University of Oregon

# SOLAR INCIDENTS

The Newsletter of the Solar Information Center

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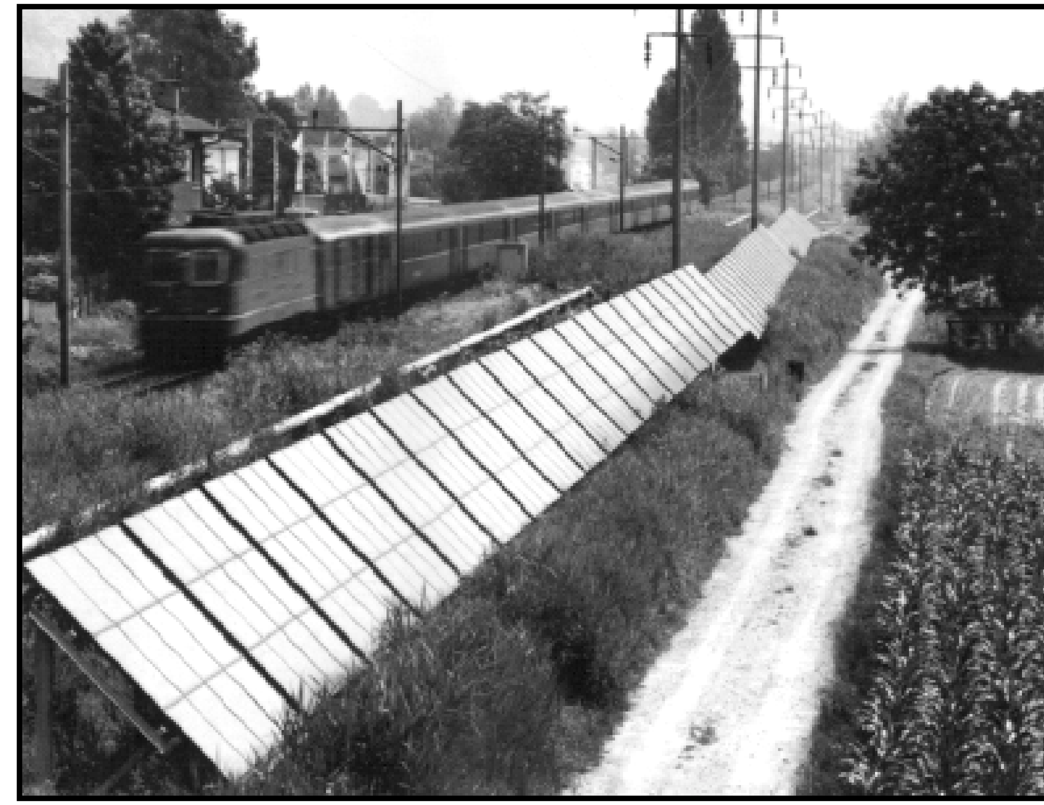

## Puerto Rico's Potential For Solar Power

**By Roberto Serralles**

**Introduction and background**

A large percentage of the electricity generated in the world today is derived from finite resources like fossil fuels and uranium. As of 1992, 65% of the electric energy generated in the world was produced from the burning of fossil fuels — mainly coal, oil and natural gas — while another 12% was derived from nuclear fission of uranium.[1] On the whole, the world is generating only approximately 23% of the electric energy consumed in a "renewable" manner: 22% from hydroelectric dams and 0.5% geothermal & other alternative sources.[2]

This dependence on non-renewable methods of production highlights the dual aspect of our global electric energy dilemma: while the finite nature of our fossil fuel resource base constitutes a threat to continued economic development, the continued combustion of fossil fuels also poses a significant environmental threat due to suspected and observed side effects, such as rapid global climate change (anthropogenic/enhanced greenhouse effect), acid rain (coal emissions) and overall environmental degradation (from extraction, transportation and processing of fossil fuels). Thus, from an economic and environmental point of view, the global

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# The Solar Page

### What is the Solar Information Center?

It is a student run organization sponsored by the ASUO and EWEB. The purpose of the center is to serve as a research, education, and information center on solar energy and alternative energies, and their applications in architecture and technology.

One of its vital functions is to sponsor a lecture series on local, regional and global energy issues to promote a higher awareness toward conservation and renewable energy. The center also provides an in-house information source of books, periodicals, abstracts, proceedings, topic-files, product-files and a World Wide Web site.

### The Restructuring of the Utility Industry

'Deregulation' in the electric utility industry has been a big topic in the media during the past year. In the 1980 Northwest Conservation Act, Congress directed that conservation and renewable resources have higher priority for meeting Northwest energy needs than power plants fueled by gas, coal, or nuclear fuel. Conservation has saved much energy since utilities began to channel resources to education and research instead of building new power plants. Renewables have also helped to improve energy efficiency and provide non-polluting sustainable alternatives to the current fossil fuel and dammed river-produced power. With deregulation in progress, short term economic interest has been the driving force in the utility markets. Gas companies have been merging and buying out electricity providers so that they can sell their greenhouse gas producing fuel. The low cost of this gas has spelled doom for renewables and conservation. The initial Carter era interest in renewables was driven by OPEC, who withheld oil in 1972 from the world market, in a stunning move from economics 101, manipulating supply to increase prices. The reverse is now happening. The problem is that the supply does have limits and the pollutants produced are endangering our health, food supply, and water supply.

The current situation for us locally is this: on October 1, 1995 Bonneville Power Administration, who administers the dams of the Columbia river slashed their funding for conservation and renewables from $87 Million to $10 million annually. Get involved in the restructuring process and make sure you the consumer are protected!

For more information, please contact:

- Northwest Conservation Act Coalition 503-417-1105 ncac@nwenergy.org http://www.nwenergy.org/ncac
- Northwest Power Planning Council 1-800-222-3355 http://www.nwpc.org

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SPECIAL THANKS TO **EWEB** FOR THEIR CONTINUED SUPPORT!



## An Introduction to Rammed Earth

**By Doug Eure**

What is rammed earth, why would one build with it, and why is it a center of controversy? With this article we will attempt to get into the thick of these questions while accepting the limits of a brief introductory article. For more depth in all these issues please refer to the 'For Further Reading' list which follows the text.

### What Is Rammed Earth?

Rammed earth walls look and feel like monolithic slabs of stratified rock. This is because ramming earth is basically a way of building walls that duplicates the geological processes which transform sedimentary deposits into stone, but in a relatively short period of time. Rammed earth walls are built using pneumatic compaction upon a certain mixture of sand, clay, portland cement, and water within a stout formwork.

### A Brief Genealogy of Rammed Earth

No newcomer to the theatre of building techniques, rammed earth has a family tree which spans the four cardinal points and precedes historical records on most continents. When the Chinese made the core of their Great Wall out of rammed earth, they employed a technology later to be used by the Roman emperor Trajan as he marked imperial territories in Western Europe. In North America, around 1000 C.E., Native Americans at what is now Casas Grandes, Mexico employed earth wall-building techniques similar to those later experimented with by such great American architects as Thomas Jefferson, Frank Lloyd Wright, and Bernard Maybeck.

In the 1970's, the practice of rammed earth was 'rediscovered' and wedded to modernized construction techniques, most notably in France, Australia, and the United States. Californian David Easton was then and remains the United States' most visible proponent of rammed earth. An author and lecturer with over 100 rammed earth buildings to his credit, Easton has helped bring rammed earth into its own in the United States as an attractive alternative to conventional wall materials. For this reason, Easton's system, among a variety of different American rammed earth techniques, remains the definitive one.

### A Description of the Rammed Earth Process

Building rammed earth walls involves a host of tools, machinery, and formwork, but the principal component of successful walls is an ancient recipe for soil that assures walls of optimal strength. This recipe calls for roughly two thirds sand and aggregate to one third clay (of the non-expansive variety). To this mix, most modern Americans add a percentage of portland cement for stabilization. A stabilized wall is one with improved water resistance and compressive strength.

A manageable quanitity of these ingredients is mixed thoroughly and then moistened until the mix shows a 10% moisture content. The mixing process is accomplished with the bucket of a front-end loader, a tractor with a roto-tiller attachment, or an automated pug mill of the sort pioneered by New Mexico rammed earth czar Stan Huston.

Rammed earth requires an elaborate forming system that varies widely in design from builder to builder. In essence the forms provide a mold for the massive earth walls. Earth is delivered into the forms using the bucket of a front-end loader or Bobcat® and rammed in layers or 'lifts'. These lifts result in visible 'strata' lines that are not to exceed 6 vertical inches by code.

Rammed earth formwork typically consists of laminated 3/4" plywood panels reinforced with a system of stout horizontal 'walers' and other stays made of wood or steel. Pipe clamps (or 'pony clamps') often play an important role in holding the forms together as they are subjected to the levels of compressive force that one would expect from a geological process made man-ageable.

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community must invest heavily in the development of renewable electric energy generation technologies in order to address this inevitable and fundamental dilemma.

The main obstacles currently hindering the broad-scale development of renewable electric energy systems stem from economic considerations like cost-effectiveness and perceived viability of most renewable electric energy technologies at current stages of development. While numerous technological barriers plague the expansion of renewable electric energy systems, the cost of producing electricity with “renewables” has steadily decreased over the last two decades. For example, the cost of electricity generated by wind turbines (with appropriate wind resource) has dropped from 32¢ per kilowatt hour (kWh) in 1981 to 7¢/kWh in 1995; for photovoltaics the price has dropped from $3.39/kWh in 1980 to 18¢/kWh in 1995; for solar thermal the price has dropped from 85¢/kWh in 1980 to 12¢/kWh in 1995.[3]

In addition, geographical variability affects the rate at which some renewable technologies become cost-effective. Since most renewable energy technologies are relatively site specific, some localities are advantageously positioned to exploit renewable resources right away. Such is the case with Puerto Rico and its solar resource. Puerto Rico on average receives approximately 5.2 hours of unobstructed, direct sunlight per day in a typical year.[4] This amount places Puerto Rico among the best suited locations worldwide for the production of solar-derived electric energy.

In San Juan, Puerto Rico, located on the north coast (less sunny, on average, than the south coast), direct solar radiation on a flat surface (0˚ tilt) averages 5.3 kW hours per meter squared per day (kWh/m$^2$/day) with the lowest month (Dec) averaging 4.0 kWh/m$^2$/day and the highest months (Apr, Jun, Jul) all averaging 6.1 kWh/m$^2$/day.[5] At this rate, a flat surface in San Juan receives on average 1934 kWh/m$^2$/year (5.3 x 365 days). To put this amount in perspective, global averages range from a low of 800 kWh/m$^2$/year to a high of 2500 kWh/m$^2$/year.[6] The vastness of the solar resource coupled with the fact that Puerto Ricans pay on average 14¢ per kW hour of electricity makes solar-derived electric energy generation an attractive and potentially cost-effective energy option.

**Current status of electric energy generation in Puerto Rico**

The small island-nation of Puerto Rico currently faces an economic and developmental dilemma that in many ways mirrors some of the more salient electric energy issues facing the global community. With a population growing at a 1.3% annual rate and a rapidly expanding economy (3.3% growth in the GNP for fiscal year 1995)[7] , the demand for electric energy is growing at a faster rate than previously expected. According to a government report published last year, Puerto Rico will experience an electric energy deficit by the year 2000 unless the overall system capacity is quickly expanded. In order to overcome this deficit, the Puerto Rico Electric Power Authority (PREPA) estimates that the island will need to add at least 1,000 MW of new electricity generating capacity to meet expected demand by the year 2000.[8]

Currently, Puerto Rico is heavily dependent on oil-fired electric energy plants with ≈98% of the total electric-grid capacity derived from this resource.[9] The inherent volatility of the oil market coupled with the fact that world supply of cheap oil will be exhausted over the next 25-40 years[10] , makes Puerto Rico’s electric-energy generation systems extremely vulnerable to market price fluctuations and long-term oil availability. Plans to diversify the island’s electric-energy generation capacity are being drawn, but preliminary drafts call for an electricity-production breakdown still heavily dependent on fossil fuels. PREPA’s latest plan proposes a system-wide generating capacity drawn from 60% petroleum, 31% natural gas, 7% coal and 2% hydroelectric power by the year 2010.[11]

To achieve this goal, at least two private-public ventures have been launched in the last two years that will add close to 900 MW to the overall system capacity. Starting in August, 1996, Applied Energy Services Inc. will build a 415 MW coal-fired power plant in the southeast region of the island at a projected cost of $750 million (US dollars).[12] In addition, Kenetech Energy Systems and Enron Development Corp. expect to begin construction of a 461 MW natural gas-fired cogeneration plant in the southwestern region of the island by the end of 1996 at a projected cost of $600 million (US dollars).[13] Even though several federal and commonwealth permits regarding import and transport of liquefied natural gas (LNG) are still pending, a power purchase contract between PREPA and Kenetech/Enron has been signed and a preliminary contract has been drawn with an Enron subsidiary in Trinidad & Tobago for the supply of the expected 80 MMcfd of natural gas needed for the power plant.[14]

PREPA’s blueprint for the island’s future electric-energy sources fails to incorporate any significant role for renewable energy technologies. Not only is Puerto Rico simply delaying the inevitable need to produce electricity from renewable resources, but unfortunately it is investing large sums of capital on developing an electric energy infrastructure that shifts the dependence on oil alone to oil and other finite fossil fuels. If anything, we should be using the energy derived from fossil fuels to develop an infrastructure that promises a long-term supply of electricity and at same time helps reverse the well-known negative environmental and political effects associated with fossil fuels.

**Advantages of large-scale photovoltaic support of utility grid**

Interest on the part of utilities towards integrating PV systems to electric grids stems from the growing realization that PV technology complements some of the most recent management trends in the industry. Specifically, PV systems’ modularity offers utilities the flexibility of incremental and localized generation capacity. This means that regional electric peak-loads can be matched on a case-by-case basis as demand increases and that electricity can be generated closer to where it will be consumed. In addition, PV support of grid capacity offers utilities efficient peak-load management capabilities. Since PV systems generate most of their output during peak-load hours, especially during hot summer days when peak-load demands can be almost twice as much as base-load demands, utilities can forsake massive capital investments for generating plants that would mostly operate well-below rated capacities. Also, grid supporting PV systems can help reduce substation transformer’s hot-spot-temperature by up to 4˚ C, which can defer a transformer upgrade for up to 4 years and provide an economic benefit of $400,000.[15] When one adds environmental and social costs associated with disposal of transformers and associated PCB contamination, the advantage of PV grid support becomes even more pronounced.

**Economic Assessment**

An assessment of the overall economic viability of a utility-scale PV plant in Puerto Rico is possible with the data derived from one of the Photovoltaic for Utility Scale Application Program (PVUSA) projects. Specifically, a series of utility-scale PV plants built in Puerto Rico can be modeled after the 428kW$_{AC}$ thin-filmed (amorphous silicon - a: Si) PV plant designed and built by Advanced Photovoltaic Systems, Inc. (APS) at Davis, California. In order to maximize available solar radiation, large-scale (10-50MW) PV plants should be built in Puerto Rico’s southwestern region where the solar resource is on average greater than that available in the rest of the island. From here, electricity can be transmitted to population centers around the island and to areas less suited for PV electric generation. Some of the latest calculations place transmission losses for high-voltage electricity at approximately 1% net loss per 60km.[16] Thus, a small island like Puerto Rico (56kms wide and 160kms long) could afford to incur transmission losses in the 2-4% range while maximizing a propitious regional solar-resource.

Both the large-scale and small-scale PV plants will be built in increments of 428kW$_{AC}$ — the largest field-tested a: Si system currently on line. Each of the 428kW$_{AC}$ power substations will use 9,600 a: Si photovoltaic modules measuring 1.22 m$^2$ each for a total array area of 11,712 m$^2$. Each module is rated to deliver 50 watts peak of power. The costs for each of the

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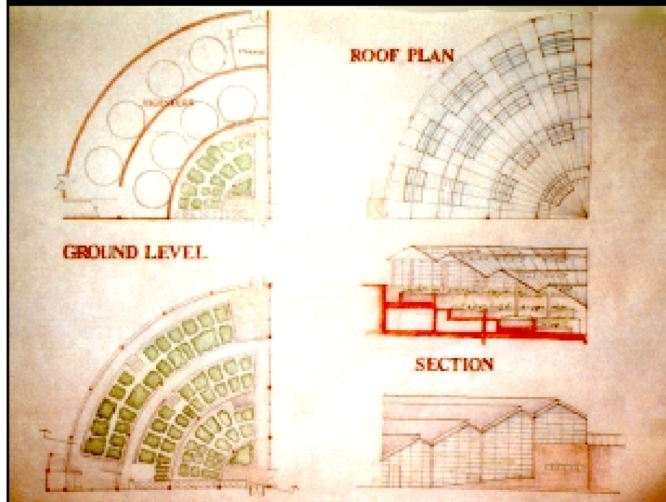
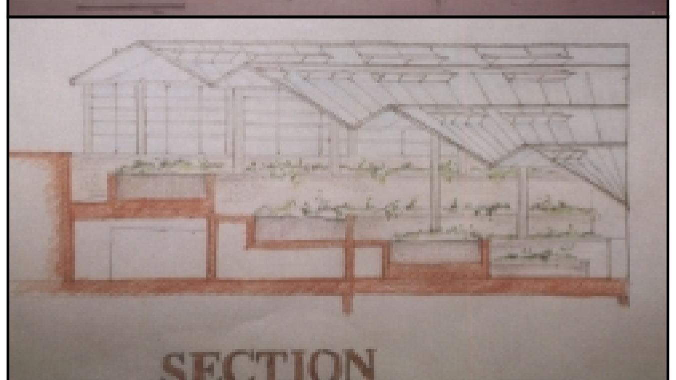
# Solar and Sustainable Design Showcase



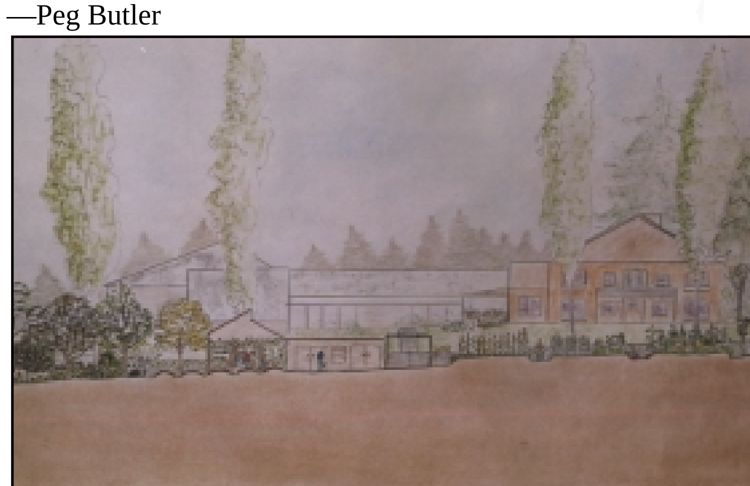

## Fall Term 1996

Chuck Rusch's studio was rather unique in its organization of student group consensus on most design decisions. The project was a mixed-use commuters' bicycle terminal where commuters on bikes can lock them up in secure lockers, take a shower, change into business dress, eat healthy meals, and have their bikes serviced while they are at work. In short, this design will make it easy to bike to work by treating bikes with the same care we now pay to autos and buses. The project included the Center For Appropriate Transport, a bicycle shop, co-housing units, a health food store, a restaurant and commercial space.

- In house waste water treatment
- Organic garden and green house
- Passive solar design

Oak Hill School is a private, not-for-profit school for children in kindergarten through 12th grade located on 70 acres of diverse landscape a few miles south of Eugene, Oregon. The Campus designs for Oak Hill School were based on the need to; provide for future school population growth and necessary site accommodations; everyday needs of teachers and students; and the desire to create spaces where learning is multi-disciplinary allowing students the opportunity to learn naturally from natural systems to think holistically, systemically and connectively. Some of the key design features include; the phasing in of site development, building siting with regard to solar aspect, constructed wetland waste disposal system, rain-water collection, wind-power generation, permaculture garden, nature sanctuary and nesting habitat, bioswales in parking areas,hedgerows instead of fencing, and artisan studios and a farmers market to invite the community to become a part of the learning experience.

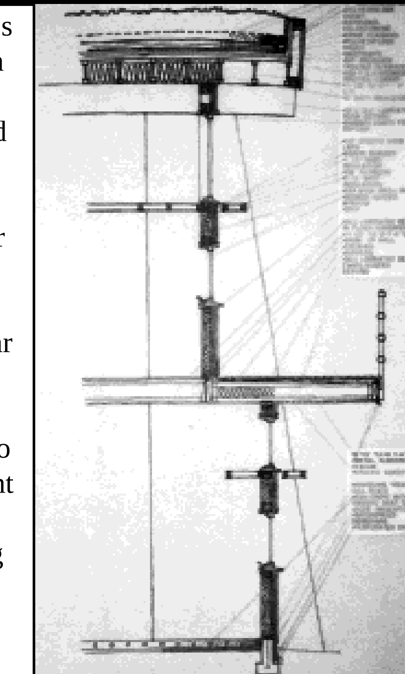
—Peg Butler

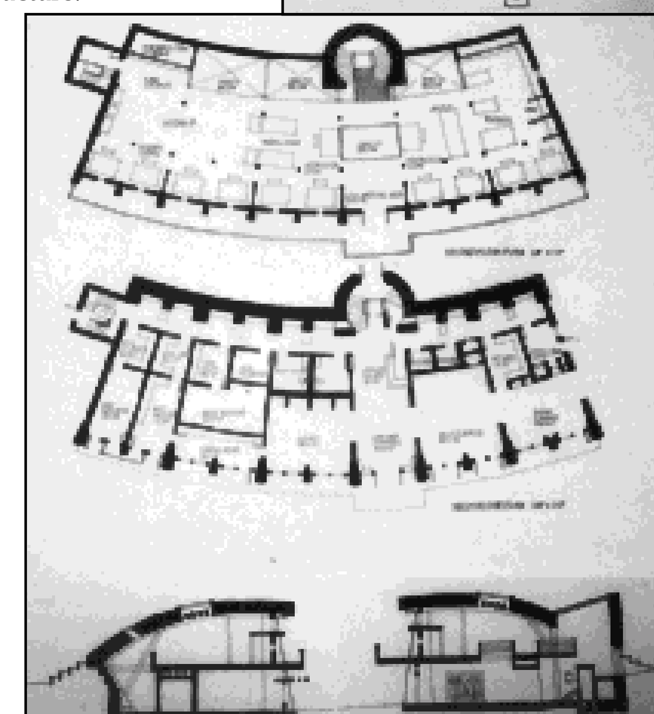



This is a 281 studio project; a weaver's school located on Morse Ranch in South Eugene.

- Rammed earth columns support curved glu-lam beams and a sod roof.
- The sod roof curves down to the North and becomes a continuation of the larger field area, thereby integrating the building with the site.
- Southeast glazing provides passive solar heat gains.
- The North end of the weavers school is bermed up to the second floor, helping to stabilize the fluctuations of day and night temperatures.
- The curved glu-lam beams, intersecting angle braces as well as the gentle curve of the building provide a easily understood and lively structure.

—Jason Wilkinson





**Each term the Solar Information Center conducts the Solar and Sustainable Design Showcase to promote these issues in the architecture, landscape, and interior studios.**

**Submissions for Winter quarter are due March 20th (contact the SIC)**

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The protagonist of rammed earth tools is the 30-pound pneumatic tamper. A 120 cfm air compressor provides sufficient air pressure to several tampers. The tamper's round head cycles rapidly up and down (hence the nick-name 'pogo-stick') as the operator moves it over the loose soil, packing it instantly into stone-like firmness. Less frequently, compaction is achieved using a heavier jack hammer fitted with a square tamping foot. Careful tamping, or ramming is essential because under-tamping results in inadequate compressive strengths while over-tamping tends toward blowing out the forms with too much compacting pressure. This is a delicate balance and mistakes are often difficult or impossible to correct. Rammed earth walls are designed and built to defy alteration.

Chases for electrical wiring are installed in the formwork before ramming begins, as are electrical switches and outlets, window and door void boxes, niches, and other details such as chamfer strips, just as they are in conventional concrete formwork. Water pipes should be located elsewhere than an earth wall because pipe damage is very difficult to fix if it is buried in 'stone,' and leakage will weaken if not destroy a rammed earth wall.

Water is the natural enemy of an earth wall. Broad eaves and tall foundation stemwalls, the proverbial "Good hat and a good pair of boots" are age old means of adapting an earth wall to the elements. When a wet climate poses a special problem, or when pursuing a multi-story rammed earth design, stabilization will be necessary to protect the walls from certain erosion and to provide additional compressive strength.

**Why Build with Rammed Earth?**

With wall thicknesses ranging from 18" to over 3', rammed earth conjures up images of old-world stone fortifications. Rammed earth is fortress-like in other ways, too; it fortifies an occupant against a host of incursions. Fire serves only to strengthen rammed earth walls,. just as it hardens ceramic clay. Gunshots do not have the force necessary to penetrate them. Household pests such as insects and rodents find no haven in their impentrable, sheer surface. Likewise, the forces of decay which render the typical stick-frame house in need of serious renovation after 50 to 75 years have little effect upon rammed earth walls over the course of centuries. For example, France's Rhone River Valley contains hundreds of rammed earth buildings still housing occupants after 500 years.

Rammed earth presents an attractive source of thermal mass to the passive-solar designer who utilizes the 'thermal flywheel' effect to stabilize interior temperatures to comfortable levels. With proper design and within a range of climates, rammed earth provides comfortable indoor temperatures while reducing one's reliance upon expensive and environmentally destructive mechanical heating, cooling, and ventilation sytems. Thus, rammed earth walls may represent considerable savings in costs normally due to buying, operating, and maintaining elaborate HVAC systems.

Rammed earth is the last affordable, thick, massive wall system. Comparable thick walls (over 18") of brick, stone, adobe and even ferro-cement all cost substantially more to build than their rammed earth counterpart.

**The Intangible Benfits**

On the surface, rammed earth reveals a variety of hues and textures. Sometimes these variations are subtle, as with designer Steve DeKoch's smooth, uniform wall surfaces defined with crisp chamfer details. Other walls, such as those of Texas's Jim Wilson, bear dramatic strata lines and traces of lightly-packed and poorly-mixed earth. Spalling patches and areas of 'honeycomb' provide his walls with a pleasing quality of old-age, though they are quite new. In Western Australia, builder Giles Hohnen draws upon the stunning array of colors availible in that area's clay deposits to ram earth layers of shifting hue reminiscent of the American Southwest's Painted Desert. Taken together, these effects demonstrate rammed earth's inherent visual richness,

When one pentrates the surface of a rammed earth wall- that is to say- walks through a 2' thickness in a doorway, or fits one's entire body on a window sill, one gathers a heigthened awareness of the passage from indoors to out, or from room to room. Accompanying this remarkable sense of the thickness of the walls is a perception of interior space that is qualitatively different from that which is defined by a thin partition, or a facade wall that appears to be thick but is not. Religious advisors might speak of being one with oneself much as a rammed earth wall employs no art or artifice in displaying its structural and material composition as the light falls across its depth in a window reveal. •

**For Further Reading:**


Easton, David. The Rammed Earth House. White River Junction, VT: Chelsea Green Publishing Company, 96.

McHenry, Jr., Paul Graham. Adobe and Rammed Earth Buildings. Tucson: University of Arizona Press, 84.

Tibbets, Joseph M. The Earthbuilders' Encyclopedia. Belen, NM: a Southwest Solaradobe School publication, '88.


**Look for part 2 of this article in the next issue.**

## A VACUUM BUILT TO LAST

**By Jason Wilkinson**

A sight-seeing trip to BRING recycling with my parents in mid October proved to be a fruitful one. I discovered a gem in the haystack. In a dusty loft I spied a stream lined vacuum, bulbous like a 50's Chevy; it called out to me. On The head light cover someone had scrawled "$10.00 Works" with a black Sharpie. The skeptic that I am, I hauled it down the rickety stair case to the nearest outlet. Flipping the switch, the head light illuminated the half inch layer of dust on the floor while the motor rushed like a Boeing jet to fill the cloth bag. Thoroughly impressed with its performance, I paid for its freedom and took this Kirby vacuum home.

Without tools and in a matter of minutes I had dismantled the whole thing. I began scrubbing away the layers of sediment from the cast aluminum parts. Then I shook out and rinsed the heavy canvas bag (it doesn't use paper bags). After the cleaning I reassembled it as quickly as it came apart. I was truly amazed at how well this vacuum worked, removing buckets of dust and dirt each time it was used. I have never been so thrilled with a household appliance.

Impressed with the design, I ventured to the local Kirby dealership in search of more information. There I found out that the model I bought was built around 1955. While I recall my parents (no offense mom and dad) going through at least four vacuums during my childhood, what was to stop this Kirby from lasting another 40 years? If the Kirby rep was right about it being infinitely repairable then it may last even longer.

**Products should be:**

- **infinitely repairable** - cutting waste and improving longevity
- **of simple design** - easy user maintenance and parts replacement
- **well crafted** - improving longevity and establishing respect by user
- **beautiful** - instilling a sense of pride in ownership and construction.

I found these qualities in a 40 year old vacuum, and I recomend that you search out products of similar value.

## These events are free and open to the public

**"The Politics of Eugene Water & Electric Board and Renewables"**
**by Jeffrey F. Osanka**
**Wednesday, February 12 , 12:00 - 1:00 pm, room 206 Lawerence Hall, U of O**
Jeffrey Osanka is a Commissioner for Eugene Water & Electric Board since 1994. The responsibilities of the commissioners include providing electricity, clean water, and steam heat for over 100,000 customers and they are responsible for a budget of $300 million and a staff of almost 500.

**" Landscapes for Ecological Living: An Introduction to Permaculture"**
**by Jude Hobbs**
**Thursday, February 13, 7:30 pm, room 177 Lawerence Hall, U of O**
Jude Hobbs is a consultant, landscape designer, and instructor. Since the early 1980's she has helped create edible, bird attracting, and native landscapes while integrating permaculute techniques. She is the owner of Cascadia Landscape Design and an associate with Agro-Ecology Northwest, a business that does research and consultations with small scale farmers.

**"Overview of EWEB's Resource Development Program"**
**by Ken Beeson**
**Thursday, February 20, 7:30 pm, room 177 Lawerence Hall, U of O**
Ken Beeson is currently the Energy Resource Projects Manager at Eugene Water & Electric Board (EWEB). He now has 25 years experience in the electric utility industry. He will present the current resource development program including the Wauna Cogeneration project, the Wyoming Wind Project and the Newberry Geothermal Project. He will discuss issues such as the citizen review process and economics.

**"Forest Conservation Perspectives"**
**by Gary Kutcher**
**Wednesday, February 26 , 12:00 - 1:00 pm, room 206 Lawerence Hall, U of O**
Gary Kutcher is a Eugene activist in the Pacific Party and was this party's senatorial candidate in the last election. He has worked with the Forest Conservation Council, fighting to protect endangered salmon runs and other fragile habitats from the massive clearcutting that is devastating Oregon's ecosystems. Gary will be speaking primarily on the Oregon Conservation Initiative he is working on which would ban clear cutting and chemical spraying on forest lands.

**HOPES Eco Design Arts Conference**
**April 11-13 Lawerence Hall, U of O**
This year's theme for the third and most intriguing conference to date is "Cultivating Communities, Healing Environments" which will take a multidisciplinary and interactive approach to looking at developing holistic and effective patterns of living within our environment. Speakers, panels, and workshops fill the weekend. Contact HOPES at 541-346-3696 for more infornation.

For more information, please contact us at **541-346-3696.**





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$428kW_{AC}$ power plants are divided into array costs and balance-of-system (BOS) costs. BOS costs are divided into area related BOS costs (which includes module installation, site preparation and land costs) and power related BOS costs (which includes power conditioning equipment, DC subsystem preparation and AC subsystem preparation).[17]

Array costs are estimated at $120 per module. Total cost of array is $1,152,000 for each $428kW_{AC}$ power plant ($120 per module x 9,600 modules). The prospects of a: Si costs to dip below the $120/50W range are very favorable as the technology improves and economies of scale in production get established. Area related BOS costs are estimated at 50¢/$m^2$. This translates into a total area related BOS cost of $5,856 per each $428kW_{AC}$ power plant. Power related BOS costs are approximately 35¢/W. Total power related BOS costs equal $149,000 (428kW x .35/W). Finally, replacement costs incurred over the lifetime of the power plant (30-40 years) for modules, AC inverters, Power Conditioning Units and related hardware should run at approximately 15% of array and power BOS costs ($1,152,000 + $149,000 x .15 = $195,000). Total system costs for each $428kW_{AC}$ power plant is $1,501,856.

This total system costs does not take into account savings incurred from the benefits of PV support utility grid capacity discussed earlier. Savings associated with low operation and maintenance cost, grid voltage support, extended transformer life and especially from avoidance of electric line extension (which typically cost between $20,000 and $50,000/mile)[18] can significantly reduce the cost of a PV system up to 30%. In Puerto Rico, a $428kW_{AC}$ PV plant will generate on average 859,210 kWh/year of electricity based on a solar radiation input of 2007.5 kWh/$m^2$/year (5.5kWh/$m^2$/day at tilt = latitude x 365 days).[19] If we sell that electricity at the going rate in Puerto Rico for residential customers, 14¢/kWh, annual revenues would be $120,894/year. At this rate, year before payback of complete investment would be only 12.5 years ($1,501,856/$120,894).

As I discussed earlier, the coal-fired and natural gas fired plants proposed for Puerto Rico will generate electricity at an investment cost of $1.54 million/MW ($1.35 billion/876MW). The PV plant profiled can generate electricity at an investment cost of $3.35 million/MW ($1,501,856/428kW). This investment profile does not take into account the savings available to utilities resulting from grid-supporting PV systems. In addition, once in place the PV plant will generate electricity with minimal maintenance and operation costs and with zero fuel costs during the 30-35 years of expected power plant lifetime. It is this fact which makes the investment profiles much more comparable. Thus, once we account for coal and natural gas costs, transportation costs and associated safety and health costs, investment in utility-scale PV system becomes very advantageous.

**Conclusion**

In this era of budgetary constraints, governments increasingly allocate public funds in a purely 'rational' manner; how to get the most 'service' for the least amount of investment. However, since current pricing decisions do not consider issues which governments should always consider — scarcity, sustainability, human and ecological health — we are left in a situation where the purely economic argument for renewable energy can not currently stand against 'cheaper' fossil-fuel energy. Although market imperfections will continue to influence energy pricing-decisions worldwide, Puerto Rico's propitious solar-resource and the fact that electricity is very expensive in the island surely means that solar-derived electric energy will be a significant component of Puerto Rico's future energy equation. Therefore, the sooner we can develop a renewable electric energy infrastructure, the better equipped Puerto Rico will be to withstand future energy uncertainties, and the more likely that the island will establish a truly sustainable electric energy model for the rest of the world to follow. •

*Editors note:
This paper has been reduced by the author to fit within our newsletter. For a list of refrences, please contact the Solar Information Center, or visit our website to read the complete paper with sources.

# CALENDAR

***"The Politics of Eugene Water & Electric Board and Renewables"***
**by Jeffrey F. Osanka**
**Wednesday, February 12**
**12:00 - 1:00 pm room 206 Lawerence Hall**

***" Landscapes for Ecological Living: An Introduction to Permaculture"***
**by Jude Hobbs**
**Thursday, February 13**
**7:30 pm, room 177 Lawerence Hall**

***"Overview of EWEB's Resource Development Program"***
**by Ken Beeson**
**Thursday, February 20**
**7:30 pm, room 177 Lawerence Hall**

***"Forest Conservation Perspectives"***
**by Gary Kutcher**
**Wednesday, February 26**
**12:00 - 1:00 pm room 206 Lawerence Hall**

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# SOLAR INFORMATION CENTER

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