option for the Bungalow, this should absolutely be the first choice energy source. A passive system is likely to be the best option. The Solar Heat and Solar water heat sections should be consulted if this option does become possible. (See pg. 49)

taking up space in a landfill is converted into usable energy. Assuming bedrooms will be unoccupied for most of the day, using space heat just for the main living space will allow the thermostat for the whole house to be set several degrees lower, saving energy overall.

Although most pellet stoves on the market incorporate a modern aesthetic, there are those that mimic the appearance of more traditional wood stoves. Many are available that vent directly outdoors, eliminating the need for a complicated chimney installation. The stove and vents must be checked and cleaned annually by a professional. Of course the area around the stove must be clear of combustible surfaces. In this area of the living room the floor and wall should be tiled, rather than covered in wood or drywall. *GeoStone* and *EcoCycle* tiles (available from *Crossville Ceramics*) are porcelain stone tiles made from recycled materials. A fire extinguisher should be kept on hand near the stove.

Since a hot water storage tank will already be present for space heating, it makes sense to use it for domestic hot water as well. Energy can be saved by using one system in place of two. Any water storage system with enough capacity to heat the space should provide adequate hot water. Do not oversize the water boiler, as it wastes energy.

Cooling

Especially since the Bungalow is meant to showcase efficient and responsible energy consumption, conventional air conditioning is inappropriate. Passive solutions and low impact ventilation techniques should be employed instead.

The large clearing to the southern side of the Bungalow can be a liability during the summer when solar gain is unwanted. Since much of the roof will be replaced, the overhangs should be designed to provide shade on the southern side during the summer, when the sun is highest in the sky. A general approximation of the appropriate overhang length can be found by divididing the wall height (window height plus wall above) by four for south-facing windows. This will allow in winter light but keep out direct sunlight in the summer when it is unwanted. This simple detail can be highlighted in educational materials describing the Bungalow's energy efficiency.

Natural ventilation should be maximized to provide cooling air movement. In any redesign or addition, care should be taken so that all interior spaces have access to at least two windows on different walls. This will facilitate air movement through the house. Windows should be fitted with screens so that they can be opened in warmer weather. Ceiling fans can have a significant impact on the comfort of occupants, making temperatures tolerable up to 5˚ warmer than otherwise. Guests should be reminded, however, that ceiling fans are only helpful in occupied rooms. They should be switched off when leaving a space. Appropriately sized fans should be used in the main living area and possibly in bedrooms as well. Rooms without permanent fans should have window fans available for especially warm spells.

Manual shading devices are also key for minimizing solar gain and keeping the interior during the summer. Rehabilitating the exterior shutters and providing an easy method for closing them from the interior will provide dramatic cooling effects when windows are exposed to direct sunlight. Interior devices are less effective because they still allow the sunlight to radiate through the glass; the heat is then trapped on the interior. However, to ensure that moveable shading is easily accessible to guests, it is recommended that reflective shades or blinds are installed over the windows.

Recommendations: Bungalow

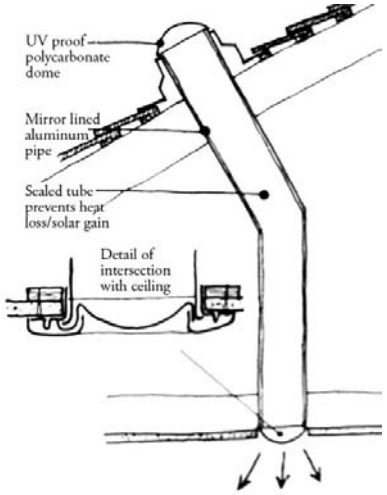
Electricity & Lighting

The vast majority of electricity is produced at large coal-burning plants. This comes with significant environmental costs, from the ecologically damaging process of coal-mining, to the pollution released during combustion. Worse still, a large percentage of electric energy is lost as it travels through the wires from the power plant to the point of use. Unfortunately, there is not a reasonable alternative for producing electric current at the Bungalow other than acquiring it from the grid. Therefore, the best way to be environmentally responsible is to limit its use. In large part this is done by avoiding water or space heating systems that use electricity as a power source. Secondly, this is accomplished by minimizing the number of electric appliances.

Whenever possible, daylighting should be used as an alternative to artificial lighting. Assuming that the Bungalow will perform primarily as a retreat and lodging space, there is no need for overall bright lights. Light fixtures should be kept to a minimum and limited to specific task lighting. No more than one light source should be attached to one switch to avoid unnecessary use. Guests should be encouraged and reminded to turn off lights when they are unnecessary. Guests who have chosen Arcola Mills as a nature focused site for retreat may easily be encouraged to organize their activities to the cycle of daylight, using the daily cycle to determine sleep schedules and daytime activities.

Interior walls should be painted in light shades to reflect light. Similarly, bathroom tile should primarily consists of light colors. This simple measure will dramatically increase the efficacy of daylighting. With new additions to the west of the Bungalow it is likely that the bathroom will be without access to a window for daylighting. Because much of the Bungalow's roof will require replacement, there is a fortuitous opportunity to enhance interior daylighting. A light pipe can be installed to funnel daylight into the bathroom. It should open to a south-facing portion of the roof.

With compact fluorescent lights (CFLs) available now in tones that mimic the warm glow of incandescents, there is no need to use the latter. CFLs are dramatically more efficient and last much longer. The reduced energy cost and long lifetime easily pay for their more expensive initial cost. Choose CFLs with electric high frequency ballasts (rather than magnetic) as they further reduce the oscillating associated with older fluorescent lights and do not pause when switched on.



Light pipe; image from *Eco-Refurbishment*

If security lighting is necessary outside, choose a HID bulb which is among the most efficient available. This can be outfitted with a light sensor so that it automatically turns on at night and off when it is light again.

Water

Water for the Bungalow will likely come from a well (yet to be drilled) and sourced out of its basement. This well will also serve other nearby cabins, including the Mill House and Houseboat. Like electricity, the best way to be environmentally responsible with water is to limit its use.

In a residence like the Bungalow which will have minimal kitchen needs, no laundry facilities, and no need for landscape irrigation, the toilet will consume the vast majority of water. The best choice for the Bungalow is a dual flush toilet that allows users to choose a half flush or

full (still low) flush depending on necessity. If used properly a dual flush toilet can be a significant source of water savings.

Other points of water use in the Bungalow should be equipped to minimize consumption. Low flow fixtures on the sink, and especially on the shower should be used. A lever tap on the sink (rather than dials) reduces water use because it minimizes water wasted while re-finding the desired water temperature.

Because of the Bungalow's proximity to the St. Croix River, wastewater must be handled carefully to avoid any harmful pollution of ground or river water. Traditional septic tank systems are prone to malfunction, releasing smelly effluent that is harmful to the surrounding environment. If time and finances permit, a greywater recycling system should be considered. This would recirculate water from the sink and shower for flushing the toilet. Wastewater from the toilet (blackwater) still requires a septic tank though. A pre-treatment system can minimize the negative environmental effect of such a system. The *Dyno2* system which is planned for the Mansion at Arcola Mills, provides wastewater pretreatment before it percolates into the ground. This system should be used to prevent water contamination from a regular septic tank. Consult with the manufacturer to determine whether the Bungalow should have its own system, or if the treatment system should be shared with one or more other cabins.

Landscaping

The landscape around the Bungalow has significantly changed over the past century. Some trees growing near the building or on the site of the addition will have to be chopped down. Their wood should be salvaged for mulch or firewood. Otherwise, natural vegetation should be left as uninterrupted as possible.

General Rehabilitation Checklist

- ☐ Insulation (spray cellulose or insoylation where possible)
  - Roof: R-50
  - Exterior walls and floors over uninsulated spaces: R-30
  - Basement walls: R-20
  - Interior bathroom walls
  - Window quilts, with tight-fitting seal
  - Insulated interior shutters in addition
- ☐ Draft-proof
  - Seal fireplace
  - Weatherstrip exterior doors and windows
  - Baseboard on compressible strip
  - Restore east and south porches as thermal buffer
- ☐ Ventilation
  - Attic
  - Bathroom fan attached to occupancy sensor
- ☐ Windows
  - Double paned, low-e, wood frame, screens
- ☐ Roof
  - Re-design during addition process
  - *Eco-Shake* or *Enviro-Shake* shingles
- ☐ Wood Cladding
  - Re-use existing siding where possible
  - Replace and add on with reclaimed or FSC certified timber
  - Seal with naturally derived product
- ☐ Flooring
  - Re-use as much as possible
  - Replace with reclaimed timber
  - Linoleum in bathroom

- Use *Homasote* or *WoodStalk* underlayment with natural adhesive
- Recycled porcelain stone tiles around hearth area
- Natural area rugs

☐ Walls & Finishes
- Replace damaged studs with reclaimed timber
- Gyp. board wall with high recycled content
  - –Paper joint tape
  - –Low VOC, dry-mix joint compound
- Natural, zero-VOC paint
- Natural wood sealer for woodwork
- Recycled glass tile in bathroom

☐ Space Heat
- High efficiency, condensing gas boiler (extra insulation)
- Small or micro bore radiators in first floor rooms OR in-floor radiant heat
- Programmable thermostat
- Pellet-burning stove

☐ Hot Water
- Integrated with space heating system

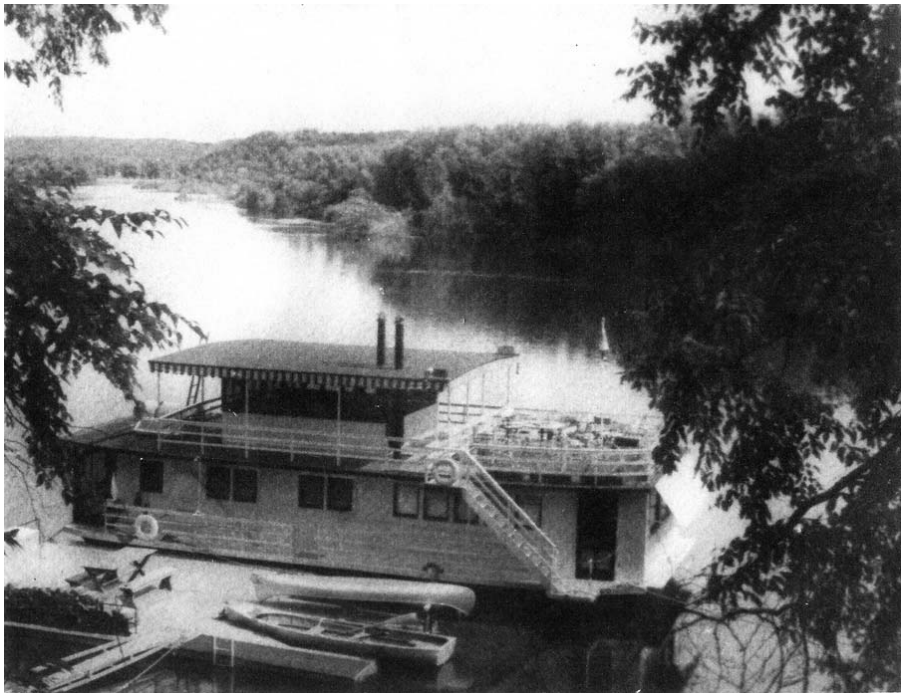
☐ Cooling
- Redesign roof for deep overhangs
- Ceiling fans and temporary window fans
- Repair shutters
- Interior reflective blinds or shades

☐ Lighting
- Paint and tile walls with light colors
- Light pipe for interior bathroom
- Task lighting (no permanent light fixtures)
- CFL bulbs with electronic ballasts for interior
- HID bulb for exterior security, attached to light sensor

☐ Water
- Sourced from well in basement (also distributed to other cabins)
- Dual-flush toilet
- Low-flow fixtures
- Recycle greywater for flushing toilet
- Wastewater treated with *Dyno2* system

☐ Landscape left as natural as possible

Recommendations: Houseboat



Historic photo of Houseboat on the St. Croix River, 1930s

Overview

The Houseboat was built in 1922 and was originally, in fact, a functioning houseboat. Though it never had its own engine, it was towed up the St. Croix River every summer and docked just below its current position on the bluff. In the 1950s, it was moved to its current location. The Houseboat retains the character of a river vessel in its narrow bedrooms, outdoor decks, and river view. The Houseboat is not currently listed on the historic register. It is strongly recommended that efforts to list the building wait until *after* rehabilitation.

The rehabilitated Houseboat will have two one-person bedrooms on the lower floor and a larger bedroom above. Because of the thin walls of the structure and the desire to maintain its visual character, the Houseboat is not intended for year-round occupancy, as it will not be possible to adequately insulate it. The structure will be moved inland as a remedy to its precarious position right at the edge of a steep hillside. It will also be given a more stable foundation.

Appropriate to its structure and former use, the Houseboat's thematic emphasis will be water. Educational displays will highlight the environmental concerns surrounding water consumption and pollution. Although most of us pay little attention to water consumption and view clean, potable water as an infinite resource, this is unfortunately not the case. The world's supply of freshwater is limited and dwindling due to pollution. The Houseboat will focus on minimizing unnecessary water consumption. It will also highlight materials, systems, and ways of acting within the environment that avoid groundwater pollution.

Current Status

The Houseboat currently rests on CMU blocks right at the edge of the bluff that descends to the St. Croix River. Slow erosion of the hillside, and the under-developed foundation make this an unsatisfactory situation.

Unsound CMU foundation

The hull of the Houseboat is constructed of mahogany and is primarily without observable rot, though there is some on the north side. Much of the perimeter deck on both levels has rotted badly. Fortu-

nately, though, the extent of water damage is surprisingly limited. The rest of the Houseboat's structure and interior materials are reparable and not overwhelmingly damaged by rot. The interior beadboard is also mahogany and in relatively good condition with a few discreet areas of decay.


Rot on north side


Damaged wood on lower deck




Most interior woodwork remains in good condition

At first glance the overall structure of the boat seems adequate. However, on the second floor there is evidence that the roof is inadequately supported. The structure is currently being supplemented by an additional metal pole in the center of the second floor space. Some of the joists in that space may be in need of replacement, or at least reinforcement.

The roof over the current kitchen area has partially collapsed.

The floor of the bathroom and kitchen (located on the north end of the first floor) appear to be inadequately supported, and the kitchen floor has a large hole in it.

The roof (on both levels) is plagued by serious leaks. A large tarp is currently being used to prevent excessive moisture infiltration into the interior.


Temporary support pole in top bedroom


Hole in kitchen ceiling


Hole in kitchen floor


Tarp covers leaks in roof

Currently the houseboat is clad on both the interior and exterior with painted mahogany beadboard, except for the first floor hall and bedrooms which are unpainted. There is little room within the wall and no evidence that any part of the boat is insulated. The original single-pane windows of the boat are opened by sliding them into cavities below on the first floor. On the second floor they open outward on hinges. None of the windows have screens or storm windows.

First Priorities

The first priority of rehabilitating the Houseboat must be to ensure its structural integrity. This will entail replacing those elements that are badly damaged or those that are inadequately sized for their function. In some cases, reinforcement or repair may be an acceptable alternative to

replacement. A structural engineer or experienced contractor should be consulted for all structural and construction decisions. A full analysis of what is necessary structurally is beyond the scope of this report. What follows is a basic outline of items that need to be addressed and recommendations for dealing with those issues in an environmentally responsible way. Contractors, architects, or engineers involved in the project should be apprised of the environmental concerns of the Arcola Mills center, and these suggestions shared with them.

To ensure the safety of the structure, the boat must be moved inland at least 6′. This will involve cutting down several trees to the immediate west of the building. The wood of these trees should be salvaged for firewood or mulch on the premises. The relocated building must rest on a new permanent foundation. Options for foundations include 18″ diameter posts or perimeter footings. A structural engineer should be consulted. In any case, the new foundation must allow the wood of the boat hull to rest a minimum of 8″ above the ground level. When the boat is lifted onto its new foundation, the opportunity must be taken to inspect the hull for any damaging rot or decay which is not currently visible.


Houseboat currently sits at edge of bluff


Trees to immediate west will be cut down

Some of the Houseboat's structure may require replacement. Floor and ceiling joists should be checked to be sure they are providing adequate support and that they are not damaged by moisture or decay. Wherever necessary, beams should be replaced or resized to meet the requirement of their load. The posts supporting the roof overhang on the second floor are undersized for their function. They should be replaced with sturdier posts. A structural engineer and/or contractor should be consulted to determine the specific details of the structure.


Undersized posts support roof overhang

It appears that interior floorboards currently extend all the way to the exterior of the building where they are exposed. This poses a number of problems in terms of water and air infiltration. This detail may need to be redesigned to ensure that all exterior elements are well sealed and that moisture is not able to infiltrate the interior environment via external elements. An architect, engineer, or contractor should be consulted.


Stairs to be repaired

The perimeter deck should be selectively replaced, preserving areas that are still viable. The lower deck is almost entirely rotted away. This part should be torn off and the opportunity used to inspect the revealed areas for rot. The exterior stairs will require repair. Care should be taken so that they meet basic guidelines for their run to rise ratio, and that they are structurally sound with a handrail.

Any interior wood that shows sign of rot or mold will need to be replaced. Because of the unique character of the wood walls, as much of it should be salvaged as possible. In some areas, such as the west bedroom on the first floor, this can be achieved simply by adding a base-

board along the perimeter. This will allow the rotted portion to be removed without necessitating the removal or replacement of the entire panel.


Rot along floor in west bedroom

Much of the wood currently present in the Houseboat will be able to be salvaged. This strategy should be used as much as possible. In some areas, however replacement will be necessary. Although the original Houseboat is primarily built of mahogany, it is difficult to locate new mahogany that has been harvested in a responsible way. Even when it can be located, it requires excessive energy consumption in transportation costs. And of course, any energy consumption that relies on the burning of fossil fuels produces pollution that can eventually make its way into natural waterways. Therefore, alternative local hardwoods should be sought out for any replacement or additional wood used on the Houseboat.

For wood items that require replacing, the first priority should be to use reclaimed wood from another source. Using salvaged wood avoids the need to harvest from living forests. It also prevents old wood from being sent to the landfill. Much salvaged wood is old-growth hardwood, of a higher quality than the new wood available. Many companies in Minnesota specialize in reclaimed timber for used in floorboards, dimensional lumber, and heavy timber.

For some applications where it is not possible to secure reclaimed wood, every effort should be made to purchase new wood products from a sustainable source, namely products that are FSC certified. Refer to the Wood section for an explanation on the importance and benefit of specifying wood from an FSC certified source.

For any areas of the Houseboat that require treated wood to deal with moist exterior environments or to avoid problems with insects, seek out the least environmentally harmful treatments possible. For areas where the concern is limited to insect infiltration and not water resistance, choose a borate based treatment. If moisture resistance is necessary, choose ACQ treated wood over CCA treated wood, or, even better, consider a natural alternative such as *Lifetime Wood Treatment* which is a non-toxic product and is safer for the environment as well.

Should particleboard or plywood be necessary in the Houseboat's rehabilitation, an alternative product should be considered instead. Many products such as *DuraCane, EcoPanel, and PrimeBoard* are manufactured from agricultural waste with similar properties.

Because of concerns with leaking, a new roof assembly should also be a first priority of the Houseboat's rehabilitation. Refer to the Roof recommendations (pg. 104) in the following section for more details about its assembly and materials.

First Priorities Checklist:

- ☐ Relocation
  - • New foundation
  - • Inspect for hull's integrity
- ☐ Structural Support
  - • Floor joists and beams
  - • Roof overhang posts
- ☐ Exterior
  - • Redesign of details
  - • Weatherproofing
- ☐ Perimeter Decks—replace decayed portions
- ☐ Repair exterior Stairs
- ☐ Interior
  - • Add baseboard
  - • Selectively replaced rotted or damaged areas
- ☐ Roof

Environmental priorities:

- Wood Source
  - 1–Reuse
  - 2–Salvaged/Reclaimed wood
  - 3–FSC certified wood
- Wood Treatment
  - 1–Untreated
  - 2–Borate
  - 3–ACQ or *Lifetime Wood Treatment*
- Wood alternatives (*DuraCane, EcoPanel, and PrimeBoard*)

General Rehabilitation

Insulation

It is unrealistic to view the houseboat as a year-round inhabitable space while maintaining its aesthetic character. The beadboard on interior and exterior walls prevents the addition of sufficient insulation without ruining the appearance of at least one side of the wall. Still, as much insulation should be applied as possible to extend the habitable season of the boat as long as possible and to keep it efficient during that time.

Wherever possible, cellulose (or soy, if it is available) spray or loose-fill insulation should be used. Cellulose has a low embodied energy and a high recycled content (from newspapers), reducing resource depletion. Cellulose insulation typically use borates as a fire-retarder, one of the least environmentally offensive chemicals used for that purpose. Applying it as a spray helps to minimize air infiltration.

The hull space below the first floor should be heavily insulated with blown cellulose well above code requirements. Some storage areas are currently set into the floor of the first level. If these spaces are still desired, they should be rebuilt with insulation around them on all sides within the hull and the trap door in the floor should be fitted with insulation (probably rigid board).

Floor storage space

The roof of the boat (on both levels) also requires significant insulation. Because hot air rises, roofs have the greatest potential for losing heat. In these areas, cellulose is not likely to be a reasonable solution. It may be more sensible to use rigid foam insulation as part of the new roof assembly. Compare manufacturers to find a product with the lowest CFC and HCFC content. Although this insulation has a much more harmful and energy-intensive manufacturing process than cellulose, it will save energy in the building's operation. An architect or contractor should be consulted to determine the exact assembly of this element within the roof structure.

Although providing large amounts of insulation in the roof and below the floor of the Houseboat is an important step in increasing the efficiency of the building, simply adding insulation above and below cannot make up for the fact that the walls pose little resistance to heat transfer. Loose-fill or blown cellulose should be applied to any available cavities in the walls. The beadboard in the north rooms (current kitchen and bathroom) is no

Current wall conditions in bath and kitchen; to be tiled and insulated

longer in especially good condition. Since large portions of the walls in these rooms should be tiled anyway, it makes sense to add thickness to the wall from the interior and to fill the cavity with blown cellulose insulation. Cellulose should also be blown into the walls between the bathroom spaces and other interior space to prevent losing heat from warm water and as a sound barrier.

Interior walls of 1st floor bedrooms and living room; to be insulated with second layer of beadboard applied to interior

If FSC certified beadbord can be found to mimic the appearance of the current interior, it makes sense to add a cavity to the exterior walls of the first floor rooms and to fill the cavity with blown cellulose. This will not significantly change the appearance of the interior, nor will it dramatically affect the usable interior space. As is, these spaces already reveal a stud frame that can be used to attach a second layer of beadboard. The cavities below the first floor windows should not be filled in with insulation, as the space is needed for opening the windows.

Moveable insulation will be crucial to extending the habitable period of the Houseboat. Window quilts with tight edge seals are recommended for the windows of the second floor bedroom. They should be employed during the heating season whenever windows are not receiving direct sunlight.

Interior pop-in panels with a rigid foam core will add significant R-value to the first floor windows. They should be employed (in the heating season) on all windows at night and in any windows that are not receiving direct sunlight in unoccupied rooms. Removable pop-in panels provide a much higher R-value than other temporary insulation options (about R-4 per in of foam thickness). They can be handmade (and even embellished by a local craftsperson or quilter—look for volunteers). Pop-in panels are made of rigid lightweight insulation like polystyrene or polyurethane (purchase at Home Depot or similar retailer). They can be covered in decorative fabric on the interior side. A vapor retarder on the warm size of the insulation will minimize the possibility of condensation on the window and frame. Care should be taken so that the panels fit snugly in the window frame with minimal air infiltration. Guests of the Houseboat should be made familiar with the use of the panels, and their important energy-saving function explained.

Once the season for open windows has ended, insulation can be placed in the cavities below the first floor windows. These can be made of rigid foam insulation like that used in the window pop-in panels. These panels should be carefully designed to fit snugly in the cavities. During the non-heating season, window and window-cavity pop-in panels will require storage, probably in the main building.

Windows on the second floor should be outfitted with snugly fitted window curtains or thermal shades. These shades should be pulled at night or whenever the windows are not receiving direct sunlight during the day. The shades must seal tightly on the sides and espcially at the bottom to the window sill. This can be achieved with velcro, magnets, or other means.

To maximize the benefits of insulation, the Houseboat should be thoroughly draft-proofed. All exterior doors should have weatherstripping. Windows, likewise, should be carefully sealed. Baseboard should rest on a compressible strip above the floor to prevent any air leakage.

Strategic ventilation should be coupled with the insulation and draft-proofing process. A bathroom extract fan should be used to removed humid air from the living space and vent it to the exterior. It is recommended that the fan be attached to an occupancy sensor so that it turns on automatically whenever a guest uses the bathroom.

Recommendations: Houseboat

Windows

Windows open by sliding into cavity below

The first floor windows of the Houseboat display a charming ingenuity in their design. The single pane squares open by sliding into removable pockets in the wall below. Every effort should be made to restore the windows to their original functionality. Most of the glass is in fine condition; many of the frames may need repair. Certainly they will require paint stripping and careful realignment in their respective spaces. If any pieces of the windows' wooden frames require replacement, use reclaimed or FSC certified wood.

Still, to make the Houseboat reasonably efficient, additions will have to be made to increase the R-value of the windows. The current single pane of glass provides only R-1 insulation value. Sturdy storm windows should be fitted to the exterior of the windows as secondary glazing. These should be in place for the extent of the heating season (including when the building is unoccupied. In the warmer months, storm windows should be removed and replaced with custom-fit screens so that windows can be opened for ventilation without allowing insects to enter.

Secondary glazing should not significantly alter the exterior appearance of the Houseboat. In addition, the storm windows are a removable feature and should therefore should not pose a problem if and when a historic designation is sought.

Windows on the second floor swing out on hinges. These should be replaced with similar models of casement double glazed windows. Screens should also be fitted for these windows for use in warmer months.

Roof

View from upper deck overlooking river

For a flat roof, like that of the Houseboat, EPDM (synthetic rubber) is the best material choice. Although it poses environmental hazards in its manufacture, its initial production has a low embodied energy and its impact is lower compared to most other options. In addition, its durability means that it will not require frequent replacement and is less likely to leak than alternative products, assuming it is carefully installed. EPDM remains flexible at low temperatures, is not prone to damage from the freeze-thaw cycle, and resists damage from hail. Newly available solvent free (i.e. no VOCs) EPDM should be specified. Choose black rather than white EPDM to absorb the most heat.

The upper deck/first floor roof will require an additional wear level so that the space can be used as an outdoor patio without damaging the roof materials. This might be achieved with wooden boards or tile. An architect or experienced contractor should be consulted to make sure that any finish layer does not interfere with appropriate water drainage.

Cladding

The exterior beadboard mahogany siding of the Houseboat is still in relatively good condition. If any requires replacement, an alternative wood to mahogany should be used. Seek FSC certified beadboard suitable for exterior use.

The current siding needs to be stripped of its paint which likely

contains lead. This should be done according to approved procedures for lead paint removal and disposal. The exterior should then be resealed with an exterior latex paint. Older photographs of the boat reveal that it was originally white. This is therefore an appropriate shade for the renovation. Seek out paints or exterior stains with low toxicity from companies like *BioShield Paints* or *AFM Safecoat*. The exterior of the houseboat should receive regular maintenance and painting to maintain the durability of the siding.

Exterior details such as this sign should be preserved

Flooring

As much of the interior wood flooring should be preserved as possible. Any necessary replacement floorboards should use reclaimed timber from one of the many local suppliers. If for any reason this option is not feasible, the new wood should be from an FSC certified source. The wood floor should be sealed and maintained with natural products from a company like *BioShield Paint* or *AFM Safecoat*. Both penetrating oils and floor wax are suitable finishes for the wood floor so long as they are properly maintained, though they create different tactile effects. The *BioShield Paint* catalog provides a description of the differences as well as maintenance requirements for each method.

The floor of the bathroom spaces should be rehabilitated with a more resilient flooring, one that can cope with the moist environment. The current flooring in the kitchen (to be converted to a shower) and bathroom appears to be vinyl or linoleum but is not salvageable. A new linoleum floor should be applied in these areas. This will ensure the durability of the space and a high indoor air quality. Linoleum is made of natural materials, biodegradable, and naturally anti-microbial. Vinyl should not be used. The adhesive used to attach the floor deserves careful selection. Many adhesives contain high levels of VOCs and harmful chemicals. If possible, a natural adhesive should be chosen over a synthetic. *BioShield Paints* makes such adhesives. Check with the linoleum manufacturer to make sure that the adhesive is compatible with the flooring and underlayment. If a synthetic adhesive must be used specify with low or zero VOC content.

Choose an environmentally responsible underlayment for the linoleum floor such as *Homasote* or *WoodStalk* (see manufacturer listings).

Area rugs in the living spaces and bedrooms can keep the floor warmer in the winter and also protect the wood floor. If new carpet is purchased, it should be made of natural materials on a natural backing. Several manufacturers of such products are listed in the appendix. Avoid synthetic carpets, as they have negative environmental effects and contribute to poor indoor air quality.

Interior Walls & Finishes

The interior walls of the Houseboat should be preserved as much as possible, both to conserve resources and to retain their unique appearance. Wood walls provide the fortunate opportunity to avoid interior finishes like paint or wallpaper which come with negative environmental side effects. The painted areas of the interior should be carefully stripped in accordance with approved guidelines for removing lead paint. All interior wood should be carefully cleaned and then sealed with natural products. Synthetics can release harmful VOCs and detract from indoor air quality. *BioShield Paints* and *AFM Safecoat* both manufacture interior wood sealers and waxes made from natural materials.

If any areas are painted, a natural paint should be used. Refer to the

Interior Finish part of the Information section (pg. 37) to determine the most environmentally sound choice.

Exposed wood in the bathroom should be sealed with a water-resistant finish (again, see natural options from *BioShield* or *AFM*). In areas that are susceptible to frequent water exposure (near the sink, around the shower, etc.) choose tiles rather than wood on the walls. Although ceramic and glass tiles are energy intensive in their manufacture, their durability makes them an environmentally sound choice. Choose reused tiles if they can be found or those that are made from 100% recycled materials (several options listed in appendix).

Heat & Water Systems

Choosing the best systems for any building is a complicated decision-making processes. Because efficient systems are interdependent, a change in one element can have repercussions for others. That is, what is a good choice in the context of specific other choices may no longer be the best option if other elements change. This should be kept in mind when considering the recommendations in this section. Use the Information section of this report to gain a familiarity with the different options available, their appropriate use, and general pros and cons of each and use that knowledge to guide decision-making. Unanticipated conditions may require departing from the recommendations outlined here, and as one element changes, others may need to be adjusted accordingly.

Solar energy, when available, is among the cleanest energy sources for space and water heating. However, because of its shaded location, solar power (for heat, hot water, or electricity) is not a reasonable choice for the Houseboat.

During the portion of the season that does require space heating, radiators are a good choice for the Houseboat. They should be placed in the main living space, the two lower bedrooms, and bathroom spaces. Floor vents in the second floor bedroom should connect to the lower spaces. Because the Houseboat is a small building, the natural movement of air should provide adequate heat for the upper bedroom, especially if it is used primarily as a sleeping space. Choose radiators with low capacity and small- or micro-bore pipes which increase efficiency. Radiators should be individually adjustable with thermostats rather than simple on/off switches. All pipes running from the boiler to the radiators must be well insulated to avoid heat loss.

Place radiators along interior walls rather than beneath windows to slow heat loss. In addition, place a shelf above each radiator and an insulated reflector behind to direct heat into the living space.

A high efficiency condensing gas boiler is the most efficient choice for water-based heating. In a condensing boiler, the steam that results from gas combustion is cooled by the return water from the heating system. As the steam condenses it releases latent heat which is used by the boiler. Condensing boilers are about 20% more efficient than conventional gas boilers. Check manufacturer's information to compare their efficiency rating and choose one that is not oversized for the required job. Consider converting the back (north) porch into a mechanical space (not accessible to guest)s for the boiler and any other necessary mechanical equipment. If this is done, the space must be fully insulated from the exterior. The boiler itself also requires plenty of insulation. If space allows, add more batt insulation to the exterior of the storage tank.

A programmable thermostat is worth the expense. This will allow temperature settings to fluctuate during the day (and even in weekly cycles) to match the building's use. Temperatures should be set significantly lower overnight. Guests should be reminded of the energy and pollution savings created by lowering the thermostat even just a couple of degrees, and be encouraged to add more blankets rather than bumping up the thermostat. Position the thermostat away from extreme tem-

peratures (i.e exterior walls, windows, doorways, radiators). The thermostat should also be equipped with a manual override to accommodate changes in routine use.

Current wood stove and prior fireplace

There is evidence in the Houseboat of several permutations of spaceheating stoves and fireplaces. This remains a good option for heating the living space on cool days or evenings before the true heating season begins. This will avoid the energy consumption involved in warming the boiler. The space heat provided by a wood burning stove can also supplement the main heating system when it is in use. Although older wood-burning stoves were inefficient at heating and were often sources of pollution both within and outside the home (releasing between 30–80g of particulates per hour), highly efficient modern stoves are available that eliminate these problems (releasing less than 6g/hr).

The current wood stove is small in order to minimize its intrusion on the limited interior space of the Houseboat. There are a number of new efficient wood stoves available that have a similarly small footprint. Amongst these are a few specifically designed for boats. *Jotul* and *Marine Wood Stoves* manufacture small, EPA approved stoves with minimal emissions. Efficiency ratings and emission ratings should be compared before making a choice.

Care must be taken to install the wood-burning stove safely. It should have appropriate clearance from all combustible surfaces, including wall, floors, and furniture. The hearth space surrounding the stove requires special fire-proofing elements. This is currently achieved in a fairly makeshift and unattractive fashion. Instead, the beadboard and wood floor in this area should be replaced by non-combustible tile. Ideally the tile should come from a salvaged source; if this is not possible seek tiles with a high recycled content. Manufacturer instructions should be consulted to determine the necessary chimney capacity, height, and location. The current stove chimney runs through the upper bedroom. This feature should be maintained as it keeps more of the heat inside the building. Appropriate safety measures should be taken to ensure that all areas near the chimney have a non-combustible finish, and to be sure that guests cannot inadvertently touch the chimney pipe.

Guests of the Houseboat must be instructed on how to operate the stove properly in order to ensure its efficiency. Firewood should be thoroughly air dried to ensure efficient energy extraction. Consult the Heat information section (pg. 42) for more detailed instructions on operating a wood stove properly. Chimneys, vents, and pipes must be checked annually. Chimneys should also be cleaned anually to remove built-up creosote. A chimney temperature gauge should be installed to display the temperature of exiting gases. It can be used to monitor the stove's use and prevent the excessive production of harmful creosote. A sufficiently sized fire extinguisher should be available near the stove.

Because the Houseboat will not be occupied year-round (limiting the use of space heating elements like large storage boilers), a demand water heater for showers and sinks is recommended. Demand systems do not store any hot water; instead they heat water on demand near the point of use. Although demand water heating is a less efficient way of heating water, for buildings with limited hot water use, they can save energy overall because no energy is spent maintaining the heat of a large body of stored water. An appropriately sized gas model should be chosen. *ProTankless* manufactures several gas powered demand models. The water supply to the demand heater should run from the conventional boiler and the demand heater should be equipped with a temperature

sensor. That way, during the limited part of the year when the space heat is running, the demand heater will not have to operate.

Cooling

Trees around the Houseboat will provide some shade during the summer months and help to keep it cool. Natural ventilation should be maximized in the summer and will provide a comfortable environment on all but the very hottest days. Those few days when the temperature does slightly exceed the comfort range do not warrant the expense or energy consumption of air conditioning.

As mentioned previously, all of the Houseboat's windows should be fitted with exterior screens so that they can be opened in warmer weather and encourage ventilation. The overhangs from the upper deck and roof will significantly shade the interior during the summer months when the sun is high. Unfortunately, because the Houseboat's long axis runs north-south, it is especially vulnerable to eastern and western solar gain in the morning and afternoon. Interior shading devices can prevent overheating. A curtain rod is already in place in the living area. Opaque curtains (dark on the inside, light and reflective on the outside) should be used when the sun is directly heating the interior on hot days. There is also a curtain rod currently above the door between the living space and bedroom hallway. A curtain may be placed here for times when privacy in necessary. However, the curtain should be kept to the side when possible to allow for air movement.


Curtain rod in living space


Curtain rod over doorway

Because of the low ceilings in the Houseboat, ceiling fans are not appropriate. Instead, each room should be equipped with a standing space fan that can be used to facilitate air movement in the summer. Interior doors should be kept open whenever possible to encourage ventilation.

Electricity & Lighting

There is not a reasonable alternative for producing electric current for the Houseboat other than acquiring it from the grid. Therefore, the best way to be environmentally responsible is to limit its use. In large part this is done by avoiding water or space heating systems that use electricity as a power source. Secondly, this is accomplished by minimizing the number of electric appliances.

All rooms in the Houseboat are well supplied with windows. Daylighting should therefore be considered the primary source of interior illumination. The main living space, with windows on both the east and west sides, should be well daylit for the most of the day.

Light fixtures should be kept to a minimum. Assuming that the Houseboat will perform primarily as a retreat and lodging space, there is no need for overall bright lights, nor would they be historically appropriate. The large fluorescent fixture currently in the living space is obviously not an original fixture and is an example of the


Current living room light fixture

type of lighting that should be avoided. Lights in the Houseboat can be limited to small areas of task lighting in the living space and bedroom. No more than one light source should be attached to one switch in order to avoid unnecessary use. Guests should be encouraged and reminded to turn off lights when they are unnecessary. Guests who have chosen Arcola Mills as a nature focused site for retreat may easily be encouraged to organize their activities to the cycle of daylight, using the daily cycle to determine sleep schedules and daytime activities.

With compact fluorescent lights (CFLs) available now in tones that mimic the warm glow of incandescents, there is no need to use the latter. CFLs are dramatically more efficient and last much longer. The reduced energy cost and long lifetime easily pay for their more expensive initial cost. Choose CFLs with electric high frequency ballasts (rather than magnetic) as they further reduce the oscillating associated with older fluorescent lights and do not pause when switched on.

If security lighting is necessary outside, choose a HID bulb which is among the most efficient available. This can be outfitted with a light sensor so that it automatically turns on at night and off when it is light again.

Water

Potable water for the Houseboat will likely come from a well (yet to be drilled) and sourced out of the basement of the Bungalow. Like electricity, the best way to be environmentally responsible with water is to limit its use.

In a residence like the Houseboat which will have minimal kitchen needs, no laundry facilities, and no need for landscape irrigation, the toilet will consume the vast majority of water. Because the educational focus of the Houseboat is water, the toilet's water consumption is worth some consideration. Using a traditional toilet system, a residence like the Housboat could use more than 40% of its water consumption for toilet flushing. This wastewater is usually directed to a septic tank. Septic tanks, unfortunately, are notorious for leaking, polluting natural waterways with untreated effluent.

A composting toilet offers the opportunity to provide clean, odor-free toilet facilities without the use of any water. As an additional benefit, the by-product of a composting toilet is a rich compost excellent for plants. Because the Houseboat does not provide any space with easy access below the bathroom, a remote unit is not appropriate. *Sun-Mar*, *Envirolet*, and several other manufacturers make a variety of self-contained units. In order to maintain satisfactory performance it is critical that the composting toilet receive regular and appropriate maintenance and that it is properly sized and installed. Refer to the Water section (pg. 68) for more information on the maintenance required for the upkeep of a composting toilet.

If cost, site, aesthetics, or other issues prevent the use of a composting toilet, the Houseboat's bathroom should be equipped with a dual flush toilet which allows users to choose a half flush or full (still low) flush depending on necessity. If used properly a dual flush toilet can be a significant source of water savings. If a dual flush toilet is used, the *Caroma* brand is recommended. These toilets look like and install similarly to traditional toilets.

Other points of water use in the Mill House should be equipped to minimize consumption. Low flow fixtures on the sink, and especially on the shower should be used. A lever tap on the sink (rather than dials) reduces water use because it minimizes water wasted while re-finding the desired water temperature. If a flush toilet is used, greywater from showers should be recirculated for flushing. (Because sink water may contain food residue, it should not be recirculated). Currently the bathroom contains only a sink and toilet. It is recommended that the current

kitchen space be converted into a shower space. If necessary, the back porch can be converted into a mechanical area for the water heater.

In addition to reducing water consumption, it is important to responsibly treat used water. Arcola Mills is not connected to a sewer system (nor are those systems typically well designed to avoid overflowing and leaking untreated sewage into natural waterways). Traditional septic tanks do not provide an environmentally satisfactory solution for disposal of wastewater. However, a pretreatment system like the *Dyno2* that is being installed for the Arcola Mansion's wastewater, provides a responsible alternative for dispersing wastewater back into the natural environment. The effluent from a septic tank is filtered through a plant root system to remove bacteria and release cleaner water into the designated dispersal area. Discussions with the manufacturer should determine whether the Houseboat should have its own *Dyno2* system or if a larger system should be combined to treat water from a group of cabins.

Landscaping

The landscape around the Houseboat is generally reflective of native plant species. Efforts must be made during construction to disturb the natural environment as little as possible. A few trees, however, will need to be cut in order to relocate the Houseboat. The wood from these trees should be mulched for use on site or chopped and dried for firewood. Formal landscaping should be kept to minimum. Damaged waterways near the Houseboat should be restored to encourage a natural watershed.

General Rehabilitation Checklist

- ☐ Insulation (spray cellulose or insoylation where possible)
  - Cellulose in hull (very high R-value)
  - Insulation detail around hull storage compartments
  - Roof insulation—rigid foam with low CFC and HCFC content
  - Add cavity and cellulose to bathroom
  - Bathroom interior walls
  - Add cavity and cellulose to lower bedrooms and living space (do not fill in window cavities)
  - Pop-in window panels for first floor
  - Moveable window cavity insulation panels
  - Window quilts with tight seal for second floor
- ☐ Draft-proof
  - Weatherstrip doors
  - Compressible strip below baseboards
- ☐ Ventilation
  - Bathroom extract fan with occupancy sensor
- ☐ Windows
  - Repair (with FSC certified wood where needed)
  - Add exterior storm windows and screens to first floor
  - Replacement double glazed windows for second story
- ☐ Roof
  - Black EPDM (solvent-free, low VOC)
  - Finishing material for accessible patio
- ☐ Cladding
  - Reuse/replace with FSC certified beadboard siding
  - Strip lead paint
  - Paint white(ish) with *BioShield* or *AFM Safecoat* exterior paint

Recommendations: Houseboat

☐ Flooring
- Reuse/replace with reclaimed timber
- Seal, maintain, and clean with natural-based products
- Linoleum in bathroom
- Use *Homasote* or *WoodStalk* underlayment with natural adhesive
- Natural area rugs

☐ Interior Walls & Finishes
- Repair interior beadboard
- Add baseboard on compressible strip
- Strip lead paint
- Clean and seal interior beadboard with natural product
- Natural paint, if used
- Tile water-exposed bathroom areas with reclaimed or recycled tile
- Tile area around wood-burning stove

☐ Space Heat
- High-efficiency condensing boiler (extra insulation)
- Low capacity small or micro-bore radiators in each room on 1st floor
- Floor vents in upper bedroom
- Place radiators on interior walls
- Shelf above and insulated reflector behind each radiator
- Insulate hot water pipes
- Programmable thermostat
- Small, efficient wood burning stove; chimney routed through upper bedroom

☐ Hot Water
- Gas demand water heater with temperature sensor, intake water from boiler

☐ Cooling
- Reflective curtains
- Room fans

☐ Lighting
- Limited fixtures; each with own switch
- CFL bulbs for all interior lighting
- HID exterior security light

☐ Water
- Self-contained composting toilet (1st choice)
- Dual flush toilet (2nd choice)
- Low flow fixtures, lever taps
- Kitchen converted into shower room
- Recirculate shower water to flush toilet
- *Dyno2* pretreatment system

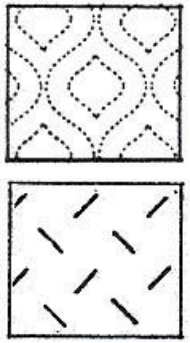
☐ Landscaping
- Repair watershed paths
- Cut down trees necessary for relocation
- Minimize disruption to natural environment

Manufacturers & Products

Insulation

Moveable Insulation

1 Window Quilts



Information:
- Exterior: 70% polyester and 30% cotton; Fill: 100% polyester
- Available in regular light diffusing or room darkening
- Several colors available
- Available with fire retardant
- R-value: 4.99

Address: 4 Laurette Dr; Essex Jct., VT 05452
Phone: 877.966.3678
Fax: 877.366.3678
Email: service@1windowquilts.com
Website: 1windowquilts.com

***Search internet for other window quilt manufacturers**

Fiberglass Insulation

CertainTeed

Information:
- Batt and blown-in fiberglass insulation with 30% recycled content, some from curbside recycling
- Available in standard unfaced or faced

Address: P.O. Box 860; Valley Forge, PA 19482
Phone: 800.233.8990 (building professionals)
800.782.8777 (consumers)
Website: www.certainteed.com
*See website for distributor
*See supplemental manufacturer brochure for more information

Johns Manville

Information:
- Fiberglass blankets, batt, board and loose fill with 20% to 30% recycled glass
- Formaldehyde-free, acrylic binder
- R-11 to R-25 batts

Address: P.O. Box 5108; Denver, CO 80217
Phone: 800.654.3103 (product and sales info)
303.978.2000 (insulation expert)
Website: www.jm.com
*See website for distributor and to email
*Available from:
- Alpine Insulation
  1177 North Birch Lake Road; White Bear Lake, MN 55110
  651.426.7510
- Insulation Supplies
  1415 South Fifth Street; Hopkins, MN 55343
  952.932.9000
- Menards (available at most locations)
  www.menards.com

*See supplemental manufacturer brochure for more information

Ottawa Fibre, Inc.

Information:
- Fiberglass insulation products from 100% recycled glass (overall recycled content 65%)
- R-value is R-11 to R-38

Address: 3985 Balgreen; Ottawa, Ontario Canada K1G 3N2
Phone: 613.736.1215; 1.877.634.7378 (store locator)
Website: www.ofigroup.com

Mineral Wool Insulation

Roxul, Inc.

Information:

- Mineral wool from basalt rock and recycled steel slag
- Available in batt and board forms
- Naturally insect resistant
- Non-combustible, withstands 1832° F, and can act as fire barrier
- Manufacturing plant has recycling facility to redirect waste back into manufacturing process, resulting in 50% water usage reductions and raw material consumption and energy usage reduction

Address: 551 Harrop Drive; Milton, Ontario; Canada L9T 3H3
Phone: 800.265.6878
Website: www.roxul.com
*Find dealer via website, email via website

ThermaFiber LLC

Information:

- Loose-fill rock wool with 50% to 70% recycled content from iron ore slag.
- Non-combustible: resists temperatures up to 2000˚F.
- Vermin proof

Address: 3711 W. Mill St.; Wabash, IN 46992
Phone: 888.834-.371; 260.563.2111
Fax: 800.294.7076; 260.563.8979
Email: info@thermafiber.com
Website: thermafiber.com

Cellulose Insulation

American Insulation, Inc.

Information”

- 100% recycled newsprint content in various sized bags and brands
- Distribution limited to Midwest

Address: P.O. Box 9; So. Main Industrial Park; Bloomer, WI 54724
Phone: 715.568.3898

Applegate Insulation

Information:

- Loose-fill and blown cellulose insulation from 85% post-consumer recycled materials
- Uses one-fifth the energy it takes to manufacture Fiberglass

Address: 1000 Highview Dr.; Webberville, WI 48892
Phone: 800.627.7536
Fax: 517.521.3597

Modern Insulation, Inc.

Information:

- 80% of Weather Blanket brand from post-consumer recycled newsprint

Address: P.O. Box 157; Spencer, WI 54479
Phone: 715.659.2446

P.K. Insulation Manufacturing Co.

Information:

- Cellulose insulation made from post-consumer recycled newsprint for spray and loose-fill applications.

Address: 2417 Davis Blvd.; Oplin, MO 64802
Phone: 417.781.6380
Website: www.pkinsulation.com

Natural Fiber Insulation

Bonded Logic: Ultratouch

Information:

- 85% post-industrial recycled natural fibers (cotton and denim contents are 100% post-industrial)
- Does not itch, easy to handle, no chemical irritants, no VOCs
- Meets highest ASTM testing standards for fire and smoke ratings, fungi resistance and corrosiveness
- Oversized widths to ensure a tight friction fit and fill capacity
- Boron-based fire retardant also impedes growth of fungus, mold, and resists pests
- 3.5″ has R-value of 13; 5.5″ is 19

Address: 411 East Ray Road; Chandler, AZ 85225
Phone: 480.812.9114
Fax: 480.812.9633
Website: www.bondedlogic.com
*Email via website
*Available from:

- Architectural Surfaces, Inc.
  123 Columbia Court; Chaska, MN
  952.448.5300

*See supplemental manufacturer brochure for more information

Inno-Therm

Information:

- Recycled cotton & denim fiber
- Fire-retardant
- Rates 10% better than fiberglass in Sound Transmission (STC), sound absorption and complies with existing ASTM standards for batting insulation
- Self supporting in stud wall applications
- 3.5″ has R-value of 13; 5.5″ is 19

Address: P.O. Box 226; 1633 Shea Rd.; Newton, NC 28658
Phone: 877.466.0612; 828.466.1147
Fax: 828.466.1498
Email: sgillett@twave.net
Website: www.innotherm.com

Alternative Insulation

Icynene (spray foam)

Information:

- No loss of R-value over time (R-value: 3.6/in)
- Contains no CFCs, HCFCs, or HFAs, no detected emissions
- Made from organic by-product of petroleum distillation process
- Suitable for wood frame structure
- Insoluble in water, combusts at 400˚; won't sustain combustion on its own
- Can also be applied as loose fill through 1/2" drill holes

Address: 6747 Campobello Rd; Mississauga, ON L5N 2L7 Canada
Phone: 800.758.7325
Fax: 905.363.0102
E-mail: inquiry@icynene.com

Insoylation (spray soy)

Information:

- Annually reproducible base product, no VOCs or CFCs, no formaldehyde
- Does not support mold growth, resists pests—no food value
- Class 1 fire rated
- Open-cell, semi-rigid; behaves similar to petroleum based plastic foam

Contact: Tom Lorger
Address: 160 South Second Street; Milwaukee, WI 53204
Phone: 414.333.4524
Fax: 414.344.3411
Email: tlorger@insoylation.com
Website: www.insoylation.com

Windows

Anderson Windows

See Windows section and company website for product description
Address: 100 Fourth Avenue North; Bayport, MN 55003-1096
Phone: 888.888.7020 (customer support)
800.426.4261 (brochures, find dealer)
651.264.5150 (corporate office)
Website: www.andersonwindows.com
*Email via website

Marvin Windows

See Windows section and company website for product description
Address: P.O. Box 100; Warroad, MN 56763
Phone: 888.537.7828
Website: www.marvinwindows.com
*Email and dealers available via website

Wood

FSC Certified Wood

Aacer Flooring

Information:
FSC certified flooring, hardwood
Northern hardwood, several species available
Thicker than industry standards (25/32″)
Random length boards in standard widths: 1 1/2″, 2 1/4″, 3 1/4″
Peshtigo river plank, wide plank flooring: 3″, 4″, 5″ in several species
Address: PO Box 151 Peshtigo, WI 54157
Phone: 877.582.1181; 715.582.1181
Email: genaacer@aacerflooring.com
Website: www.aacerflooring.com

Bennet Lumber

Information:
FSC certified Dimensional lumber and other wood products
Locations at Clarkston, Washington and Princeton, Idaho
Address: P.O. Box 49; Princeton, Idaho 83857
Phone: 208.875.1121; 208.875.1321 (sales)
Fax: 208.875.0191
Website: www.bennett-lumber.com
*Available at:
• True Value Hardware (special order only)
2828 Emerson Avenue S; Minneapolis, MN 55408
Phone: 612.870.0801

Brunkow Hardwood Corp.

Information:
FSC certified lumber, many species
Locations at Clarkston, Washington and Princeton, Idaho
Contact: Bob Brunkow
Address: S1102 Mill Road; Nelson, WI 54756
Phone: 715.675.4343
Fax: 715.673.4318

Cecco Trading Co

Information:

FSC certified, naturally durable hardwoods "IronWoods" with natural resistance to decay, good for outdoor uses
Fire-resistant, no chemicals used
Lumber available in standard sizes
Location of wood harvesting unknown
About $4-$6/sq. ft.

Contact: Roger Kasper
Phone: 866.295.2326

Certified Wood Products, Inc

Information:

FSC certified paneling, siding, beams, posts, framing lumber (2x4s–2x12s; l=10–20 ft) in west coast hemlock fir, plywood (4′x8′x1/2″, 4′x8′x3/4″) in western fir

Address: 11742 Fairfield Road Suite 201; Minnetonka, MN 55305-7433
Phone: 612.868.9934
Fax: 952.543.8465
Email: certifiedwood@mn.rr.com

Collins Co: CollinsWood

Information:

FSC certified **hardwood flooring**: cherry, red oak, beech, red maple, ash.
Dimensional softwood lumber from California and Oregon (ponderosa pine, lodgepole pine, white fir, sugar pine, incense cedar)
Lumber, logs, and dimensional hardwood lumber from Pennsylvania (black cherry, red oak, white oak, ash, hard maple, red maple, beech, yellow poplar, basswood, birch)
Particleboard (CollinsWood) with high percentage of western pine; available FSC certified; manufactured from 100% post-industrial waste

Phone: 800.329.1219; 503.417.7755
Fax: 503.417.1441
Email: rbyers@collinsco.com
Website: www.collinswood.com
Available from:

- Home Depot (special order)
  www.homedepot.com

*See manufacturer brochures for more information

Hill Wood Products

Information:

FSC certified lumber from Minnesota White Birch
7/16″–11 1/2″ thick, 31 1/2″–53 1/4″ wide, 40″–48″ tall

Address: P.O. Box 398 9483 Ashawa Rd.; Cook, MN 55723
Phone: 800.788.9689
Fax: 218.666.5726
Website: www.hillwoodproducts.com

Living Forest Coop

Information:

FSC certified wood harvested from northern WI
Flooring in hard maple, white ash, red maple, aspen, white birch; sold in random widths from 2 1/4″–5″; $2.75–$5.50 sf. (can be sold in uniform width for extra charge)
Kiln dried lumber in aspen, hard maple, white birch, red maple
Can buy unfinished logs
Wood harvested during freeze to minimize soil disturbance

Address: 422 Third Street West, Suite 103; Ashland, WI 54806
Phone: 715.682.0007; 866.995.9663
Fax: 715.682.8425
Email: info@livingforestcoop.com
Website: www.livingforestcoop.com
*See supplemental manufacturer brochure for more information

Midwest Hardwood Corp.

Information:

FSC certified, kiln dried Northern and Appalachian wood: alder, basswood, cherry, hard maple, red oak, soft maple, white ash, walnut, white oak, white pine, white birch, yellow birch, walnut, white oak, white pine, white birch, yellow birch

Address: 9540 83rd Ave. North; Maple Grove, MN 55369

Phone: 763.425.8700

Fax: 763.391.6742

Email: inquiries@midwesthardwood.com

Website: www.midwesthardwood.com

Upper Mississippi Certified Group

Information:

FSC certified aspen, balsam fir, basswood, birch, black ash, pine, red oak, spruce, tamarack, larch

Flooring, furniture, logs, lumber (green or kiln-dried), millwork, mouldings, siding

Contact: Ross Wagner

Address: Economic Development & Forest Industry Coordinator; 217 Second Street NW, Suite 131; Aitkin, MN 56431

Phone: 218.927.7305

Fax: 218.927.7374

Email: rwagner@co.aitkin.mn.us

Wood flooring International: Single-strip American quartered collec.

Information:

Engineered wood flooring product resembling solid wood plank.

75% FSC certified wood, 25% postindustrial recycled wood content.

Wood sourced from around the globe (American Woods are the only FSC certified)

9/16″ thick, with 1/8″ thick wear layer, widths of 3″ and 5″, random lengths 12″–84″

May be nailed, glued or floated

Acrylic Urethane w/aluminum oxide finish

Address: 122 Kissel Road; Burlington, NJ 08016

Phone: 856.764.2501

Fax: 856.764.2503

E-mail: info@wflooring.com

Website: www.wflooring.com

Available from:

- Justus Lumber
  330 11th Avenue So; Hopkins, MN
  952.938.2741
- Scherer Bros. Lumber
  612.379.9633
  www.schererbros.com
- T & G Hardwood Distributors
  2972 Cleveland Ave; Roseville, MN 55113
  Contact Greg Patterson
  651.633.3343
  *Wholesale distributors only. Can refer to flooring installers.

Woodland Forest Products (lumber)

Information:

FSC certified kiln dried lumber: ash, aspen, bass, white birch, yellow birch, butternut, cherry, hickory, hard maple, soft maple, red oak, white oak, ponderosa pine, northern white pine, yellow poplar, walnut

Various grades and thickness. specialized lengths available.

Contacts:

- Dan Jacobson, Truckload Sales: dan@woodlandforestproducts.com
- Marc Connaway, Truckload Sales: marc@woodlandforestproducts.com
- Bill Rogers, Distribution Sales: bill@woodlandforestproducts.com
- Lianna Moody, Traffic/Customer Service: lianna@woodlandfo

restproducts.com
Address: 1272 Helmo Avenue North; Oakdale, MN 55128
Phone: 651.714.8100
Fax: 651.714.8215

Salvaged Wood

A & B Disposal

Information:
- Runs a landfill site where you can take/buy salvaged wood.

Contact:Alex Lillies
Address: 592 Division Street; Kingston, ON K7K 4B6, Canada
Phone: 613.542.4126, 613.546.7591 (yard)
Fax: 613.542.1210

Duluth Timber Co.: Reclaimed Timber

Information:
- Salvaged timbers, planks, and floor: douglas fir and heart pine
- Custom sawn flooring and millwork
- All products salvaged from demolition of industrial structures
- Kiln dried to 8-12% moisture

Contact: Liz
Address: P.O. Box 16717; Duluth, MN 55816
Phone: 218.727.2145
Fax: 218.727.0393
Email: Liz@duluthtimber.com
Website: www.duluthtimber.com

Elmwood Reclaimed Timber

Information:
- Reclaimed from pre 1930s buildings that are condemned, abandoned, or beyond repair
- Wide plank flooring, solid wood beams, dimensional lumber, cabinet lumber, millwork

Address: P.O. Box 10750; Kansas City, MO 64188-0750
Phone: 816.532.0300; 800.705.0705
Fax: 816.532.0234
Email: sales@elmwoodreclaimedtimber.com
Website: www.elmwoodreclaimedtimber.com

Manomin Resawn Timbers

Information:
- Wide plank flooring available in 4″, 5″, 8″, 10″ widths, some very rustic looking
- Lumber for open-beam ceilings, custom-cut boards, fireplace mantels, and other custom woodworking.

Phone: 651.464.1771
Address (Showroom): 15152 Freeland Ave; Hugo, MN 55038
(Mailing): PO Box 417; Hugo, MN 55038
Phone: 888.207.6072
Fax: 651.464.3907
Email: info@mrtimbers
Website: www.mrtimbers.com

Old Growth Woods Inc.

Information:
- Flooring, woodwork, and furniture from reclaimed wood originally harvested in early 1900s
- Group of Midwest artisans dismantles old buildings that are beyond repair and helps preserve structures that can be saved
- Large supply of 1″ and 2″ oak, call for availability of other species/sizes

Address (Shop): 6456 160th St.; Rosemount MN 55068
(Office): 1896 Norfolk Ave.; St. Paul MN 55116
Phone: 651.690.3188

Fax: 651.698.6641
Email: Sales@oldgrowthwoods.com
Service@oldgrowthwoods.com
Website: www.oldgrowthwoods.com

Wood Treatment

Chemical Specialties, Inc. (CSI)

Information:

- Has phased out use of CCA in favor of ACQ (check specific brand, some still rely on CCA); see Preserve Plus
- TiberSaver treatment uses borate for protecting wood from decay and insects

Address: 200 East Woodlawn Rd, Suite 250; Charlotte, NC 28217
Phone: 800.421.8661; 704.522.0825
Fax: 704.527.8232
Email: acqinfo@chemspec.com
Website: www.treatedwood.com
*Retailers and distributors can be found on website
*See supplemental manufacturer brochures for more information

Lifetime Wood Treatment: Valhalla Wood Treatment

Information:

- Non-toxic: releases no harmful residue in soils and water; can be used in direct contact with garden soil without any toxic effect
- Manufactured in Canada from naturally occurring plant and mineral substances; contains no solvents
- Appropriate for decks, posts, log homes, sheds, doors, and posts and retaining walls that make contact with ground; also safe for indoors (recommended that fence posts be soaked in LifeTime for at least 2 days)
- Available as powder concentrate in 1 and 5 gallon packages (1 gallon covers 160 sf); mix with water and apply to bare, untreated or pressure treated wood with brush, roller, spray, or by dipping
- Can be applied in any weather; even 32˚ F
- Powder concentrate is light and easy to ship with indefinite shelf life
- Inexpensive

Phone: 250.538.5516
Fax: 250.538.5517
Website: www.valhalco.com
*Available at TrueValue Hardware, Ace Hardware

Osmose Wood Preserving, Inc

Information:

AdvanceGUARD and **Hi-bor**:

- Pressure treated with borate preservatives to protect against termites, carpenter ants, and fungal decay
- For use in above ground weather protected structural framing; recommended for sill plate, furring strips, joists, studs, roof trusses, blocking, rafters, beams, and other framing applications
- Also recommended for sill plate, furring strips, joists, studs, roof trusses, blocking, rafters, beams, and other framing applications
- May be sawn, drilled, or routed with standard woodworking equipment.
- Non-corrosive and may be placed in contact with aluminum
- Should not be used for outdoor structures exposed to weathering
- Field treatment of all end cuts and borings, including plumbing and electrical holes is required on all lumber and timbers over 2” in thickness

Naturewood:

- Uses ACQ, environemntally preferable lternative to CCA
- Durable and designed for outdoor construction
- Appropriate for structural lumber, sill plates, outdoor furniture, playground products, patios, decks, garden edging, and landscaping structures
- Use with hot-dip galvanized, stainless steel, or other recommended hardware

Address: 1016 Everee Inn Road; Griffin, Georgia 30224
Phone: 800.241.0240
Fax: 770.229.5225
Email: treatedwood@osmose.com
Website: www.osmose.com/wood/usa

Wood Products & Alternatives

Collins Co: CollinsWood

FSC-certified particleboard

*See FSC certified wood, pg. 116

*See manufacturer brochure for more information

DuraCane; Acadia Board

Information

- Particleboard alternative made from bagasse, the fibrous portion of sugar cane leftover after the juice is removed
- Bagasse comes from nearby farmer-owned sugar cane coop
- Bonded with MDI, a formaldehyde-free resin
- Exceeds ANSI standards for particleboard
- Appropriate wherever particleboard might be used

Contact: Alan Boyd

Address: New Ibera, LA

Phone: 318.367.8542

Email: duracane@bellsouth.net.

EcoPanel

Information:

- Panels made from fibrous agricultural waste products (sugar bagasse, water hyacinth, elephant grass, etc.)
- Uses only non-toxic binding agents
- 97% waste material, 3% binding agent
- Intended as alternative to softwoods, chipboards, MDF, and hardwood ply in some cases
- Superior water resistance to chipboard, not prone to distortion, not susceptible to infestation
- Can be sawn, nailed, glued, sanded

Email: enquiries@ecopanelsystems.com

Website: www.ecopanelsystems.com

PrimeBoard

Information:

- Particleboard alternative with formaldehyde-free binder
- Made from blend of agricultural residue fibers (wheat straw & sunflower hulls); may affect individuals allergic to grasses if surfaces remain exposed
- Available in range of sizes, thicknesses and grades.
- *See attached brochure for applicability of different board types

Address: 2441 North 15th Street; Wahpeton, ND 58075

Phone: 800.943.2823; 701.642.1152

Fax: 701.642.1154

Email: sales@primeboard.com

Website: www.primeboard.com

*Available from:

- Northern Forest Products, Centerville, MN
  651-429-9990
  *Wholesale only. Any lumberyard can special order product from them.

*See supplemental manufacturer brochure for more information

SierraPine: Medex and Medite II (Medium Density Fiberboard:MDF)

Information:

- **Medex**: no-added formaldehyde, moisture resistant MDF panel engineered for interior high moisture areas; use in place of sanded plywood and solid wood in non-structural applications
- **Medite II**: no-added formaldehyde MDF panel engineered for non-structural applications; use in place of sanded plywood and solid wood.
- Both use formaldehyde-free synthetic resin. (in Medex and Medite II panels are independently certified for no-added formaldehyde)

Phone: 800.676.3339

Website: www.sierrapine.com

*Available from:

- Scherer Bros. Lumber
  612-379-9633
  www.schererbros.com
  Call to confirm is in stock.

• www.royalplywood.com (special order)
562.404.2989

*Locate other dealers via website

Roof

Slate & Tile Roofing

Durable Slate Co.

Information

Specializes in historic restoration and repair

Buys salvaged slate and tile, over 100,000 pieces of salvaged roofing slate and tile in stock.

Address: 1050 North 4th St.; Columbus, OH 43201

Phone: 800.666.7445; 614.299.5522;

Fax: 614.299.7100

Website: www.durableslate.com

Cementitious Roofing

FiberCrete International, Inc.

Information:

Roof tiles made from composite of organic refuse and Portland cement, fly ash and concrete epoxy. Fibrous waste material varies by plant location, but may include rice hulls, straw and other agricultural waste or recycled paper sludge. Product includes 40-50% fiber in composite.

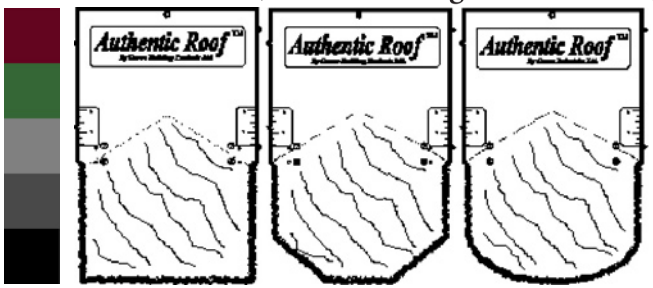
Address: 400 North Tustin Ave., Suite 400; Santa Ana, CA 92705

Phone: 800.659.2783; 714.565.2900

Fax: 714.565.2910

Recycled Material Roofing

Authentic Roof Co.(Crowe Building Products, Ltd.)



Information:

Recycled materials used to make with Baljen TPO, an alloy made of Polyethylene, Polypropylene and EPDM rubber without the use of binding agents or plasticizers (TPO is recyclable

UV protected, hail resistant, 50 year limited warranty

Priced comparatively with high end roofing materials; installation costs slightly more than asphalt shingles, less than cedar shakes

For sloped roof with no less than 3/12 pitch

Phone: 905.529.6818

Fax: 905.529.1755

Website: : www.authentic-roof.com

*See website for distributor

*Available from:

• Allied Building Products Corp. (special order)
4810 Lilac Drive N; Brooklyn Center, MN 55429
763.535.2300

• Available for special order through any roofing distributor.)

Eco-Shake from Re-New Wood, Inc.


Teak


Umber


Charcoal

Information:

Class A fire-rating, 50 year warranty, , class 4 impact rating (highest), resists mold, mildew, and fungus, freeze-thaw resistant, UV protected

Meant to resemble wood shingles

Available in random widths of 5, 7, and 12"; all 22" long

Nailed over solid decking with 30# felt applied directly to roof deck

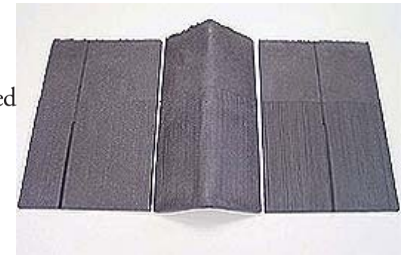
Address: 104 N.W. 8th; PO Box 1093; Wagoner, OK 74467

Phone: 800.420.7576; 918.485.5803

Email: customerservice@renewwood.com

Website: www.renewwood.com

Enviro-Shake



Information:

Mix of post industrial plastics, recycled rubber elastomers, and cellulose fibers

Color: starts out as a brownish grey color and converts to a silver-grey color that resembles a cedar roof.

Recommended for roofs with a pitch of 4/12 or greater.

Similar to Eco-Shake, meant to replicate look of cedar shingles

Hail resistant, 50 year warranty, trimmable, install like normal shingles

Address: 650 Riverview Dr., Unit # 1; P.O. Box 1462; Chatham, Ont. N7M 5W8

Phone: 866.423.3302; 519.380.9265

Fax: 519.380.0689

Email: info@enviroshake.com

Website: www.enviroshake.com

* Available from:

- Mid-America Cedar, Osseo, MN
  763.425.0125
  Steve_Bush@midamericacedar.com
  www.midamericacedar.com
  *Wholesale distributor

Recycled Rubber Roofing

Moore Enviro Systems and Tread Mill Inc

Information:

Roof tiles made from recycled rubber tires

Contact: Richard Moore, CEO

Address: Box 1459; Squamish, BC V0N 3G0, CANADA

Phone: 604.898.4877

Fax: 604.898.5683

Email: moore_enviro@yahoo.ca

Cladding

FSC-Certified Wood Siding

Certified Wood Products, Inc

Information:

FSC certified paneling, siding, beams, posts, framing lumber (2x4s–2x12s; l=10–20 ft) in west coast hemlock fir, plywood (4′x8′x1/2″, 4′x8′x3/4″) in western fir

*See Wood section (pg. 116) for contact information

Fiber Cement Siding

James Hardie Bldg Products: Hardiplank, Hardi Shingleside, Hardipanel (Fiber Cement Siding)

Information:

- Durable, long-lasting product resembles wood siding
- Consists of Portland Cement, sand, clay, and wood fiber.
- Resists rotting and cracking, water and hail damage, insects, shrinking and swelling
- Non-combustible
- Limited warranty up to 50 years
- Lap siding, shingle siding, individual shingles available
- Can be painted
- Installed over braced wood or steel studs spaced maximum of 24″ o.c. or directly to minimum 7/16″ thick OSB sheathing; can also be installed over foam insulation up to 1″ thick

Phone: 888.542.7343

Email: info@JamesHardie.com

Website: www.jameshardie.com

*Available from:

- Allied Building Products Corp.
  4810 Lilac Drive N; Brooklyn Center, MN 55429
  763.535.2300
- Home Depot
  www.homedepot.com
  *Call to verify product is in stock.
- Justus Lumber
  330 11th Avenue S; Hopkins, MN
  952.938.2741
- Lampert Yards Inc.
  14555 Galaxie Avenue W; Apple Valley, MN 55124
  952.432.0600
- Scherer Bros. Lumber
  612.379.9633
  www.schererbros.com
- Stock Building Supply
  915 Yankee Doodle Road; Eagan, MN 55121
  651.454.4985
- United Building Centers

Bark Cladding

Furniss Enterprises

Information:

- Poplar bark siding
- $6/ft^2

Address: P.O. Box 269;
Lake Toxaway,
NC 28747

Phone: 828.966.4035

Email: jfurniss1@citcom.net

Website: www.naturalbarksiding.com

Highland Craftsmen

Information:

- Poplar bark siding
- No chemical additives
- Bark comes from trees already felled for lumber; would otherwise be a waste product

Bark shingles come in two lengths (26″ or 18″) and ; two grades (standard: 1/2″–7/8″ thick, Premium: 1″–1 1/2″ thick with more pronounced crevices; widths 4″–4′-0″

Also produces flat panels and sheets made from different kinds of bark, for use as specialty finishes; rarer, thus more expensive; treat like standard panels; 2′–4′ wide, 8′–10′ tall

Address: PO Box 2011; Blowing Rock, NC 28605
Phone: 828.295.0796
Email: chris@highlandcraftsmen.com
Website: www.highlandcraftsmen.com

Indoor Air Quality

BioShield Paint Co.

Information:

Household cleaners: laundry soap, chlorine-free bleach, organic plant-based hand soaps, vinegar cleaner, toilet cleaner, dishwashing soap, glass cleaner; all made of natural ingredients without phosphates, petroleum, synthetic fragrances, dyes, or preservatives

*See Natural Paint section for contact information (pg. 133)

AFM SafeCoat

Information:

Variety of formaldehyde-free all purpose and carpet cleaners

*See Synthetic Paint section for contact information (pg. 134)

Flooring

FSC Certified Hardwood

Aacer Flooring

Information:

FSC certified flooring, hardwood

Northern hardwood, several species available: thicker than industry standards (25/32″), random length boards in standard widths: 1 1/2″, 2 1/4″, 3 1/4″

Peshtigo river plank, wide plank flooring: 3″, 4″, 5″ in several species

Address: PO Box 151 Peshtigo, WI 54157
Phone: 877.582.1181; 715.582.1181
Email: genaacer@aacerflooring.com
Website: www.aacerflooring.com

Collins Co: CollinsWood

Information:

FSC certified **hardwood flooring**: cherry, red oak, beech, red maple, ash.

Phone: 800.329.1219; 503.417.7755
Fax: 503.417.1441
Email: rbyers@collinsco.com
Website: www.collinswood.com
Available from:

- Home Depot (special order)
  www.homedepot.com

Living Forest Coop

Information:

FSC certified wood harvested from northern WI

Flooring in hard maple, white ash, red maple, aspen, white birch; sold in random widths from 2 1/4″–5″; $2.75–$5.50 sf. (can be sold in uniform

width for extra charge)
Kiln dried lumber in aspen, hard maple, white birch, red maple
Wood harvested during freeze to minimize soild disturbance

Address: 422 Third Street West, Suite 103; Ashland, WI 54806
Phone: 715.682.0007; 866.995.9663
Fax: 715.682.8425
Email: info@livingforestcoop.com
Website: www.livingforestcoop.com
*See supplemental manufacturer brochure for more information

Upper Mississippi Certified Group

Information:
FSC certified aspen, balsam fir, basswood, birch, black ash, pine, red oak, spruce, tamarack, larch

Contact: Ross Wagner
Address: Economic Development & Forest Industry Coordinator; 217 Second Street NW, Suite 131; Aitkin, MN 56431
Phone: 218.927.7305
Fax: 218.927.7374
Email: rwagner@co.aitkin.mn.us

Wood flooring International: Single-strip American quartered collection (Engineered wood flooring)

Information:
Engineered wood flooring product resembling solid wood plank.
75% FSC certified wood, 25% postindustrial recycled wood content.
Wood sourced internationally (American Woods are the only FSC certified)
9/16″ thick, with 1/8″ thick wear layer, widths of 3″ and 5″, random lengths 12″–84″
May be nailed, glued or floated
Acrylic Urethane w/aluminum oxide finish

Address: 122 Kissel Road; Burlington, NJ 08016
Phone: 856.764.2501
Fax: 856.764.2503
E-mail: info@wflooring.com
Website: www.wflooring.com
Available from:

- Justus Lumber
  330 11th Avenue So; Hopkins, MN
  952.938.2741
- Scherer Bros. Lumber
  612.379.9633
  www.schererbros.com
- T & G Hardwood Distributors
  2972 Cleveland Ave; Roseville, MN 55113
  Contact Greg Patterson
  651.633.3343
  *Wholesale distributors only. Can refer to flooring installers.

Reclaimed Hardwood Flooring

EcoFriendly Flooring

Information:
Reclaimed wood flooring: yellow heart pine and douglas fir from WI; $4.50-$11.50/sq. ft.
Provide installation services for Minnesota
*See website for color/palette options

*See Bamboo Flooring for contact info (pg. 127)

Duluth Timber Co.: Reclaimed Timber

Information:

Salvaged planks, and floor: douglas fir and heart pine
Custom sawn flooring and millwork
All products salvaged from demolition of industrial structures
Kiln dried to 8-12% moisture

Contact: Liz
Address: P.O. Box 16717; Duluth, MN 55816
Phone: 218.727.2145
Fax: 218.727.0393
Email: Liz@duluthtimber.com
Website: www.duluthtimber.com

Elmwood Reclaimed Timber

Information:

Wide plank flooring reclaimed from pre 1930s buildings that are condemned, abandoned, or beyond repair

Address: P.O. Box 10750; Kansas City, MO 64188-0750
Phone: 816.532.0300; 800.705.0705
Fax: 816.532.0234
Email: sales@elmwoodreclaimedtimber.com
Website: www.elmwoodreclaimedtimber.com

Manomin Resawn Timbers

Information:

Wide plank flooring available in 4″, 5″, 8″, 10″ widths, some rustic looking

Phone: 651.464.1771
Address (Showroom): 15152 Freeland Ave; Hugo, MN 55038
(Mailing): PO Box 417; Hugo, MN 55038
Phone: 888.207.6072
Fax: 651.464.3907
Email: info@mrtimbers
Website: www.mrtimbers.com

Old Growth Woods Inc.

Information:

Flooring from reclaimed wood originally harvested in early 1900s
Group of Midwest artisans dismantles old buildings that are beyond repair and helps preserve structures that can be saved
Large supply of 1″ and 2″ oak, call for availability of other species/sizes

Address (Shop): 6456 160th St.; Rosemount MN 55068
(Office): 1896 Norfolk Ave.; St. Paul MN 55116
Phone: 651.690.3188
Fax: 651.698.6641
Email: Sales@oldgrowthwoods.com
Service@oldgrowthwoods.com
Website: www.oldgrowthwoods.com

Bamboo

Amati Bambu Ltd. (Bamboo Flooring)

Information:

3-ply, horizontally laminated with thin, vertically laminated strips in center ply; aluminum based polyurethane

Address: 350 Steelcase Road W.; Markham, ON L3R 1B3, Canada
Phone: 905.477.8899
Fax: 905.477.5208
Email: e-mail: sales@amatibambu.com

Bamboo Hardwoods

Information:

Uses the hardest species of bamboo ever discovered, available in 4 colors and several different styles

Engineered floors have maximum dimensional stability, floor is stable enough to "float", "nail-down" or glue-down. An engineered floor is much less likely to be affected by temperature and humidity changes
Solid floor is oriented in one direction, must be nailed to a healthy plywood substrate. Solid floors are cheaper
Pre-finished floors are finished with Aluminum-Oxide, a mineral resin, non-toxic. inert; does not off-gas
Bamboo harvested in china and Indonesia

Address: main office/warehouse: 510 S. Industrial Way; Seattle, WA 98108
Retail store: 6402 Roosevelt Way NE; Seattle, WA 98115-6619
Phone: 206.264.2414; 1.800.783.0557 (main office/warehouse)
206.529.0978 (retail store)
Website: www.bamboohardwoods.com
* See attached brochures for product and pricing information

D&M Bamboo Flooring Co.

Information:
Pre-finished and unfinished solid flooring
Solid, engineered, and floating parquet floors

Address: 528 Congress Circle South; Roselle, IL 60172
Phone: 630.582.1600
Fax: 630.582.1700
Email: sales@dmbamboo.com
Website: www.dmbamboo.com
*Available from:

- Walcro, Inc
  Bloomington, MN (Headquarters)
  Phone: 952.884.6033; 800.352.2763
  Roseville, MN (Store)
  Phone: 615.635.9537

EcoFriendly Flooring

Information:
Bamboo flooring ($3.00-$6.00/sq. ft)
Provide installation services for Minnesota
*See website for color/palette options

Address: 100 S. Baldwin Street #110; Madison, WI 53703
Phone: 608.441.3265; 866.250.3273
Email: ecofriendlyfloor@aol.com
Website: www.ecofriendlyflooring.com

Smart House International

Information:
Bamboo flooring: $5.50/sq ft

Address: 2024 S. Broadway; Rochester, MN 55907
Phone: 507.932.5455
Email: michelle@smarthouseinternational.com
Website: www.smarthouseinternational.com

Smith & Fong Plyboo Co.

Information:
Two colors, natural and amber in various shades
Also produces 100% bamboo plywood: 4 x 8 Sheets-Standard, unfinished, compatible with industrial finishes

Address: 375 Oyster Point Blvd. #3; South San Francisco, CA 94080
Phone: 650.872.1184; 866.835.9859
Fax: 650.872.1185
Email: sales@plyboo.com
Website: www.plyboo.com

Linoleum

Armstrong World Industries: Marmoret

Information:

Natural linoleum originally from Germany, made from renewable resources

Phone: 800.233.3823

Website: www.armstrong.com

Available from:

- STS Flooring
  17200 Medina Road, Suite 800; Plymouth, MN 55447
  763.383.7693

EcoFriendly Flooring

Information:

Linoleum: durable, biodegradable material that is comfortable, warm and quiet; $5.00/sq.ft (volume discounts avail); many colors available

Provide installation services for Minnesota

*See website for color/palette options

*See Bamboo Flooring for contact information (pg. 127)

Forbo Linoleum, Inc.: Marmoleum and Marmoleum Click

Information:

Made from renewable resources (linseed oil, rosin, wood flour, cork flour, limestone, organic pigments, jute backing)

Easy to clean, antimicrobial, natural odor, no VOCs, 200 colors

Marmoleum Click: on HDF with a cork layer in 36″ x 12″ panels or 12″ x 12″: $5.50 to $7.50 per square foot

Phone: 866.627.6653

Website: www.forbolinoleumna.com

*Available from:

- Intersource
  245 Aldrich Ave N; Minneapolis, MN 55405
  612.377.0499
- Larry's FloorCovering
  212 Commercial Street; Stillwater 55082
  651.439.6259

Smart House International

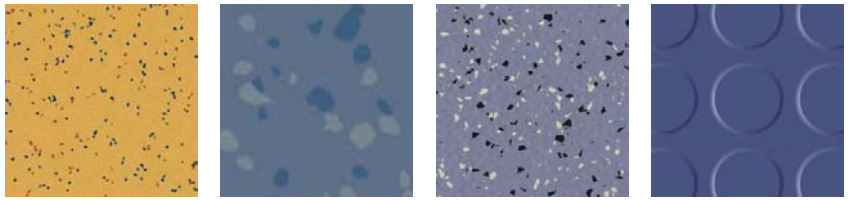
Information:

Linoleum: 3′x1′x7/16″ glueless floating floor planks; $5.50/sq.ft

*See Bamboo Flooring for contact info (pg. 127)

Rubber

Freudenberg Building Systems



Information:

Tough and hard wearing, long life expectancy

Natural rubber supplemented by raw mineral materials extracted from natural deposits and by environmentally compatible color pigments.

Does not contain PVC, plasticizers (phthalate) or halogens (e.g. chlorine)

Production scraps (such as die cut trim and sanding dust) reused in the production process to manufacture new products

Can usually be installed in rolls or tiles using solvent-free, environmentally friendly dispersion adhesives

Address: 94 Glenn Street; Lawrence, MA 01843 USA

Phone: 978.689.0530

Fax: 978.975.0110

E-Mail: info@freudenberg.com

Website: www.norarubber.com

*See website for full pattern and color options

Ceramic Tile

GeoStone/Eco-Cycle Tile (Crossville Ceramics)

Information:

Glazed Porcelain Stone tile with unfired, reused raw material body; four of the five colors have a 50% reclaimed body and 50% base body, fifth color, Night Air, has a 100% reclaimed body—reclaimed, unfired raw material, including the dust particles collected from air-filtration and waste-water treatment facilities of the plant

All tiles made of naturally occurring clays and minerals mined in Tennessee and neighboring states.

Available in five stone-look colors, 12″x12″

Suitable for floors, walls, counters

30% harder than granite, won't scratch, stain, or fade

Most tiles are shipped in recyclable paper cartons.

Filtration process takes water used during manufacturing and returns it to the city of Crossville cleaner than when it entered the factory.

Address: P.O. Box 1168; Crossville, TN 38557

Phone: 931.484.2110; 800.221.9093 (samples for architects/designers)

Fax: 931.484.8418

Website: www.crossvilleinc.com

*Available from:

- Kate-Lo
  275 Market Street #167; Minneapolis, MN 55405
  612.338.8064

*See supplemental manufacturer brochure for more information

Cork

BioShield Paint Co.

Information:

98% of ingredients in their products are natural materials

Cork Flooring: 1´ square tiles in several patterns

Floor Adhesive: elastic, water-based glue for cork

*See Natural Paint section for contact info (pg. 133)

EcoFriendly Flooring

Information:

Cork floors (ideal for comfort and high noise absorption); can be applied to any levelled surface including kitchens; starts at $3.50/sq. ft

Provide installation services for Minnesota

*See website for color/palette options

*See Bamboo Flooring for contact info (pg. 127)

Dodge Cork Co.

Information:

Unfinished, Waxed, Polyurethane Satin and Polyurethane Gloss cork tiles

Residential: 12" x 12" x 3/16", Commercial: 12" x 12" x 5/16"

Phone: 866.534.6084

Website: www.regupol.com

*See supplemental manufacturer brochure for more information

Natural Cork Inc

Information:

Parquet: solid cork glue-down tile; available in 7 standard colors and patterns; not recommended for use below grade or over in-floor radiant heating systems.

Engineered floating floor: 100% high density cork coated with U.V. cured acrylic finish (no VOCs), high-density fiberboard center core, low density cork underlayment; tongue & groove installation, no glue required; available in 18 patterns

Naturally anti-microbial, insect resistant

Eight colors and patterns.

Headquartered in Augusta, Georgia

Phone: 800.404.2675

Website: www.naturalcork.com

* Available from:
  - Floors Northwest, Inc.
    5155 E. River Road #414; Minneapolis, MN 55421
    763.586.7070
    info@FloorsNW.com
    www.floorsnw.com
  - Intersource
    245 Aldrich Avenue N; Minneapolis, MN 55405
    612.377.0499
  - Schneider Carpet One
    1112 West 7th Street
    651.224.2344
    www.carpet.one
  - Lon Musolf Distributing, Inc
    985 East Berwood Avenue
    651 484-3020
    info@lonmusolf.com
    www.lonmusolf.com

Smart House International

Information:

Floating cork floor: 3′x1′x7/16″ prefinished planks; $4–$5.50/sq.ft.

*See Bamboo flooring for contact info (pg. 127)

Carpet

Carousel (Carpet)

Information:

Sheet carpets made from wool and cotton fibers, with jute and natural latex backing (May aggravate wool allergies.)

Custom carpets and rugs.

Address: One Carousel Ln; Ukiah, CA 95482

Phone: 707.485.0333

Fax: 707.485.5911

*Available from:
  - Dadras Ltd.
    3060 Excelsior Blvd; Minneapolis, MN 55416
    612.920.8000
  - Gabberts Furniture & Design Studio (wool only)
    3501 Galleria; Edina, MN
    952.927.1500
    www.gabberts.com
  - Marshall Field's
    7235 France Avenue South
    952.896.2160

Earth Weave Carpet Mills

Information:

Broadloom or area rugs

Biodegradable: face fiber of 100% natural wool, no moth proofing or stain protections, naturally pigmented, natural primary of hemp and cotton (primary is the material that the tufting machine places the wool yarn into and holds it in place); hemp is durable, strong, and mold and mildew resistant

Adhesive is 100% natural and bio-degradable: made of natural rubber; the secondary (back of carpet) is jute, a hardy earth friendly fiber producing plant.

Natural carpet padding available: blend of coarse naturally pigmented wools mechanically needled (not glued) into a cotton scrim; free from dyes, fire retardant, glues, moth proofing or adhesives; can be recycled in garden where it will safely biodegrade while serving as a weed barrier and mulch—will completely degrade in 2-3 seasons

Rug Gripper available: 100% natural rubber non-skid rug pad for area rugs

Address: P.O. Box 6120; Dalton, GA 30722
Phone: 706-278-8200
Fax: 706-278-8201
Email: earthweave@earthweave.com
Website: www.earthweave.com
*Available from:

- Lakewinds Natural Home
  17523 Minnetonka Boulevard, Minnetonka, MN 55345
  952.742.1242
  www.lakewinds.com/index.asp
  *Call to verify product is in stock.

InterfaceFLOR: FLOR - Spring Planting Line (modular carpeting)

Information:

- Modular floor/carpet tile for the home
- Face material made from Ingeo® PLA, a corn-derived material, which takes less energy to produce and is recyclable (only applies to Spring Planting line of tiles)
- 19.5″ square; $10.99 per tile

Phone: 866.281.3567
Website: www.interfaceflor.com
*Available from:

- Re:Source Minnesota
  3700 Annapolis Lane, Suite 195; Plymouth, MN 55447
  763.694.6500

Floor Underlayment

Dow BioProducts Ltd: WoodStalk

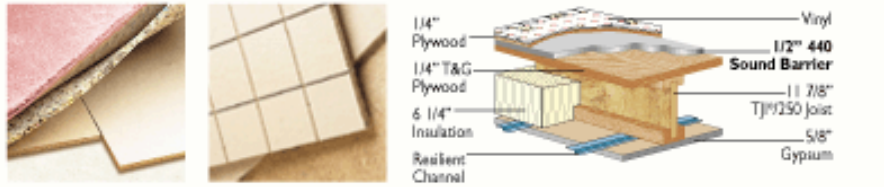
Information:

- Plywood underlayment alternative
- Made from up to 93% wheat straw fiber (may affect allergies if surface exposed)
- Formaldehyde-free polyurethane binder
- Install under vinyl, carpet, hardwood and laminate flooring; 50% harder than most plywood underlayments
- 1/4″ & 3/8″. Thicker (1/2″, 5/8″, 3/4″) to level floors.
- Manufactured in Manitoba, Canada

Phone: 800.441.4369
Website: www.dow-bioproducts.com
*Available from:

- Home Depot (Bloomington and Plymouth stores; contact others for availability)
  www.homedepot.com

Homasote, Inc. 440 Sound barrier



Information:

- High-density board made from 100% recycled wastepaper and formaldehyde-fee paraffin binder
- Designed for sound control
- Flooring underlayment and in wall assemblies, roof decking
- Variety of sizes and thicknesses.
- All water in production process is recycled in closed loop system
- Shipped from NJ

Address: Box 7240 West Trenton, NJ 08628-0240
Phone: 800.257.9491
Fax: 609.884.3497
Website: www.homasote.com
*Available from Menards (www.menards.com)

Adhesives

AFM SafeCoat

Information:

Low VOC flooring adhesive for ceramic, parquet, formica, and slate tiles; lightweight wall tiles, carpet

*See Synthetic Paint section for contact info (pg. 134)

*See supplemental manufacturer brochures for more information

BioShield Paint Co.

Information:

98% of ingredients in their products are natural materials

Floor Adhesive: elastic, water-based glue for cork, natural carpeting, and linoleum with jute backing

*See Natural Paint section for contact info (pg. 133)

Franklin International: Titebond Solvent Free (Construction adhesive)

Information:

Solvent-free, nonflammable construction adhesive contains 6.6 g/l VOCs.

Performance equivalent to conventional adhesives.

Complies w/APA, AFG-01 test for subfloors.

Phone: 800.977.4583

Website: www.titebond.com

*Available from:

- Golden Valley Supply Company
  1000 Zane Avenue North; Minneapolis, MN 55422
  763.544.8907
  *Call to verify is in stock or to special order.
- Holdahl Company
  1925 Annapolis Lane
  763.231.3130

Interior Finishes

Natural Paint

BioShield Paint Co.

Information:

98% of chemicals in their products are naturally derived from plants and minerals

Wall Paint: solvent free, zero VOC in matte or satin finish; available with ultra low VOC tints; 1 gal=$29, 5 gal=$125; pigments sold separately; shipping is about an extra 10%

Casein Milk Paint: comes as dry powder (add water) to make an off-white base that can be tinted; suitable for drywall, plaster, wood

Wall glaze: water-based, transparent concentrate made of natural ingredients

Address: 3215 Rufina St; Santa Fe, NM 87507

Phone: 800.621.2591

Fax: 505.438.0199

Email: info@bioshieldpaint.com

Website: www.bioshieldpaint.com

Old Fashioned Milk Paint

Information:

Recommended for restoration projects

Consists of milk protein, lime, and earth pigments; sold in powder, add water

Good for those with allergies and promotes good indoor air quality

Comes in 16 colors, base, primer (mix with white to get correct shade)

Phone: 978.448.6336

Email: anne@milkpaint.com

Website: www.milkpaint.com

*See website for nearby dealer and color palette

Synthetic Paint

AFM Safe Coat

Information:
- Low VOC primers, interior and exterior paint
- No formaldehyde
- Interior Paint contains zero VOCs; no formaldehyde, ammonia, crystalline silica, or ethylene glycol

Phone: 619.239.0321; 800.239.0321 (voice mail)

Email: email@afmsafecoat.com

Website: www.afmsafecoat.com

* Available at:

- Lakewoods Natural Home, Minnetonka
  17523 Minnetonka Blvd.
  952.742.1242
  www.lakewinds.coop
- Ecopolitan, Minneapolis
  2409 Lyndale Ave. S
  612.874.7336
  www.ecopolitan.com

*See supplemental manufacturer brochure for more information

Benjamin Moore Paints

Information:
- Primer, sealer, flat, eggshell, and semigloss low VOC paints available
- Low odor, low VOC, 100% latex paints: Pristine® Eco Spec® Interior Latex Flat 219, Pristine® Eco Spec® Interior Latex Eggshell Enamel 223, Pristine® Eco Spec® Latex Semi-Gloss 224

Location: Montavale, NJ

Phone: 201.573.9600; 800.826.2623

Email: info@benjaminmoore.com

Website: www.benjaminmoore.com

*See website for store locations

Duron Paints & Wallcoverings: Genesis Odor-Free

Information:
- Interior acrylic latex paint, low-VOC content
- Available in flat, low-lustre and semi-gloss
- *Only the Genesis line is low VOC

Address: 10406 Tucker Street; Beltsville, MD 20705

Phone: 800.635.0038

Fax: 301.595.3919

Email: information@duron.com

Website: www.duron.com

*Available from:

- Bennett Lumber True Value (Wall Finishes)
  2828 Emerson Avenue S; Minneapolis, MN
  612.767.7014

Sherwin Williams Co: Harmony Coatings

Information:
- Durable, low-odor, low VOC, anti-microbial, interior paint formulated without silica.
- Flat, eggshell, gloss, and primer available
- Meets or exceed the criteria set forth by LEED as defined in GreenSeal's GS-11, 2002.
- *Only the Harmony Coatings line is low VOC

Website: www.sherwin-williams.com

ICI Paints: Lifemaster 2000

Information:
- Interior eggshell, semi-gloss, and primer/sealer
- 100% acrylic; no VOCs (1 gram per liter), low odor; solvent-free

Address: 2025 Rice Street; Roseville, MN

Phone: 651.489.4224; 800.984.5444

Website: www.iciduluxpaints.com

Recycled Paint

Green Paint Co.

Information:

- Recycled paint, 90% post-consumer
- Variety of paint types, including urethane reinforced alkyd floor enamel, exterior oil-based primer, solid exterior oil stain, exterior latex house paint, interior latex eggshell finish and interior latex flat finish
- Recycled and recyclable packaging

Address: P.O. Box 430; Manchaug, MA 01526

Phone: 508.476.1992; 800.527.8866

Wood Finish

AFM Safe Coat (stain, sealer, oil)

Information:

- AFM Naturals include penetrating oil and oil wax made of natural ingredients
- Low VOC stains and sealers
- No formaldehyde
- Safecoat Polyureseal BP: very low VOC content, comparable to conventional urethanes in performance for use on wood, metal, concrete, furniture, cabinetry

*See Synthetic Paint section (pg. 134) for contacts

*See supplemental manufacturer brochures for more information

BioShield Paint Co.

Information:

- 98% of chemicals in their products are naturally derived from plants and minerals
- Aqua Resin Stain Finish: solvent free, zero VOC, water based interior and exterior wood stain; available in natural wood and accent colors
- Aqua Resin Trim Enamel: solvent free, zero VOC, water based weather resistant satin finish for interior or exterior
- Resin & Oil Stain Finish: colorize and preserve interior and exterior woodwork, provides UV protection
- Wood Impregnation Stain & Sealer: exterior wood preservative, made of linseed oil and other natural ingredients
- Citrus Thinner: low-odor solvent for clean-up of oil based products
- Penetrating Oils & Sealers: made from linseed oil, plants and other non-petroleum based materials; breathable, elastic, water-resistant coating for interior or exterior
- Floor & Furniture Finishes: oil based resin finishes and natural waxes

*See Natural Paint section for contact info (pg. 133)

United Gilsonite Laboratories (UGL): Aqua ZAR

Information:

- Clear wood finish, water-based polyurethane
- Low-odor, non-yellowing, fast drying, and resists most abrasions.

Phone: 800.845.5227

Website: www.ugl.com

*Available from:

- Abbott Paint & Carpet Co.
  1808 Grand Avenue; St. Paul, MN 55105
  651.698.5518

*Locate more retailers via website

Wallcoverings & Wallpaper

Duron Paints & Wallcoverings: EnVision Portfolio Collection

Information:

- Nonwoven textural, natural fiber, breathable, water-based inks, No PVCs or harmful substances
- Low sheen with pearlescent overprint, or metallic background with opaque Overprint; 54″ x 30 yd bolts
- Class A fire-rated

Address: 10406 Tucker Street; Beltsville, MD 20705

Phone: 800.635.0038
Fax: 301.595.3919
Email: information@duron.com
Website: www.duron.com
*Available from:
- Bennett Lumber True Value (Wall Finishes–special order from catalogues in paint department)
  2828 Emerson Avenue S; Minneapolis, MN
  612.767.7014

Eisenhart Wallcoverings Co: Paperez (wallpaper)

Information:
Nonwoven, water-based inks, No PVCs or VOCs
100% strippable on properly prepared walls
Washable with sponge and solution of mild soap and water
Class A fire rating
Use Golden Harvest GH79 E-Z Hang Adhesive from Roman Decorating Products

Phone: 800.555.2554
Email: direct@Eisenhart.net
Website: http://my.eisenhart.net/default.asp (not navigable)
* Available from:
- Hirshfield's Inc.
  8470 City Centre Drive; Woodbury, MN 5512
  651.578.2694

Innovations in Wallcoverings, Inc: InnVironments

Information:
Wide variety of wallcoverings made from cork, sisal, cellulose, and other natural, renewable and/or recyclable materials.
No solvents or heavy metals

Phone: (New York) 800.227.8053; 212.807.6300
Website: innovationusa.com
*Minnesota representative:
7254 Pontiac Circle; Chanhassen, MN 55317
952.401.9059
paulorep@yahoo.com

Muraspec Walls Natural Environments (Wallpaper)

Information:
Grasscloth papers handcrafted of natural farmgrown fibers and water-based inks; 36″x 8 yds
Treviso non-woven cellulose and polyester with 100% cotton scrim; 54" width
Abaca non-woven from wood pulp/polyester fibers/nylon; water-based inks; no heavy metals; pulp from managed forests; 54" x 30 yd bolts;
Agave non-woven wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 56" x 30 yd bolts;
Fusama non-woven wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 56" x 30 yd bolts;
Kamiko non-woven mulberry bark/wood pulp/polyester fibers; water-based inks; no heavy metals; pulp from managed forests; 42" x 30 yd bolts;
All have class A fire-rating
Shipped from Europe

Phone: 800.717.5651
Email: samples@muraspecna.com
Website: www.muraspecna.com/browser.php?brand=muraspec_walls
*Available from:
- Hirshfield's Commercial Division (Individuals may purchase from commercial division)
  725 Second Avenue N; Minneapolis, MN
  612.374.0243
  www.hirshfields.com

Tile

Amdec Glass Tile

Information:

- Made from 100% recycled post-consumer and post-industrial bottle glass
- Use anywhere ceramic tile would be used: counter tops, back splashes, fireplace hearths, showers, walls, pools, spas and floors in light traffic areas
- Exceed ANSI specifications for breaking strength.
- Translucent, opaque, semi-gloss, matte; individually handcrafted

Address: 8905 SW White Pine Ln.; Portland, OR 97225
Phone: 503.297.5933
Fax: 503.292.6409
Email: amdec@amdecglasstile.com
Website: www.amdecglasstile.com

EcoFriendly Flooring

Information:

- Glass tile: made from 100% recycled glass from post-consumer or post-industrial sources; appropriate for countertops, backsplashes, showers, and landscaping; 2″, 4″, and 6″ square; many colors/finishes available
- *See website for color/palette options

*See Bamboo Flooring for contact info (pg. 127)

Quarry Tile Company's Eco-Tile

Information:

- Ceramic Tile
- Contains a combination of post-consumer recycled glass, post-industrial grinding paste from the computer industry, and post-industrial mining waste from the sand and gravel industry

Phone: 800.423.2608
Website: www.quarrytile.com
*Available from:

- Daltile (special order)
  2920 NW Blvd; Plymouth, MN 55441
  763.694.9700
  *Additional location in White Bear Lake

Sandhill Industries (recycled glass tile)

Information:

- 100% recycled glass; each tile takes less than one-half of the energy to produce than ceramic tile, and less than one-fourth of the energy it takes to produce a cast-glass tile
- Manufacturing facility in Boise, Idaho
- Available 36 colors, glossy or matte finish
- Available as field (loose) tile or mosaic mounted on front faced film
- Used for interior and exterior installations on both horizontal and vertical surfaces

Address: 6898 S. Supply Way, Ste. 100; Boise, ID 83716
Phone: 208.345.6508
Fax: 208.345.4424
Email: sales@sandhillind.com
Website: www.sandhillind.com
*Available from:

- Fantasia
  275 Market St #102; Minneapolis, MN 55405
  612-338-5811; 612.338.7866

Smart House International

Information:

- Glass tile: some with 100% recycled content (not all sizes)

*See Bamboo Flooring for contact info

Heat

Geothermal

Econar

Information:;
- 50 year warranty
- Can be incorporated into forced air and radiant heat systems
- Can also be used for domestic hot water
- Typical home of 2000 sf costs between $10,000-$15,000 (about double cost of conventional heating, cooling, and hot water system)

Address: 19230 Evans Street; Elk River, MN 55330
Phone: 800.4.ECONAR
Email: sales@econar.com (sales and quotes)
info@econar.com (product literature and videos)
Website: www.econar.com
* See website to locate dealer
* See supplemental manufacturer brochure for more information

Stirling Engine

WhisperTech: WhisperGen

Information:
- Gas-powered Stirling engine produces residential heat and supplemental electricity
- Not currently available in the United States

Email: info@whispertech.co.nz
Address: PO Box 13 705; Christchurch 8031; New Zealand
Phone: +64 (3) 363.9293
Fax: +64 (3) 363.9294

Wood & Pellet Stoves

Jøtul: Jøtul F 602 CB & Jøtul F 118 CB Black Bear (wood stoves)

Information:
- All models made of 100% recycled cast-iron

Jøtul F 602 CB:
- Smallest cast-iron wood-burning stoves on market
- Non-catalytic combustion; max output
- EPA approved; 68% efficient; 5.2g/hr emissions
- Top or rear venting
- Functional cookplate
- About $700

Jøtul F 118 CB Black Bear:
- Non-catalytic secondary combustion
- Emissions: 2.4g/hr; EPA approved
- Efficiency unknown
- Top or rear venting

Address: 400 Riverside St; PO Box 1157; Portland, ME 04104
Website: www.jotulflame.com
*See manufacturer website for specifications and dimensions
Available from:
- Cozy Corner Fireplaces
  2263 No. McKnight Rd, Ste 2; North St. Paul, MN 55109
  Phone: 651.748.3135
- Stove & Fireplace Showroom
  255 Highway 97 Unit 3A; Forest Lake, MN 55025
  Phone: 651.464.9761
- See manufacturer website for more local dealers

*See supplemental manufacturer brochure for more information

Lennox Hearth Products (wood & pellet stoves

Information:

Spectra CI2000HT and Spectra CI1000HT (wood)
- Cast-iron, non-catalytic
- Meets EPA Phase II; Emissions: 2.72g/hr, 4.42g/hr respectively
- 96,662 BTU/hr, 87,301 BTU/hr respectively

Traditions T300P-2 (pellet)
- Cast-iron; Achieves nearly 100% combustion
- Single load of pellets provides up to 36 hours fuel.
- Up to 32,000 BTUs/hr; 85% efficiency delivers; 0.9 g/hr emissions
- Self-igniter button starts fire; remote controls monitor/control fire and heat output.

Address: 1110 West Taft Ave; Orange, CA 92865-4150

Website: www.lennoxhearthproducts.com

*Available from:

- Country Fireplace and Spas
  24139 Greenway Road, Suite B; Forest Lake, MN 55025
  651.464.0040; 651.464.0041 (fax)
  Info@CountryFireplaceandSpa.com
  www.countryfireplaceandspa.com
- Menomin Energy
  2512 Wilson St; Menomonie, WI 54751
  715.235.7283; 715.235.7512 (fax)
- See Lennox website for more retailers

*See supplemental manufacturer brochure for more information

Marine Stoves: Sardine & Little Cod

Information:

Sardine:
- Very small wood fired cast iron stove (12″x12″), $650
- 7,500–18,000 BTU output
- EPA Certification
- Non-catalytic, efficiency and emissions unknown

Little Cod:
- First produced circa 1917 for cod fishermen
- Cast iron 18″x13.75″, $1075
- 10,000–28,000 BTU's output
- EPA Certification
- Non Catalytic, efficiency and emissions unknown

Phone: 360 376 5161

Fax: 501.694.6094

Email: marinest@marinestove.com

Website: marinest@marinestove.com

Thelin Stoves

Information:
- Pellet heaters equipped with battery back-up in case of power outage
- Wood stoves all surpass EPA standards

Little Gnome:
- 34″ tall; 16″ diameter
- Heat up to 750 sq. ft. ;21,600 BTU output
- Combustion efficiency: 94%; heat exchange efficiency 69%

Parlour 3000:
- 42″ tall, 20″ diameter
- Heat up to 2000 sq. ft.
- 40,000 BTU/hr
- Efficiency: 78.5%

Parlour T-4000:
- 3.62 g/hr emissions; efficiency unknown
- Heats 1200–1500 Sq. ft.

Address: P.O. Box 847; Nevada City, CA 95959

Phone: 800.949.5048; 530.273.1976

Fax: 530.273.3707

E-Mail: sales@thelinco.com

Website: www.thelinco.com

*Available from:

- Fire Works Fireplace Installation
  3030 4th Street South; Waite Park, MN 56387
  320.240.9490
  harlanhill@earthlink.net
  www.fire-works-fireplace.com
- Wilkening Fireplace
  9608 State 371 NW; Walker, MN 56484
  218.547.3393; 800-367-7976
  wilkenfp@eot.com
  www.wilkeningfireplace.com

***For more local wood and pellet stove retailers see:**
http://hpba.org/consumer/asp/members.asp

Water Heat

Demand Water Heater

ProTankless

Information:
- Gas and Electric point water heaters
- Transportation from Vermont
- Efficiency rating: 87%, can supply 2 showers at once, 6 gal/min

Address: 340 Mad River Park; Waitsfield, Vermont 05673
Phone: 866.330.2725
Fax: 802.496.6924
Email: info@protankless.com
*See supplemental manufacturer brochure for more information

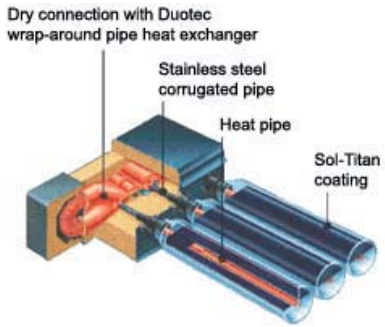
Vacuum Tube Solar Collector

Viessmann Manufacturing: Vitosol 300

Information:
- Can utilize diffused radiation
- Dry connection of the collector tubes allows for individual tubes to be mounted and disassembled without having to drain the solar heating system
- Integrated solar system package available including collectors, storage tank, pump, control unit, etc.

- Waterloo
  Address: 750 McMurray Rd; Waterloo, ON N2V 2G5, Canada
  Phone: 519.885.6300; 800.387.7373
  Fax: 519.885.0887
  Email: info@viessmann.ca
- Warwick
  Address: 45 Access Rd; Warwick, RI 02886
  Phone: 401.732.0667; 800.288.0667
  Fax: 401.732.0590

Website: www.viessmann-us.com



Photovoltaics (Solar Shingles)

OKSolar

Information:

- Bypass diodes mean that system continues to work, even in part shade or cloudy conditions
- 12″ x 86.5″ (exposure is 5″ x 85.4″)
- Nailed in place on roof decking over 30 lb. felt sheeting
- Electric lead wires (#18AWG) extend 12″ from underside through roof decking for connections on the interior
- Roof build like normal, then a template from manufacturer shows where to drill holes for wiring
- An electrician does the wiring under the roof to a combiner box

Phone: 347.624.5693
Fax: 347.534.9155
Email: Sales@OkSolar.com
Website: www.oksolar.com

Uni-Solar

Information:

- Bypass diodes mean that system continues to work, even in part shade or cloudy conditions
- Mounted 35” up from eave to ensure adequate wiring space
- VersaShield underlayment goes on wood decking and is extended 12″ around perimeter of shingle installation
- Slope 15°-60°. Ideal is the latitude plus 15º for maximum winter gain

Address: 3800 Lapeer Rd; Auburn Hills, MI 48326
Phone: 248.475.0100; 800.843.3892
Fax: 248.364.0510
Email: info@uni-solar.com
Website: www.uni-solar.com

Water

Wastewater Treatment

ReactorDynamics: Dyno2

Information:

- Advertised for having a simple installation (1 day), durable, low-maintenance, and minimal landscape disruption
- Bacteria-filled effluent from septic tank filtered through wetland plant system that removes harmful bacteria and releases clean water into dispersal area
- Pre-assembled, 7′ x 12′, pre-stressed concrete unit drops into place like a septic tank
- Forced Bed Aeration™ accelerates treatment from the bacteria and plants in the vertical flow wetland system.
- Plants rooted in peat used for insulation and odor control; septic wastewater enters at the root zone and trickles down; wastewater is aerated as it recirculates through the system.
- Removes 70% of the total nitrogen of effluent.
- Functions year-round
- Requires electricity

Address: P.O. Box 758; Forest Lake, MN 55025-0758
Phone: 651.255.5070
Fax: 651.255.5060
Email: contact@reactordynamics.com
Website: www.reactordynamics.com
*Available from:

- Pipeline Supply
  Grand Rapids: 877.327.1454
  Monticello: 888.295.9355

Dual-Flush Toilets

Keralor USA (Dual flush toilets)

Information:

.8/1.6 gallon dual flush toilet

Address: 501 Danube Ave; Tampa, FL 33606

Phone: 888.352.2284

Fax: 813.250.1975

Email: customerservice@keralorusa.com

Website: www.keralor.com

Caroma (Dual flush toilets)

Information:

4″ trapway to prevent blockage; ADA models available

Several MN distributors available

$300–$500

Contact: John Karas, Business Development Manager

Address: 9117 W. Lake Drive Pound; WI 54161

Phone: 920.897.2569

Fax: 920.897.4730

Email:jkaras@caromausa.com

Website: www.caromausa.com

*See website for distributors

Composting Toilets

Biolet (composting toilets)

Information:

self-contained composting toilets

Address: 150 East State Street, P.O. Box 548; Newcomerstown, OH 43832

Phone: 800.524.6538

Fax: 740.498.4073

Email: info@biolet.com; sales@biolet.com

Website: www.biolet.com

*See supplemental manufacturer brochure for more information

Clivus Multrum (composting toilet and greywater system)

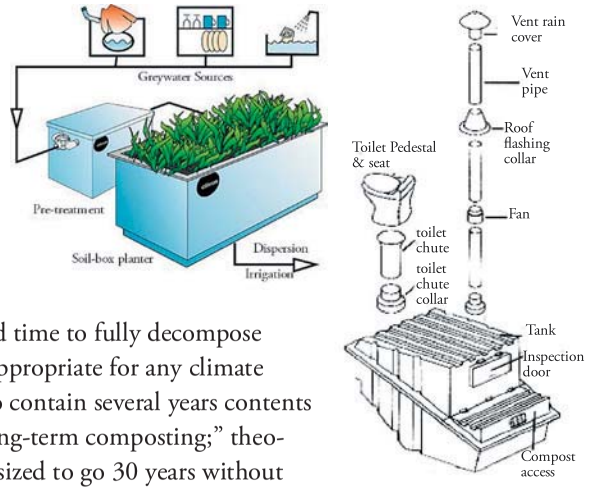
Information:

Larger than Phoenix

Competitor claims that sometimes newer waste overflows older waste and is then removed before it has had time to fully decompose

Advertises that is appropriate for any climate

Large size meant to contain several years contents for "enclosed long-term composting;" theoretically can be sized to go 30 years without emptying



Address: 15 Union Street; Lawrence, MA 01840

Phone: 800.425.4887; 978-725-5591

Fax: 978-557-9658

Website: www.clivusmultrum.com

Envirolet (composting toilet)

Information:

Available in self-contained, remote, and low-flush remote models

Manual basin trap (so you don't have to be sitting for it to open)

Address: 6391 Walmore Road; Niagara Falls, New York 14304

Phone: 800.387.5126
Fax: 416.299.3124
Email: webmaster@envirolet.com
Website: www.envirolet.com

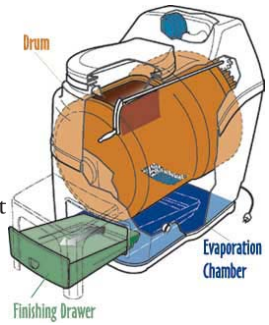
Phoenix (composting toilet)

Information:

- Periodically manually rotated (weekly); requires significant effort
- Decomposed waste falls to bottom and is removed about once a year (varies depending of frequency of use)
- Small light can be added to attract fruit flies which are then ejected from the composter
- Liquids are manually resprayed onto the top of the pile or can be drained to a conventional septic tank or peat infiltration bed
- Cost ranges from $3500-$6000
- Tank made of molded, crosslinked polyethylene and foamed linear polyethylene

Address: 195 Meadows Rd; Whitefish, MT 59937
Phone: 406.862.3854
Fax: 406.862.3855
Email: phoenix@compostingtoilet.com
Website: www.compostingtoilet.com
*See supplemental manufacturer brochure for more information

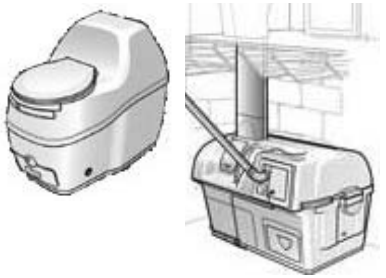
Sun-Mar (composting toilets)



Information:

- Self-contained and remote types available
- 3 self-contained areas: Rotating self-contained composting drum, evaporation chamber for excess liquid, and finishing drawer where compost finishes decomposing free from fresh material
- Available at Fleet Farm and other local distributors

Address: 600 Main St.; Tonawanda, NY 14150
Telephone: 888.341.0782; 800.461.2461 (for catalog)
Fax: 905.332.1315
E-Mail: compost@sun-mar.com
Website: www.sun-mar.com



Landscaping

Borgert Products, Inc.: Uni Eco-Stone

Information:

- Cement pavers designed to facilitate rainwater infiltration; reduces surface water pollution and sewage treatment plant loads

Address: 8646 Ridgewood Road; St. Joseph, MN 56374
Phone: 800.622.4952; 320.363.4671
Email: bourget@cloudnet.com
Fax: 320.363.8516
Website: www.borgertproducts.com
*Available from:

- Landscape Center
  313 W 61st St; Minneapolis, MN 55149
  612.866.0430
- Leitner Nursery (special order)
  945 Randolph Ave; St. Paul, MN 55102
  651.291.2655
- Shemin Nursery (special order)
  500 Malden; S. Saint Paul, MN 55075
  651.451.1042

References

References

Arctic Glass & Window Outlet. *Sunrooms Made Easy*. 8 Aug 2005 <www.kissourglass.com>.

Burns, John A. Energy Conserving Features Inherent in Older Homes. Washington, D.C. : U.S. Dept. of Housing and Urban Development, 1982.

Christensen, Bill. *Sustainable Building Sourcebook*. 29 March 2005. Greenbuilder.com. 8 Aug 2005 <http://www.greenbuilder.com/sourcebook/>.

Efficient Wood Burning Stoves. 29 Jul. 2005. Metaefficient: A Guide to the Most Efficient Things in the World. 8 Aug. 2005 <http://www.metaefficient.com/metaefficient/archives/heating/efficient-wood-burning-stoves.html>.

Environmental Resource Guide. Washington, D.C.: American Institute of Architects, 1998.

Forest Stewardship Council. 8 Aug. 2005 <www.fsc.org>.

Glance and Associates. *Historic Districts Made Energy Efficient : a Case Study*. Pittsburgh: Glance : Copies, Carnegie-Mellon University, Research Administrator, Dept. of

A Green Vitruvius: Principles and Practice of Sustainable Architectural Design. London: James & James, 1999.

Harland, Edward. *Eco-Renovation: The Ecological Home Improvement* Guide. Post Mills: Chelsea Green Publishing Co, 1993.

Land, Brenda. *Composting Toilet Systems, Planning, Design, & Maintenance*. San Dimas: San Dimas Technology & Development Center, 1995.

Nation Trust for Historic Preservation. *New energy from old buildings*. Ed. Diane Maddex. Washington, D.C.: Preservation Press, 1981.

Office of Energy Efficiency, Canada. *Insulation*. 8 Aug 2005 <http://oee.nrcan.gc.ca/keep_heat_in/chapter_2/chapter_2_1.cfm: the office of energy efficiency, Canada>.

Pellet Fuels Institute. 8 Aug. 2005 <http://www.pelletheat.org/3/residential/index.html>.

Smith, Peter F. Eco-Refurbishment: *A Guide to Saving and Producing Energy in the Home*. Oxford: Architectural Press, 2004.

Stitt, Fred A. *Ecological Design Handbook: Sustainable Strategies for Architecture, Landscape Architecture, Interior Design, and Planning*. London: McGraw-Hill, 1999.

Wilhide, Elizabeth. *Eco: An Essential Sourcebook for Environmentally Friendly Design and Decoration*. New York: Rizzoli, 2002.

Woolley, Tom and Sam Kimmins. *Green Building Handbook: A Guide to Building Products and Their Impact on the Environment*. 2 vols. London: E & FN Spon, 2000.

Wood Burning FAQ. 1 Jan 2005. Hearth, Patio & Barbecue Association. 8 Aug. 2005 <http://hpba.org/communications/FactSheets/answers.shtml>.

Yannas, Simos. *Solar Energy and Housing Design: Vol 1: Principles, Objective, Guidelines*. London: E. G. Bond Ltd, 1994.

Acknowledgments

This project was supported in part through student research assistance by the Community Assistantship Program, a program of the University of Minnesota's Center for Urban and Regional Affairs. Many thanks to others who have helped in the research for this project: John Carmody, Corri Kluba, and William Weber from the Center for Sustainable Building Research, Rolf Dittmann from River Valley Restoration, Jill Greenhalgh from the Arcola Mills Center, Brian Larson from Larson Brenner Architects, Young Lee from Two Rivers CLT, and Ryan O'Malley.