Rhode Island School of Design - RISD Solar
"Winning Teams and Innovative Technologies from the 2005 Solar Decathlon"
Science Committee, Subcommittee on Energy
2318 Rayburn House Office Building
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Testimony

Two Ways: Interweaving Passive and Active | Efficiency and Excess
Solar houses are often characterized by the "either/or" of passive or active techniques. "Passive" systems strategically use walls, window placement and overhangs to control solar gain, where "active" systems deploy pumps, piping and mechanisms to collect, store and redistribute the sun's energy. The RISD Solar team's approach interweaves these two strategies by creating a symbiosis between the building envelope and the heating and cooling system each working in both ways. With RISD Solar, building components that are traditionally static, move (through computerized servos and biological means), while elements that are normally part of a mechanized system are visually inert (they move at the chemical and atomic level). The coordination of these two strategies allows the occupant to engage the variability of the surrounding natural environment in unique ways.

RISD's 800 square foot exhibition house is formed by the intersection of two volumes, one, which incorporates "passive" techniques and the other, which houses the "active" components. The north-south orientation rewrites previous rules governing the layout of a solar house, which generally would stretch a building along an east-west axis. With the north-south axis, light changes throughout the day. The house, divided into four discrete domestic spaces: living|kitchen, bathroom|laundry, bedroom|office and garden|prospect, has a main circulation path which is designed to lead a large number of visitors parallel to this east-west movement. A shorter private circuit within the house ends at a secluded roof garden with an extraordinary vista (the U.S. Capital and the mall). Enclosing these spaces are multi-functioning double skin walls, roof and floors.

Windows and Daylight
Traditional solar homes use an excess of southern glazing in combination with thermal mass to obtain passive heating. In the RISD house, windows are carefully sized and arranged to provide a balance between the correct amount of light and well-insulated walls. To arrive at a the lighting strategy, appropriate light levels were determined based on the functions of the various spaces, then measurements were calculated and daylighting models were tested. The result is three interior spaces with distinct light effects. The south end opens to the changing light of the day with a relatively large southern glass wall. Overhangs, louvers and curtains further control the sun's rays and allow warm light to enter during the winter and keep out harsh overheated sun in the summer. The hall, which is intentionally the darkest area, brings a spot of natural light through a roof hatch that doubles as a skylight. In the bedroom/workspace, high transom windows bounce eastern morning and diffused northern light around the space while smaller windows provide isolated views. The placement of the windows is designed to avoid glare on computer and TV monitors and create a gentle glow.

Well-Insulated Surfaces

One of the primary sustainable systems used in this house is straightforward, affordable and invisible to the eye. The exterior walls, floors and roof of the structure, designed as lightweight and material efficient stressed skin panels, are filled with one of today's best performing building insulation. Between the insulation, cladding, and airspace, these walls attain an R-value (resistance to thermal transference) that is a third more than recommended by Federal Energy Code. Isonyne insulation is blown in and thereby installed to make the building "tight". This means air cannot move through unplanned openings in the floor and walls. Windows and doors also perform better than standard houses as the windows are coated with tin oxide to reflect infrared heat, double-glazed and fully gasketed. Attention to a well-insulated envelope allowed our engineers to reduce the size of their heating and cooling equipment.

Heliotropic Louvers

On the exterior walls of the house, a set of louvers literally moves with the sun. These vertical fins, offset from the main structure, are used to regulate the amount of sun hitting the house and to create a chimney effect of the cool air drawn up from the ground. In the summer, the louvers track the sun with their broad edge, reflecting its rays away from the building and keeping the house cool. In the winter, the louvers track the sun with their thin edge, maximizing the amount of sun hitting the house. A mapping of the solar light angles throughout the year was used to determine the movement of the louvers. The result is a house in motion, changing its character as the earth spins.

Roof Garden

The roof garden, which is made up of a series of shallow portable planters, provides many advantages. It plays an aesthetic role by extending the form of the house and creating a place of refuge. In addition, the variegated grasses and sedum, chosen because they require minimal water and maintenance, shade the house when full grown in the summer while the herbs can be used in the kitchen. The lightweight soil provides extra insulation, and absorbs water runoff. A water trough collects rainwater for irrigating the garden and use in a grey water system. The garden thus extends the usable living space of the house in area and in spirit.

Solar Surfaces

Like the louvers and garden, the roof of the north end is covered with a second skin. The solar collecting panels shade the light colored roofing membrane, thereby helping to cool the house while also generating energy. These panels provide both the heat and electrical energy for the house and are the first component of the mechanical systems. The RISD solar team's decision was to use as few solar panels as possible in order to make room for the roof garden and reduce the cost of construction. Therefore, they used the most efficient mono-crystalline photovoltaic panels available and energy efficient appliances to reduce the total surface area of the array. The photovoltaic panels each produce 190-Watts to form a 4.6 Kilowatt system for the house. The solar hot water collectors are of the evacuated tube cylinder type, which are more efficient than flat plate collectors and allow solar heat collection in colder climates and cloudy days.

Appliance Garage and Energy Star Appliances and Fixtures

The Appliance Garage, situated at the north end of the house, is a large storage space divided into easily accessible cabinets. This cabinet is made of thin walls to conserve space and uses nanotechnology (nanopaint) to withstand the coldest side of the house. On the exterior, the Garage contains storage space and the electric equipment that converts and stores the electricity produced from the photovoltaic panels (through inverters and batteries). The interior opens up into a home office with filing cabinets, and also includes attic storage and a wardrobe. The flat screen monitor, lights and appliances are all energy efficient and energy star rated. The use of these fixtures reduces the load and the size of the photovoltaic system without compromising functionality.

Building Systems: Heating, Cooling and Ventilation

The core is the most compact component of the house thereby freeing space for the living areas. Acting as the heart, it contains the hot water heating tank, the bathroom, the kitchen, the washer/dryer and access to the roof garden. Above the bathroom is our Sistine ceiling – a carefully designed and built mechanical space where the pumps, manifolds and ventilation equipment are housed. The central location of this high performance equipment minimizes duct and pipe runs, which increases efficiency. Three systems are used to maintain thermal comfort: a solar heating loop that heats both domestic hot water and the space, a cooling loop that is charged by cool night air, and an Energy Recovery Ventilator (ERV) that controls the building's supply and exhaust ventilation.

The heating and cooling systems use the principle of Thermal Energy Storage (TES). The storage is through Phase Change Materials (PCM's). The ability of the Phase Change Materials to store and release latent heat allows this material to store thermal energy in a smaller area, roughly 1/10 the area of water storage. For heating, we store solar thermal energy from the solar collectors during the day for usage during the night or days of no sun. For cooling, we use Phase Change Materials to store nighttime ambient air temperatures 60 Deg F or below for daytime cooling.

Heating and cooling are stored in two separate PCM containers, which use heat exchangers to transfer the stored heating or cooling thermal energies to radiant ceiling panels. The radiant panels are combination panels used for both heating and cooling. This is achieved through a variable speed primary/secondary pumping system located in the mechanical space. Using a hydronic variable speed pumping system allows us to use only the energy needed to heat and cool at a given time and requirement, at very low energy consumption. For comparison, a heat pump sized for the same heating and cooling loads would require 2,250 Watts of power at maximum design conditions. If that heat pump were of the newer variable speed type, the wattage range would be between 550 - 2250 Watts based on load conditions. Once our system is "charged" (i.e. has heating and cooling stored in the PCM's), our maximum wattage needed to heat and cool our building (because all we are using is pumps) is 167 Watts. If we were to include the energy used by the Energy Recovery Ventilator when, or if, needed to control possible condensation, we would be at a total of 489 Watts. As we are using variable speed pumping and have variable speed control on our ERV, our maximum wattage usage is from 489 Watts down to 135 Watts based on load conditions.

Building Systems: Heating, Cooling and Ventilation – Cont.
Hydronic radiant cooling and heating systems can remove or add a given amount of thermal energy using less than 5% of the fan energy that would otherwise be necessary if using an all air heating and cooling system. The advantages to our system over convential heating and cooling technologies are:

- We are using natural ambient conditions to provide the heating and cooling for the building.

- Through the Phase Change Material Storage, we presently have the capacity to store days worth of heating and cooling strictly from enviromental sources at design degree days.

- Through the use of radiant heating and radiant cooling, we are able to provide the same heating and cooling capacity as a "conventional" system using much less energy, and at a higher comfort level to the occupants. Another advantage to this system is the effect it has on the thermal envelope heat transfer of the building. Because the heating temperature of the water is lower, the temperature difference across the thermal envelope (walls, roof etc) is also lower. This translates into less heat loss out of the building. The same works for the radiant cooling which operates at a higher cooling water temperature than a conventional system. The less temperature difference across a surface, the lower the heat transfer across that surface.

- Our system was designed to be simple, both in operation and installation.

The intent of this system is to show the potential for a building to have long term energy storage and the use of natural heating and cooling through the use of Phase Change Materials.

Assembly + Structure
Because the competition required that the house be moved from Providence, RI to Washington, DC and back, the house is designed as a modular home that is disassembled into nine individual modules. The RISD team divided their house into many modules so that the internal spaces could be more generous while still conforming to highway restrictions. The modules are bolted together at seams, leaving most of the interior and exterior finishes intact. The exposed "expansion" joints and the strength of the plywood finishes allow the house to be moved without cracking. The entire structure was built with off-the-shelf, low-tech products enabling it to be built on site with minimal shop outsourcing and thus controlling costs. The team was careful to choose materials that met strict requirements. The materials have low embodied energy (i.e. local and recycled), do not aversely effect indoor air quality (low volatile organic compounds and non-toxic glues), do not harm the environment (no CFC's) and are renewable (plywood farmed with sustainable practices, and the use of fast growing cork).

Planning

While RISD built only one house for the Solar Decathlon, the building layout affords site adaptability. It can be used as a freestanding house or an urban townhouse. The orientation of the building favors the north/south axis while an offset of the parts allows for adequate light throughout even if the units are clustered together or repeated. As a “townhouse”, the project responds in a unique way to the questions posed by the organizers of the Solar Decathlon. When the units come together, their displacement in section and in plan creates interstitial spaces that can become oases within the urban context. The idea of the solar village, while not a novel concept, becomes more energy efficient with the aggregation of more units. Uniting design with urban values, our solution addresses the issues of sustainability not only within the individual house, but also on a community scale.

Less and More

Through interweaving strategies of passive and active solar techniques, we have worked to achieve both efficiency and richness. While our wall and mechanical systems work intelligently together to create substantial efficiencies, they also allow for delightful excesses. With zero emissions, the house generates surplus energy. Each one of our techniques is integrated to create a singular design. Paramount to the project has been balancing the need for energy efficiency and production with the principles of thoughtful architectural design.

Questions and Answers

(1) Given your experience, what do you think are the main technical and other barriers to greater use of solar energy? Do you have any suggestions for what might be done to overcome those barriers? How do you see the competition itself as helping to move both solar and efficiency technologies into the mainstream building market?

No barriers currently exist except public accessibility. RISD Solar uses 16 deep-cell batteries, 2 charge controllers and 2 invertors to convert and store the suns energy from 24 190-Watt Photovoltaic Panels. The system is small, robust and most importantly, off the shelf. The PV panels generate 4,560 Watts of energy and are affordable at a cost of approximately $41,000. This is $9.00 per watt, which is on the lower cost side of a battery backup system. If we assume a 20-year life, with minor maintenance costs, the system generates energy at $.29/kWh. Since our design was intended for an urban environment, battery back-up could be greatly reduced or eliminated, reducing the cost, and reducing electricity costs to $.22/kWh. By comparison, our electric bills in Rhode Island are $.14/kWh or roughly half. Over 20 years, however, the cost of electricity will surpass solar electric. If solar technologies were subsidized to the extent that the oil industry (with the associated transportation industries) are currently subsidized, there would be a boom in the market that would reduce these costs and begin to move the nation towards energy independence.

Q&A – (1) Cont.
Another path to the same goal would be to offer National incentives coordinated through pre-existing State programs. Many States offer grants combined with tax breaks to promote alternative energy, but all State programs are not the same. The cost is usually supported by a small surcharge on the public's energy bill. An increase in demand, especially supported and advertised at the Federal level will bring the market to bear, and with it the research funds to make the technology more affordable. Also, the Federal Government should continue to support University driven research and competitions such as the Solar Decathlon. Differing from conventions and trade shows, the Solar Decathlon is a public demonstration; the houses work and prove that the technology is here now. Nothing presented at the Solar Decathlon is out of the public's reach. Perhaps the competition itself should expand across the country and become regional, attracting solutions specific to the climates in the East, Midwest and West. Finally, a critical part of our design was the efficiency of our heating and cooling system. This system would require more research and development for it to enter the market as an available product.

(2) What sources of information did you draw on to figure out how to build your house? What problems arose in designing or constructing your house that surprised you?

At RISD we had the opportunity to spend time on critical research about environmental technologies, which is not commonly possible in practice. We used book sources, trade shows, consumer guides and direct evaluation of products. The RISD Solar student team researched and designed every aspect of the house but it was not until we engaged the local building industry did the choices and opportunities become much more clear. For instance, we would have preferred to use factory built SIP's (structurally insulated panels) for the roof, walls and floors but we decided to use a stressed skin panel system instead so these components could be constructed on site and by our own forces. Stress skin panels are very similar to wood frame (or light frame) construction except each panel relies on the interior and exterior sheathing (plywood or oriented strand board) for structural stability. We eventually found a local company that prefabricated the majority of our stress skin panels but we insulated and sheathed the interior surfaces ourselves.

Problems to work out next time include construction tolerances, weight and transport. The RISD Solar house was designed to come apart in too many pieces that were difficult to fit back together. The more pieces, the greater the construction tolerance required, which demands a sophisticated solution to integrate module joints within the design. Also, each stressed skin floor, wall or roof panel weighs approximately 1,000 pounds, which cannot be easily maneuvered by an untrained workforce. When 1,000-pound panels are brought together to form a module, weight becomes a serious issue and cranes or lifts are required to move pieces of the house into place. To move a house, it must be lightweight and easy to assemble and disassemble. The Solar Decathlon competition strongly favors modular homes that can be moved down the highway, set up quickly and taken down as quickly. We were pleased that our room proportions were generous, but more research is required to move a house that does not have the characteristics of a mobile home.

(3) Would your house be commercially viable? If not, what changes would make it more attractive to the mainstream homebuyer?

The size of the RISD Solar house could be commercially viable for a very limited market – young professionals or empty nesters. The total RISD Solar budget was $400,000.00, which is expensive for 800 square feet and translates to $500/ square foot or the cost of a high-end Manhattan apartment renovation. If transport, travel, lodging, etc. is removed from the budget, the cost is closer to $200/ square foot, which is not unreasonable for a new house. That is why the RISD Solar team planned an urban dwelling – the aggregation of units would lower the cost. Efficiency is an important element of our townhouse proposal: mechanical systems are centralized leaving more room for the flexible use of living space; plumbing and air duct runs are minimized lowering the cost of these expensive components; the bathroom space itself is the shower enclosure; and a Murphy (fold away) bed transforms the bedroom into the home office. While all of these space-saving strategies save money and are applicable to today's market, our house would require the addition of more area to be marketable as a house to be sold in the U.S.

Respectfully Submitted,

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