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An Affordable, Pratical Eco-House

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An Affordable, Practical Eco-House

An eco-house or zero-energy house is not a new concept- houses with extremely low impact on their surroundings and good use of local resources have been around for centuries. This particular eco-house is designed to offer full modern services and comforts while consuming very low energy and few expensive building materials. Ideally, someone would be able to use this thesis as a blueprint for actual construction.

First Things First: The Foundation

The Eco-House does not require digging to pour footers; it can be erected even in places where digging is inadvisable or local soils are unstable. Instead of a concrete slab, the Eco-house rests on a 8" pad of crushed rock extending to the outer walls. River gravels or other rounded rock may not be substituted, as these materials will shift, or "fluidize", under earth shocks or other significant changes in stress. The ideal material determined in simulation is crushed rock similar to railroad track ballast, as the sharp points and edges lock the pad together. While this technology was used extensively by Frank Lloyd Wright, much work remains to be done on exact support characteristics; thus, the Eco-House specification errs on the side of caution with support per square foot.

A ¼" layer of geotextile (non-woven fabric made of recycled plastic) is laid over the foundation pad to prevent puncturing of the cistern bladders and decrease heat transfer to the soil. Cinderblock or poured high-aggregate concrete is then placed along the edges of the pad to create a 4' crawlspace- this will be the water cistern, the primary water storage and heat mass of the house.

At this point, the pillars are formed and erected. Ideally, these are cast on-site from chipped rock (usually the "fines" from rock crushing) and minimal concrete. Depending on structural strength concerns, high-pressure grout may be substituted for some or all of the concrete mix to improve adhesion and set. The pillars are tied in to the cinderblock lines and will be both structural support and additional heat mass for the building. Rebar may or may not be included in the pillars, as per local building codes- its expense is minimal.

Ground Floor

2" x 8" x 20' supports are laid across the cinderblock to tie cinderblock, pillars, and a floor of ¾" CDX plywood in a standard plank-truss floor. At this point, large plastic bags are inserted in the crawlspace- these will store water to balance the thermal needs of the house. Circulator panels will be installed later, but the primary concern at this point is proper venting of the crawlspace to avoid humidity buildup. Since the floor is supported by the foundation at 10' intervals, a much cheaper and simpler construction can be used than if larger clear spans were needed.

Second Floor

2” x 8” x 10’ beams are connected to the pillars with cast-in anchor bolts or drilled expanding anchors. At this point, the pillars are trued to straight and any deficiencies in measurement or manufacturing adjusted to level and square. ¾” CDX plywood is then laid as the second floor.

Roof

The roof of the Eco-House is constructed by manual erection of matching barn-roof trusses on either side of a single ridge-beam. This keeps weight low for any one segment so that cranes or heavy equipment are not needed. When the trusses are in position, stringers are placed through the truss web and nailed in place, and sheet steel roofing is placed from the second floor. No scaffolding is necessary and personnel are not exposed to significant falling risks. The final ridge peak is placed as the upper course of corrugated steel is assembled, and sealed in place with threaded connectors under the ridge beam. The ends of the second floor are closed with polycarbonate greenhouse paneling, which becomes the outer layer of a beadwall insulation system. R-50 fiberglass is installed in the truss spaces and interior paneling is nailed inside.

Greenhouse/Shop

Both of these are lean-to additions to the house, with the greenhouse trusses and flooring constructed from the batterboards used in laying the foundation. Polycarbonate greenhouse glazing is sheathed over an internal aluminum frame, and the house drainage gutters are added to the rooflines on either side. The shop is insulated by a bale wall and R-30 fiberglass in the roof to decrease draft losses, but does not represent hight heat consumption in any case.

Eco-House Utility Core:
Calculations and Projections

The Eco-House is a large home without any permanent environmental impact: all utilities are self-contained and even the foundation is built to be easily renovated or removed. This design is especially useful for brownfield rehabilitation, since no digging is required and the house is immune to toxic seepage or gas infiltration. This section of this report explains its utility operation, in subsections of Water, Electricity, Heat, and Sewage.

Water

The Eco-House is designed to store rainwater in its elevated foundation pedestal. Up to 40,000 gallons of rainwater can be stored beneath the house at one time. This amount of water storage is equivalent to 18 inches of precipitation over the whole house, and can provide for the water needs of two people for a year without further recharge. Water is cleaned for use through a sand filter at the base of the downspouts, arranged so that dirt and dust from the roof first washes into the greenhouse beds and then through the sand. Graywater from showers and other low-contaminant drains is stored beneath the greenhouse, which can hold up to 20,000 gallons for grounds irrigation and other contaminant-tolerant plants. This amount would be sufficient to keep the greenhouse and 1 acre of grounds productive even through 2 months of drought. Because of the bale wall and masonry separating the two reservoirs, a leak into or out of the graywater storage does not contaminate the house, nor does the fresh water beneath the house pose an unacceptable risk to the inhabitants.

Heat

The greenhouse functions as a solar collector, catching 1 million BTUs per sunny day, enough heat by itself to keep a normal house warm. This heat is stored in the water-filled foundation, which will only warm by 2 degrees Fahrenheit absorbing it. During cloudy days, the house and greenhouse are heated by the warm water below, so that the house stabilizes its own temperature. An external solar collector focuses 40,000 BTUs per day on a water-filled boiler, making steam which turns a microturbine to generate power. Even at the expected low efficiency of 15,000 BTU per kilowatt-hour (industrial power plants use 7,000 BTUs per KwH) , this will generate more than 2 KwH per day. The heat remaining in the now expanded steam heats a molten salt tub beneath the bathroom to 170 F. , which can store up to 650,000 BTUs, enough to run 50 hot showers or 20 hot baths without further recharge. When the molten salt reservoir is "full", it rejects surplus heat to the hot tub in the greenhouse, which both warms and humidifies the greenhouse. The hot tub consumes 5,000 BTUs per hour in use and if unused consumes only 5,000 BTUs per day, rejecting any remainder into the water storage beneath the foundation. When all storage is "full" and the house is as warm as the inhabitants want, leftover heat warms a ventilation chimney, drawing cooling breezes through the house.

Electricity

This is actually the most difficult single utility, as electrical devices generally need very specific waveforms and constant supply. The Eco-House deals with this by using a bank of 20 lead-acid batteries, kept constantly charged to lengthen their lifespan.This size of battery bank will operate the house for 2 days at full use without further recharge or up to a month under power-rationing conditions. Because of hydrogen outgassing and possible environmental concerns of large battery banks, the batteries and hookup hardware are installed in the shop area. Standard house current is supplied by either a single large inverter which converts the 12 volts DC of a standard battery into 120V sine-wave 60-cycle current, or by several smaller, cheaper inverters for maximum redundancy. As power is used from the battery bank, the batteries are recharged from the steam microturbine and/or a small wind turbine. When the batteries are fully charged, the wind turbine feathers its blades to rotate silently with the wind and the steam plant shunts around the turbine.

Sewage

Sewage facilities in the Eco-House consist of a graywater recycle system for all lightly used water, and a composting toilet for food scraps and human waste. Graywater is purified through a coarse sand filter to remove large particles or grease, then stored beneath the greenhouse until needed for irrigation. The composting toilet consists of a mechanical rotation system of 10-gallon biodegradation chambers. To improve the quality of the resultant compost and decrease any odor-control issues, a low-nitrogen absorbent such as shredded corn stover or thoroughly dry grass clippings is used. Aerobic bacteria are to be regularly inoculated, so that as the mechanical system slowly shifts wastes out of the house, a completely biodegraded and pathogen-free compost is the only product.

Costs

The totals for the basic house components (exclusive of systems or furnishings) run roughly $15,000.

By item:

Rock pads
24 cubic yards @ $40/yard = $960

Grade beam
1,200 cinderblocks @ $1.05 OR
30 cubic yards high-aggregate concrete @ $50/yard = ~$1,500

Basebeam
15 2”x8”x20’ @ $14 ea.= $210

Decks/Floors

165 2”x8”x20’ @ $14 ea. = $2,310
57 sheets ¾” CDX plywood @ $20 ea = $1,140

Support Pillars

5 cubic yards high-aggregate concrete @ $50/yard =$250

Roofing

house
60 4’x8’ sheets corrugated steel @ $30/sheet = $1,800
shop
15 4’x12’ sheets corrugated steel @ $45/sheet = $675

Greenhouse

2,700 square feet R-3 doublewall glazing @ $0.80/square foot=
$ 2,160

Second floor beadwall

700 square feet R-3 doublewall glazing @ $0.80/square foot= $560

Straw bales

500 rectangle bales (18"x18"x3' approx.) @ $2/bale = $1,000

Interior and exterior stucco

5,000 square feet @ $0.15/square foot = $750

Fiberglass roof insulation

156 rolls R-25 x 22' @ $14/roll = $2,184

Systems

Not all of these pieces are needed right away. Many can be bought one piece at a time, as the house grows. $8,000 would buy all of this new without any further input- no improvising or bargain shopping required. Serious DIY could cut these prices in half.

Heat:
60' x 4' parabolic trough $1,000
Steam engine with generator $2,500
Thermal salt bank $150/ton
Homebuilt 8' hot tub $500

Electricity:
20 deep-cycle batteries @ $100 each = $2,000
5 small inverters @ $100 each = $500
2 8' wind turbines @ $500 each = $1,000

Water pressure and cycling:
Water pump @ $200
Control hardware @ $50
Filter systems @ $100 + $20 yearly replacements

Composting toilet:
Anywhere from $3,500 for a top-price commercial unit to ~$200 for a simple handbuilt, as these are not common items.

References

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