Urbansun Floating Home

North Portland's Tomahawk Island Floating Home Community is home to a new 1,200 square foot "near net zero energy" home. The small size of the home, combined with a well-insulated and designed envelope, and a combined ventilation/energy recovery system significantly reduces energy use. Innovative features include a micro-hydro system that capitalizes on the steady flow of the Columbia River and passive and active solar elements. High post-consumer recycled content engineering wood and salvaged and certified sustainably harvested lumber makes up a significant proportion of the home and rooftop greenhouse. The greenhouse is irrigated with harvested rainwater.

Project Highlights

- **Solar PV system**
- **Solar water heating**
- **Hydronic heating**
- **Rainwater collection and reuse**
- **Reclaimed and FSC certified wood**

Portfolio Contents

- **Final Report**
- **Monitoring & Verification**
- **Case Study**

EnergyTrust of Oregon
Portland Water Bureau — From Forest to Faucet
Environmental Services
Bureau of Planning and Sustainability — Innovation. Collaboration. Practical Solutions.
City of Portland, Oregon
Sam Adams, Mayor • Susan Anderson, Director

City of Portland Green Investment Fund

Grantee Final Report

PROJECT INFORMATION

Name of Primary Contact:	Steve Gray				
Company or Organization:	Urbansun Design				
Address:	354 N Tomahawk Island Dr				
City, State & Zip:	Portland, OR 97217				
Phone:	503-283-9776	Fax:		E-mail:	steve@coinet.com

PROJECT DETAILS

Project Name:	Tomahawk Floating Home Project
Project Owner:	Global Learning Systems, Inc., DBA Urbansun Design
Project Address:	354 N Tomahawk Island Dr
City, State, ZIP:	Portland, OR 97217
Date Project Started:	May, 2006
Date of Completion:	May, 2007
Building Certifications:	

Design and Construction Team

Architect or Designer:	Urbansun Design
General Contractor:	Urbansun Design
Landscape Architect:	[no land; floating on the Columbia River]
Structural Engineer:	Hannas Engineering
Civil Engineer:	n/a
Mechanical Engineer:	n/a
Electrical Engineer:	n/a
Interior Designer:	Urbansun Design
Green Building Consultant:	Urbansun Design/3E Strategies
Energy Modeler:	Urbansun Design
LEED Consultant:	n/a
Additional:	Active solar: Sunlight Solar, Sunflower, Mr. Sun Solar

Building Details

If building has mixed use, please include the sq. ft of each type of use

Gross Floor Area: 1344

Building Type

- [x] Single-family Residential
- [ ] Multi-family Residential
- [ ] Commercial
- [ ] Industrial
- [ ] Institutional
- [ ] Mixed-Use
- [ ] Other (describe)

Site Conditions (check all that apply)

- [ ] Previously Undeveloped Land
- [x] Previously Developed Land---water space
- [ ] Brownfield Site
- [ ] Preexisting Structure(s)

Project Type

- [ ] Renovation
- [x] New Construction
- [ ] Addition

Project Costs

Land Acquisition:	Additional slip [water space] = $11,000; original slip area previously purchased
Site Clearing/Deconstruction:	None - [sold & moved previous floating home in slip space in-tact to another location]
Site Development:	$4,350-[float utility hook-up costs and dock connection costs]
Public Improvements:	None - [all public infrastructure installed]
Design Fees:	None - [accomplished by Urbansun Design] equivalent fees = $5670
Permits:	$3,208 -[city of Portland], $500 [Earth Advantage test fee], $48 [ODOE solar Pre-cert.]
System Development Charges:	None – [replacement construction]
Construction:	$214,869 [total from float construction to house finishing, except the following:
Green Technologies:	$27,553 [solar PV, solar hot water, greenhouse/roof garden, framing; other green products and materials noted in matrix below]
Other Costs:	$5,000 [rents for construction space and floating home moving costs]
Total:	$254,980 [through June, 2007]

Project Measure Matrix

In the following Matrix, as requested, please provide detailed information about all green products and materials identified in the Grant Agreement, Green Building Practices and Features.

Green Building Project Measure Matrix

Product/ brand or Measure by Category	Model #	Vendor	Cost				Efficiency/ Equipment Ratings	Certifications	Incentives, Credits, rebates, grants, etc...
			Design	Material	Equipment	Labor			
Energy									
Solar PV	220	Sunpower	included		$18,320	included elsewhere	23% gross @panels; 18.5% net after DC-AC inverter.	ETO	$13,480
Solar Hot water		Mr. SunSolar	included		$6305	included elsewhere	90% gross	ETO	$4,100
Hydronic space-heating with solar pre-heat & HRV	Lifebreath #CAF-D S4A-E16	Specialty Heating & Nutech	Urbansun Design		$4888	included elsewhere	HRV= 75% Furnace = 70% @ 125° hot water temp	ENERGY STAR	unknown
Whole house energy system	custom	Urbansun Design	Urbansun Design	See construction costs above		See construction costs above		Earth Advantage on 6/25/2007; .17 air changes per hour@50	unknown
Clothes washer - Whirlpool	KLH	APP-Smith Warehouse	n/a	$471	n/a	included elsewhere	121% over Std & E.F. =2.79	ENERGY STAR	$180
Dishwasher - Kitchen-aide	KUP	APP-Smith Warehouse	n/a	$685	n/a	included elsewhere	41% over Std & E.F. =.65	ENERGY STAR	$60
Refrigerator- Kitchen-Aide	KTR	APP-Smith Warehouse	n/a	$945	n/a	included elsewhere	15% over Std & 417 kWH per year	ENERGY STAR	$50
Water Efficiency									
Dual flush toilets	Toto Aquia	George Morlan P.	included		$588	included elsewhere	.8 and 1.6 GPF	none	unknown
Shower/ restrictive facets	Danze	George Morlan P.	included		$235	included elsewhere	unknown	none	unknown

Product/ brand or Measure by Category	Model #	Vendor	Cost				Efficiency/ Equipment Ratings	Certifications	Incentives, Credits, rebates, grants, etc...
Storm-water Management									
Roof rain catchment	custom	Urbansun Design	Urbansun Design	included		$9500	unknown	none	unknown
Rain storage tank	custom	Cox Custom Welding	Urbansun Design	$1800		included elsewhere	300 gallon capacity	none	unknown
Integrated Irrigation System	custom	Living Water	Ubansun Design	included	$2880	included elsewhere	unknown	none	unknown
Materials and Resources									
Reclaimed wood	custom	Wood is Wonderful Foundation	Urbansun Design	$6465	n/a	included elsewhere	unknown	none	unknown
Paper-stone		Env. Bldg Supply	Urbansun Design	$1640 or $32.80 per sf	n/a	Urbansun Design	unknown		unknown
Cork & bamboo flooring	-Vida Cork -ET solid Bamboo	Env. Bldg Supply	Urbansun Design	Cork-$1393 for 510sf Bamboo-$1304 for 560sf	n/a	Urbansun Design	unknown		unknown
Cellulose		Magellean	n/a	included elsewhere	included elsewhere	$2901	R-value = 3.8/inch		unknown
FSC lumber, siding, & engineered wood	Century Swedish Siding TJI's	Parr Lumber lumber- mill #34 siding- Sweden	n/a	FSC lumber - $11245 FSC Siding - $3740 Engineered wood - $8004		included elsewhere	unknown	FSC chain-of-custody document	unknown
Construction and Demolition Waste Recycling									
Wood, cardboard, metal,		Metro Northwest Recycling Center	Urbansun Design	n/a	Urbansun Design vehicle	$114	n/a	n/a	

PROJECT HIGHLIGHTS

Financial Savings & Benefits

Can any soft or hard cost savings be identified from installation of green measures? Please provide actual cost savings.	1. Hard costs savings: $750 discount on HRV system provided by vendor 2. Soft cost savings: cork & bamboo flooring was incredibly easy to install saving considerable labor over conventional flooring~$3500 est savings; as was paper-stone/maple counter tops, 1700 est. savings. Sequestering carbon savings: floatation materials [8-30" diameter logs for next 100 years], framing structure, and reclaimed timbers [another 100 years] are difficult to determine, but nonetheless, real.
Can any operational cost savings from green measures be identified? Please provide actual or projected operational cost savings.	1. Estimated ACTUALS: site PGE meter of kWH usage for 2007 to-date: Jan-May: 2069/5 = 413 average/mo. * 12 = 4965 estimated annual;10,900 average per PGE residential customer – estimated annual of 4965 kWH = 5934 estimated annual kWH savings * $.09 average cost per kWH = $534 estimated annual savings plus kWH exported to grid: actual Jan-May: 612/5 = 122 * 12 = 1468 estimated annual exported * .06 = $88 credit + $534 = $622 annualized from 2007 actual to-date, plus 2480 lbs of carbon emissions saved [to date, through June 25th, 2007]. 2. PROJECTED: expect to increase this savings by 20-40% in next 12 months; as construction will be finished, insulated shades will be installed and other energy saving features implemented. 3. Many green features are air quality benefits and difficult to estimate $ cost savings.

Environmental Benefits

Please be as specific as possible. Compare against code or a similar conventional building as relevant.

Modeled Energy Savings: *(Annual kWh or therms per sq foot)*	1. PGE statement of usage for 2007 to-date: Estimated ACTUALS: site PGE meter of kWH usage for 2007 to-date: Jan-May: 2069/5 = 413 average/mo. * 12 = 4965 estimated annual; 10,900 average per PGE residential customer – estimated annual of 4965 kWH = 5934 estimated annual kWH savings 2. actual to-date greenhouse gases saved [PV meter] = 2482 lbs.
Estimated Annual Water Savings: *(Annual savings in gallons per person)*	50% of average city water use estimated as rain/river water used for plant irrigation, restricted facets, dual flush toilets, & low-water clothes washer.
Construction and Demolition Waste Recycling: *(% recycled by weight or volume of total waste)*	The total construction waste [3780 #-weighed at recycling centers] was 3.7% of the total house weight [101,500- based on floatation units employed]; of that recycled waste, over 95% was recyclable materials delivered to 2 different local recycling centers..
Estimated Annual Reduced Stormwater Runoff: *(% total permeable surface area of total site area)*	100% permeable surface area; the floating home has a relatively large roof deck [650 sqft] to capture rain water for re-use for onsite irrigation. The greenhouse roof is drained into the river or water drips into the river from cedar decks, no pavement employed onsite and no run-off to city drains/sewers.
Enhanced Habitat: *(% area of restored or new habitat of total site area)*	No destruction of habitat; 100% of slip site is available to all sorts of water habitat ,e.g., beaver, duck, fish, etc.
Other:	1. We have installed a 15-sensor data logging system with the first sensor installed [current transformer, a transducer, probe, data logger, interface cables/connections, and software] to monitor kWH consumed by the major appliance, the hot water heater, used for hot water heating & space heating for $870 in parts/software [the installation was accomplished by the electrician and me]. 2. This data/information will be available for M&V assessment over the next 5 years, as we pursue zero net energy solutions. 3. We will shortly install river water temperature and river water current

	velocity data logging [in support of an evaporative cooling system and research of micro-hydro options] and will add site air temperature, precipitation, and wind speed and direction patterns next summer.

Community Benefits

Can any specific community benefits be identified? Examples include educational opportunities, public access or community benefit programs.	1. The house is used to demonstrate green and solar design and building practices to the public; we have had many visitors to the site to demonstrate various solar and green features. The house has been featured in [2] Oregonian articles and will shortly be featured in [3] more publications. 2. The house is also scheduled for the "Build It Green" tour and likely others. 3. Our business is designing and building solar and green homes and this will serve as a model.

LESSONS LEARNED

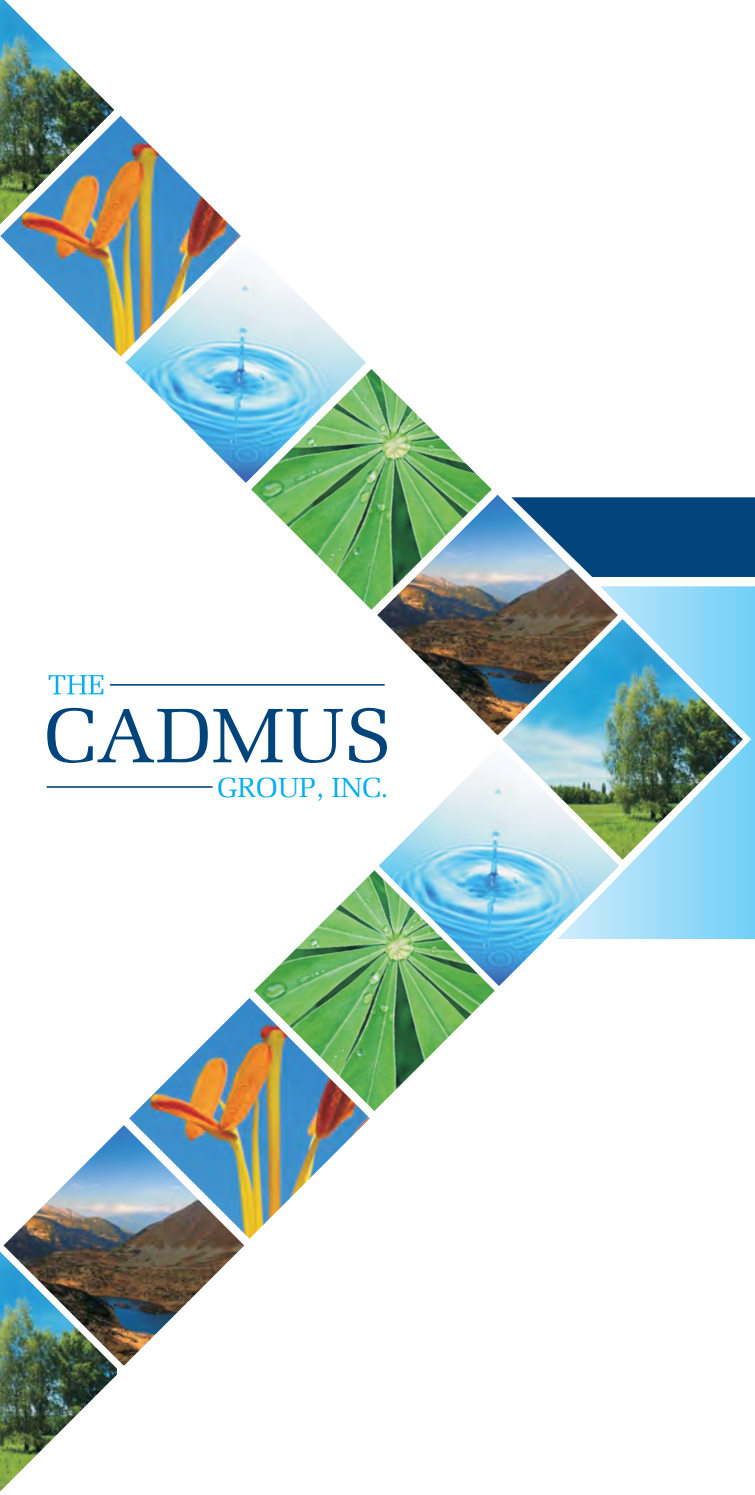
Describe key outcomes from this project. How has the project changed from its original scope and why? Would you recommend the green technology or practice to other projects? Were there any policy, zoning or building code related issues that affected the project?	**Outcomes:** 1. Better solar electricity generation than estimated and earlier timeframe for kWH exports exceeding imports of electrical energy; likely due to better weather. 2. Less space heating furnace use than estimated [stopped using space heating furnace in late February]; likely due to effectiveness of greenhouse as heat collection source. 3. Air leakage/house tightness was about as expected; ~.17AC per hour [based on testing by Earth Advantage, June, 2007]; due to combination of Earth Advantage/ENERGY STAR testing/assessment and general care in construction practices; we have 3 items to implement to get to .15AC per hour or better. **Scope changes:** Proposal to use micro-hydro system is on hold until 1-2 years of research on water current/velocity patterns and submersible generators. WHY: onsite review/research to-date by specialists concluded that our specific site characteristics made submersible micro-hydro not cost-effective to implement [at this time]. **Recommendations:** Passive solar should be implemented, as a minimum, in any/all residential construction or remodel projects and active solar implemented whenever possible; solar products have proven to be more cost-effective than planned and the green products/materials have been easy to implement; we would recommend implementation for almost all sites[some have poor/limited solar access] for solar and green products/materials for all sites; the only problems were: - some difficulty in sourcing key green products, e.g., reclaimed wood, and - the cost of green products was higher that non-green, in some cases, e.g., reclaimed wood **Policy/zoning/building code issues:** City of Portland Development was very supportive of our proposal and helped through-out the plan review and building process. The local HOA would not permit new construction building on-site, resulting in a couple of moves and additional costs of construction. **Future: get to "net zero" energy and carbon emissions 1-2 years** Near-term: we am currently implementing conservation measures and designing/building an evaporative cooling approach using deep river water to assist with integrated space cooling. Longer term; interest is to implement and evaluate diverse on-site micro-energy generation systems; will likely implement some sort of micro-hydro, micro-wind, and/or micro-fuel cell [from solar] approach to get to zero net energy and carbon emissions within 1-2 years.

IMAGES AND GRAPHICS

Please attach drawings and photos that describe the project and the green technology or practice.

1. Photos submitted under separate cover June 28th, 2007, to OSD. Photo's taken by OSD contractor should be available to your office.
2. Solar energy performance and related data through May, 2007, [and related graphs] emailed under separate cover to OSD on June 25th, 2007.

Signed: Steven D. Gray Dated: June 30, 2007 Signed: Kathryn M Gray Dated: June 30, 2007



THE CADMUS GROUP, INC.

GIF PROJECT M&V PLAN AND REPORT: URBANSUN

REPORT

December 7, 2010

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1. Executive Summary

The Urbansun floating home in North Portland was designed by owners Steven and Kathryn Gray. The project received support from the Green Investment Fund (GIF) in 2006 for the home's green building materials, passive solar design, and efficient space and water heating systems. The owners wanted to use this opportunity to design a comfortable house with lowered resource usage by implementing features such as energy-efficient windows, forced air hydronic coils, solar water heating, and a solar electric system. The Urbansun house is a two-story, single-family home that occupies approximately 768 square feet on a 2,000 square-foot slip in a floating home community. It was completed in June 2007. This monitoring and verification report (M&V) focuses on the rainwater harvesting system and energy and water savings.

The all-electric house features a number of elements designed to reduce natural resource consumption, including recycled and non-toxic construction materials and ENERGY STAR appliances. The primary innovation is a system that reduces stormwater runoff and provides water for all external irrigation and green house irrigation. The system consists of a 300 gallon tank/cistern with filtration.

Assessment of the stormwater collection system included a site inspection and an estimate of the reduction in stormwater runoff from the project site. Runoff reductions associated with the system are estimated to be approximately 15% to 20% of the average annual volume. The system also used river water to supplement the harvested rainwater, allowing 100% of Urbansun's irrigation to be met without municipal water.

The Grays implemented a number of energy saving features. Construction of the house incorporated building envelope measures that exceeded 2006 Oregon code, as well as an ENERGY STAR clothes washer, refrigerator, and dishwasher. They installed a solar thermal system with rooftop collectors to heat water in an 80-gallon storage tank, with a 55-gallon back up electric water heater. There is also a hydronic coil forced air system to assist with space heating. Based on our analysis, the combined effect of all installed appliances and measures results in a 38% reduction in annual energy usage from a baseline house. The Grays also installed a 2.2 kW photovoltaic (PV) system that offsets 42% of their annual energy consumption. Our analysis indicated the resulting savings from energy-efficiency measures and the PV system reduced the energy usage 64% from a code baseline home.

Water consumption is reduced through the installation of efficient appliances and fixtures. Three items yield water savings above the level required by current standards: the Dualmax dual flush toilet, Whirlpool clothes washer, and KitchenAid dishwasher. All three were reviewed and analyzed to estimate annual water savings. Total water savings are 3,685 gallons per year, which amounts to more than 8.5% of total baseline water consumption for the home.

As detailed in the report, the Urbansun green features and installed high-efficiency fixtures and appliances are functioning as expected.

2. Project Description

General Project Characteristics

The Urbansun project in North Portland was designed by owners Steven and Kathryn Gray. The project received support from the Portland Bureau of Planning and Sustainability (BPS) Green Investment Fund (GIF) in 2006 for the home's green building strategies. The owners wanted to design an all-electric house with low resource usage by implementing features such as high-efficiency windows, rainwater harvesting, and hydronic coil forced air heating system. Additional goals involved making the home comfortable and sustainable, so they designed a home oriented for daylighting, with a green house built into the building. The house was built on a 2,000 square foot floating lot in the Tomahawk Island Floating Home Community in Portland. Construction began in April 2006, and it was ready for occupancy in June 2007. All green measures were completed. Figure 1 shows a photo of the Urbansun floating home.

Figure 1. Urbansun Floating Home, Side View

The following firms and team members were involved in this project:

- Owners: Steven and Kathryn Gray
- Planner/Designer: Kathryn Gray

- Construction Manager: Steven Gray
- Float Contractor: Randy Olson, Duck Marine Construction
- Solar Hot Water Contractor: John Patterson, Mr. Sun Solar
- Solar PV Contractor: Kyle Bolger, Sunflower Energy Solutions
- Energy Analyst: Dick Kent, 2E Powered
- Storm-Water Analyst: MacDonald Environmental Planning
- Reclaimed Lumber Framer: Eric Anderson, EMA Industries
- Green Finish Materials: Environmental Building Supply
- Sustainable Lumber: Nate Morgan, Parr Lumber

Proposed Green Features

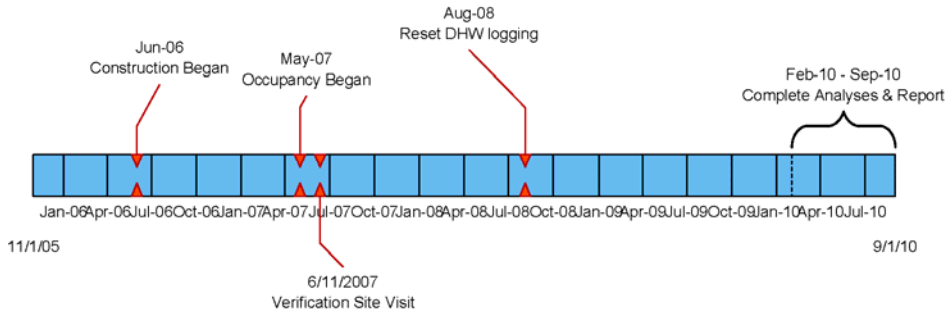
The focus of the proposed green features at Urbansun involved building a home that would come as close as practical to net-zero energy performance. The most aggressive measures involved a solar water heating system, a photovoltaic system, ENERGY STAR appliances and lighting, and passive solar design. Sustainable and recycled building materials were used when possible. The Urbansun project also attempted to reduce storm water runoff by installing a 300 gallon rainwater harvesting system for on-site irrigation. Building construction also involved a double-staggered 2x4 framing system with FSC certified timber.

M&V Scope and Schedule

In accordance with the priorities identified by the Bureau of Planning and Sustainability (BPS), the monitoring and verification (M&V) focus was on energy and water usage, and rainwater capture and use. The Cadmus Group (Cadmus, formerly Quantec, LLC) and Geosyntec performed the M&V for this project. Cadmus focused on the review of the installed green features, and energy generating systems. Geosyntec analyzed stormwater runoff and rainwater harvesting.

Our schedule for M&V activities is shown in Figure 2.

Figure 2. M&V Schedule



3. Verified Green Features

Cadmus scheduled and performed a detailed site visit to verify the green measures were incorporated into the project. All proposed measures were implemented and verified, with the exception of the micro-hydro generator. This measure was not implemented because consultants for the owners indicated the site lacked sufficient river current for energy production. In addition, the U.S. manufacturer of the generators went out of business. Cadmus also verified a number of sustainable non-GIF measures, such as a roof garden, cork and bamboo flooring, paperstone countertops, low emission fireplace, and energy-efficient lighting. Table 1 shows all reviewed measures, and notes those that are not GIF measures.

Exterior measures, stormwater harvesting equipment, and efficient appliances were all visually verified. Measures involving the use of recycled material or environmentally-friendly products (e.g., bamboo flooring) were visually verified when possible. In other cases, the owner and contractor provided documentation or details on installed measures and the rationale behind any changes.

Table 1. Checklist for GIF Measures and Installed Green Features

Proposed Measures	GIF Measure?	Installed	Comments
Exterior			
Onsite stormwater management system	Yes	Yes	Roof water is collected and stored in a 300 gallon open tank, used as thermal mass in the greenhouse. All stormwater is used for irrigation.
Roof garden	No	Yes	Over 10 small rooftop planters are watered by the collected stormwater.
Building Envelope			
Double-staggered wall system (advanced framing)	Yes	Yes	Double-staggered 2"x4" framing system. All structural timber is FSC from Warm Springs.
Energy-efficient windows (FSC harvested wood frames)	Yes	Yes	FSC windows with U=0.33 and SHGC=0.48 (low-e).
Blow-in insulation: R-54 Ceiling / R-30 Walls / R-33 Floors	Yes	Yes	Ceiling insulation: blown-in 13" cellulose topped with foam slabs achieving R-54 ceiling.
Energy Efficiency			
Solar system (Solar water heating system/PV system/Passive solar design)	Yes	Yes	Solar water heating is a draindown system. 2.2 kW PV Sunpower system. Passive design and daylighting techniques.
Micro-hydro generator (Aquair micro-hydro submersible generator)	Yes	No	Owner indicated they had committed to evaluating using a micro-hydro generator and the consultants indicated there was insufficient current to make it practical. Also, the only US company providing such systems closed. They plan to continue investigating the technology and may install one later.
ENERGY STAR appliances (See Below)	No	Yes	See below.
Solar assisted hydronic forced air furnace (air passing over heated water coils)	No	Yes	Solar-assisted Lifebreath hydronic forced air furnace. Product literature indicates rated efficiency is up to 90%.

Proposed Measures	GIF Measure?	Installed	Comments
Other: Energy efficient lighting (ENERGY STAR fixtures and CFLs)	No	Yes	All interior lighting have ENERGY STAR fixtures and CFLs, except for the kitchen area which has low voltage track lighting.
Other			
Reclaimed wood (green structure, stair treads, risers and railings, interior trim)	Yes	Yes	Reclaimed wood from the "Wood is Wonderful Foundation" by Rich Mathis; located wood from San Diego and Hawaiian Naval stations. All trim finished with Timber Pro UV.
Engineered wood (floors and roof structure)	Yes	Yes	OSB I-beams.
Site monitoring system (Energy performance monitoring system: kWh produced and consumed)	Yes	Yes	HOBO data logger records kWh produced and consumed and can support 15 inputs from appliances and equipment. Currently only the domestic water heating is recorded.
Dual flush toilet	No	Yes	[2] Dual flush toilets, both the Dualmax and Toto rated 0.9/1.6 gpf.
Renewable flooring (cork and bamboo)	No	Yes	1st floor cork floor and the 2nd floor flat grain bamboo flooring.
Sustainable harvested wood cabinetry	No	Yes	Cabinets: By IKEA, not FSC certified, but using independent certifier (World Forest Certification) with satellite verification.
Paperstone Countertops (FSC)	No	Yes	Paperstone countertops, backsplash, and fireplace border. Owner fabricated with typical wood working tools. Paperstone purchased at Environmental Building Supplies.
Low/Zero VOC paint	No	Yes	Yolo zero VOC paint.
Green house (2-story)	No	Yes	Acts like a solarium and structure built from reclaimed timber.
Low emission fireplace	No	Yes	Low emission fireplace EPA (rated 2 - emits 4g) burning compressed logs, not traditional wood.
C&D Waste	Yes	Yes	Recycling receipts provided; owners indicated almost everything was recycled or re-used.
Energy Efficient Appliances			
Dishwasher			KitchenAid dishwasher
Refrigerator			KitchenAid refrigerator.
Clothes washer			Whirlpool, LHW0050PQ, ENERGY STAR

4. Energy M&V

Project and Counterfactual Characteristics

Construction of the Urbansun floating home incorporated envelope and space heating measures that were more efficient than required by 2006 Oregon code, as well as several ENERGY STAR appliances. Table 2 provides a comparison between each energy-efficiency measure and its corresponding code requirement. As noted earlier, this is an all-electric home which does not rely on natural gas or other fossil fuels for heating.

Table 2. Comparison of Energy-Efficiency Measures

Measure	Code Requirement (Counterfactual)	Project As-Built
Windows	U-value 0.40 (OR code)	U-value 0.33
Wall insulation	R-21 (OR code)	R-30
Floor insulation	R-30 (OR code)	R-33
Attic insulation	R-38 (OR code)	R-54
Space heating	Hydronic floor heating, 78% efficient	Hydronic forced air system with heat recovery ventilator and solar assist, 90% efficient
Solar water heating	None	Installed
Solar PV system	None	2.2 kW system installed

ENERGY STAR appliances (refrigerator, clothes washer, and dishwasher) were compared to federal requirements from 2006 when the house was built. The KitchenAid refrigerator with top-mounted freezer is 20% more efficient than the minimum federal standard. The clothes washer is a front-loading Whirlpool LHW0050PQ with a modified energy factor of 2.79, which is 121% more efficient than the federal standard of 1.26. The dishwasher is a KitchenAid with an energy factor of 0.63, a 37% improvement over the federal standard of 0.46.

Analysis Approach

Envelope, passive solar, and heating system energy savings were calculated through a custom energy performance analysis spreadsheet developed by the homeowners, who are home energy design professionals. The analysis spreadsheet examined site and building characteristics, heat losses and gains, and solar performance factors. Cadmus reviewed the analysis tool in detail and determined that the building characteristics and loads were reasonable, based on the verification site visit.

The analysis tool indicated approximately half of the home's heating load could be satisfied through solar gain, as shown in Table 3.

Table 3. Urbansun Passive Solar Gain Results

	Energy (MMBtu)
Total Space Heating Load	31.1
Heating Load Reduced by Passive Solar	15.84
Remaining Heating Load	15.26

Cadmus first calculated energy savings due to the Lifebreath Clean Air Furnace (CAF) with forced air hydronic coils. Lifebreath claims the CAF can achieve 90% combined annual efficiency in conjunction with a high-efficiency water heater.[1] The Urbansun electric water heater has a 0.91 EF, which is slightly above code. Therefore, Cadmus assumed a combined annual efficiency of 90% was reasonable. Cadmus used the equations below to compare the energy required for this system to meet the remaining 15.26 MMBtu[2] annual heating load with that of a code compliant gas furnace at 78% AFUE.

Required energy = Heat Load / Efficiency

Lifebreath required energy = 15.26 MBtu / 0.9 = 16.96 MMBtu

Code furnace required energy = 15.26 MBtu / 0.78 = 19.56 MMBtu

The Lifebreath savings represented the difference between annual energy use for the two systems, equal to 2.6 MMBtu.

The next step involved estimating the additional energy use for a conventional baseline home that was offset due to passive solar design. All homes receive some level of solar gain, particularly due to south-facing windows. The Oregon Department of Energy (ODOE) developed a number of criteria for windows to qualify as "solar windows":

- windows must face within 30 degrees of *true* south
- have a Solar Heat Gain Coefficient (SHGC) of not less than 0.60
- be located in a room with thermal storage

The Urbansun home had windows facing due south with an SHGC of 0.88, located in a room with floor tiles to absorb thermal energy. ODOE developed a number of other criteria as a prescriptive path to qualify for a passive solar tax credit.[3] The ratio of south-facing window to heated floor area represented a major factor in the savings calculations. ODOE required a ratio of at least 9%, while the Urbansun home included 23%. Cadmus adjusted the Gray's calculation tool to set the baseline home at a conservative value of 8% south facing window to floor ratio and SHGC of 0.59. Many conventional homes have values equal to or below these, but Cadmus determined it was reasonable to calculate savings by applying values just below the ODOE threshold. The required heating energy for both situations was determined using the 90%

[1] < http://www.lifebreath.com/en/consumer/products/residential/caf/>

[2] MMBtu indicates million Btus.

[3] < http://www.oregon.gov/ENERGY/CONS/RES/tax/docs/SolarPassive.pdf?ga=t>

efficient Lifebreath CAF rather than a code baseline furnace to reduce interactive effects between measures. After comparing the simulation results, Cadmus determined the increased passive solar gain should save an additional 1,067 kWh per year over a conventional home, equal to 3.64 MMBtu.

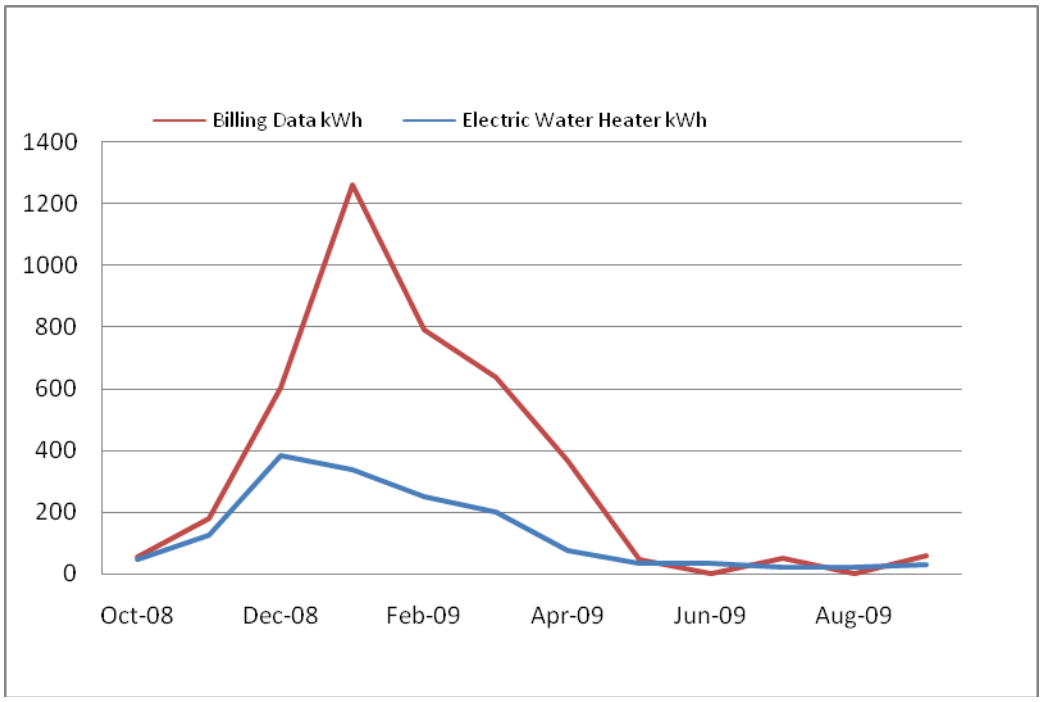
Cadmus also applied the Gray's calculation tool to determine the building envelope savings relative to a code baseline. Building characteristics such as wall and roof R-value and window U-value were adjusted to meet code requirements, although the window area and SHGC were left at the as-built values. Floor insulation savings were not calculated due to the negligible difference in R-value between the as-built and code requirement. The resulting heating load not met by passive solar gains was then compared to that with the higher efficiency envelope. The required heating energy for both situations was again determined using the 90% efficient Lifebreath CAF. The higher efficiency envelope should save 308 kWh per year, equal to 1.05 MMBtu.

The analysis approach for the efficient appliances was relatively straightforward. Energy savings were estimated from ENERGY STAR calculators by comparing annual usage for the refrigerator, clothes washer, and dishwasher to baseline, non-ENERGY STAR appliances with the same specifications.[4]

We calculated savings associated with the solar water heating by modeling the system with RETScreen, an Excel-based tool developed by Natural Resources Canada. The RETScreen inputs include site location, number of occupants, back-up water heating fuel, estimates of daily hot water use, and solar collector and storage system characteristics. RETScreen contains a database of product specifications and monthly average solar irradiance characteristics by location. The software used these values to calculate an annual energy savings estimate of 1,800 kWh per year, equal to 6.14 MMBtu. The homeowner metered electric usage on the 55-gallon back up water heater to provide more information on energy savings. The resulting data can be observed in Figure 3, and further validate the analysis by showing a significant reduction in electric water heating during the summer and shoulder months when solar gain offsets electric use.

[4] Note that we did not attempt to adjust the water heating savings to account for the more efficient appliances.

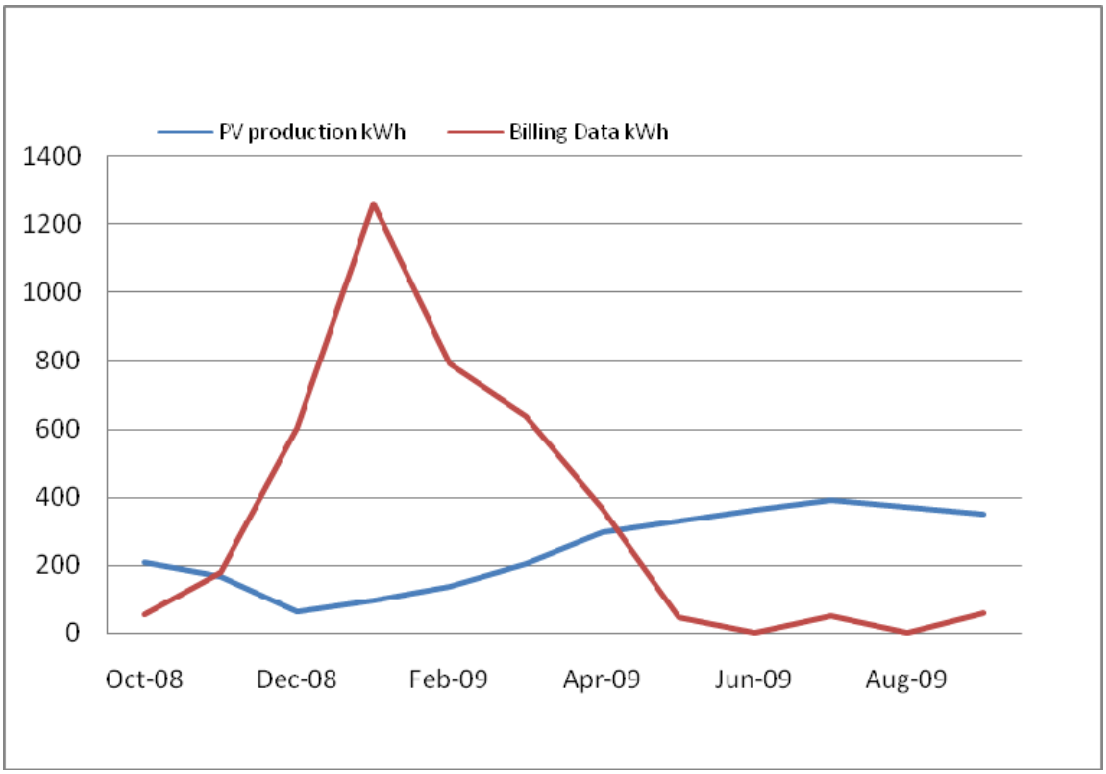
Figure 3. Electric Water Heater Usage Compared with Billing Data



Additional savings estimates were derived using a whole-house energy system spreadsheet model developed at the Oregon Department of Energy in connection with the High Performance Homes Initiative. The model uses standard ASHRAE calculation methodologies with Oregon weather and insolation data files. The model required inputs for building envelope and mechanical system parameters to calculate end use energy use. Using this model we determined there is no significant contribution from the solar water heating to the hydronic forced air system. Since solar radiation is reduced during the heating season, the solar water heating provides minimal support and first brings the domestic hot water system up to the desired temperature set point. This results in a negligible contribution to the hydronic heating system.

The photovoltaic (PV) system provided a significant offset to annual energy use. The Grays tracked system performance and provided energy production per month for the analysis. Figure 4 shows the PV system production compared to the overall consumption of the home, and indicates the PV system produced significant portions of overall energy use during summer and shoulder months. During the analysis period the PV system offset 42% of the home's overall electric use.

Figure 4. Photovoltaic Production Compared to Electric Billing Data



Results

Our analysis indicated the ENERGY STAR refrigerator, dishwasher, and clothes washer produce a total annual savings of 400 kWh, as shown in Table 4

Table 4. Energy Savings for Appliances

Appliance	Standard Annual kWh	ENERGY STAR Annual kWh	Energy Savings (kWh)	Energy Savings (MMBtu)
Kitchen Aid Refrigerator	492	417	75	0.26
Kitchen Aid Dishwasher	512	351	161	0.55
Whirlpool Clothes Washer	376	212	164	0.56
Combined	1,380	980	400	1.36

The Urbansun home was billed for 4,049 kWh during the one year post-occupancy analysis period. The photovoltaic system generated 2,986 kWh, for a total annual consumption of 7,035 kWh, equal to 24 MMBtu. The total energy savings for energy efficiency measures was 14.79 MMBtu, as shown in Table 5.

Table 5. Energy Savings by Measure

Measure	Energy savings (MMBtu)
Lifebreath Clean Air Furnace	2.6
Passive solar gain	3.64
Building envelope	1.05
Solar water heater	6.14
ENERGY STAR appliances	1.36
Total Annual EEM Savings	14.79

Adding the metered consumption, photovoltaic generation, and savings from the efficiency and solar measures, a standard code baseline home would be expected to use 38.79 MMBtu annually. Therefore, the Urbansun floating home's annual use of 4,049 kWh (equal to 13.82 MMBtu) represented a 64% reduction in annual energy usage over a baseline home.

5. Water M&V

As detailed previously, the Whirlpool clothes washer and Kitchen Aid dishwasher are high-efficiency models. The other significant contribution to water savings is from the Dualmax dual flush toilet. This model allows the user to choose between a 1.6 gallon flush (equal to the current standard) and a more efficient 0.9 gallon flush.

Analysis Approach

For this analysis, the homeowner provided an estimate of the average number of clothes washer loads, dishwasher loads, and low-volume flushes per week. We obtained the 2006 requirements for these products and the ratings of the installed appliances. Water savings for the dual-flush toilet were estimated by multiplying the number of low-volume flushes per year times the difference in water usage of the low-volume and standard-volume flushes. Water savings for appliances were estimated by multiplying the number of clothes washer and dishwasher cycles per year by the difference in the water usage between the installed unit and a unit meeting the standard.

In the Tomahawk Island Floating Home Community, there is only one meter for the entire community with no sub metering for each floating home and the water bill is included in the homeowner's fees. Consequently, we could not obtain municipal water bills for the Urbansun home. The analysis was complicated by the interaction with the stormwater harvesting system, which provides a source of water for irrigation. Since the stormwater system was not metered to establish the rainwater capture rate, it was not possible to determine what portion of the home's water usage was saved through the efficient fixtures and appliances. Thus, we analyzed the calculated annual water savings in comparison with the baseline water use estimate of 62 gallons per day per occupant[5], excluding any water use for lawn watering since it is a floating home without a lawn. There were two people living in the home during the analysis period.

Results

The estimated volumetric water savings from use of the efficient appliances are shown in Table 6. Water savings ranged from approximately 300 to nearly 3,000 gallons per year by appliance. Overall savings were estimated to average 10.6 gallons per day, resulting in an 8.5% reduction in the annual water consumption from standard efficiency fixture usage. Based on these values, we estimated an average of only 57 gallons per person each day for the Urbansun floating home.[6]

[5] http://permanent.access.gpo.gov/lps21800/www.epa.gov/safewater/wot/howmuch.html.

[6] Email from Jeff Sandberg, City of Portland Water Bureau, 4/29/09

Table 6. Water Savings

Efficient Device	Weekly Usage	Annual Water Savings (gal/year)	Total Water Savings (gal/year)	Baseline Household Water Use (gal/year)	Savings, % of Baseline Water Use
Dual flush toilet	28	866	3,865	45,260	8.5%
KitchenAid Dishwasher	3	312			
Whirlpool Clothes washer	3	2,686			

6. Stormwater M&V

Introduction and Purpose

The stormwater features at Urbansun consist of a stormwater capture and irrigation reuse system. This chapter summarizes those features and provides an evaluation of their effectiveness. The stormwater features included in the project are described in the next section, followed by a brief description of Portland area rainfall. The remaining sections describe the site visit, a discussion and assessment of project stormwater runoff reductions, and conclusions regarding the stormwater system performance.

Stormwater Features and Rainfall

Urbansun includes the following stormwater features:

- 600 square feet of impermeable rooftop and planter boxes draining to a single 4-inch drain in the center of the roof
- A 300 gallon tank/cistern that stores the roof runoff
- A 1/2 hp pump with 68 gallon reservoir
- A 240 micron filter in outflow distribution pipe to provide filtration prior to irrigation reuse

Since the design of a typical floating home discharges stormwater directly to the river, the major benefit of the stormwater capture and reuse system is reduction in demand for City water. Due to the proximity of the airport and freeway, rainwater likely contains higher concentrations of particulates and metals. Therefore, the reuse of stormwater also potentially provides a small amount of water quality benefit.

Stormwater monitoring and verification included:

- Site inspection
- Rainwater harvesting system assessment

The selection and design of stormwater features is based in large part upon the precipitation characteristics of the location where they will be used. The analysis of the rainwater harvesting system components in the following sections is based upon local rainfall data collected at the Portland International Airport (PDX) from January 1949 through December 2005.

Portland area rainfall is generally of low intensity, but makes up for this with its frequency. Portland averages around 155 days of rain annually with the majority (~75%) of rainfall occurring during the fall and winter months from October through March. Nearly 55,000 hours of hourly rainfall data (measurements > zero) collected at PDX were analyzed to investigate

rainfall intensities and the temporal distribution. Ninety percent of area rainfall is less than 0.08 inches per hour and over 99 percent of the analyzed rainfall data are less than 0.20 inches per hour. Average annual rainfall at PDX for the 56 years of data analyzed was 36.6 inches with a standard deviation of 7.3 inches. Figure 5 displays the annual rainfall totals used in the analysis; Figure 6 shows the temporal distribution of Portland rainfall.

Figure 5. Portland Yearly Rainfall Totals (PDX Rain Gage)

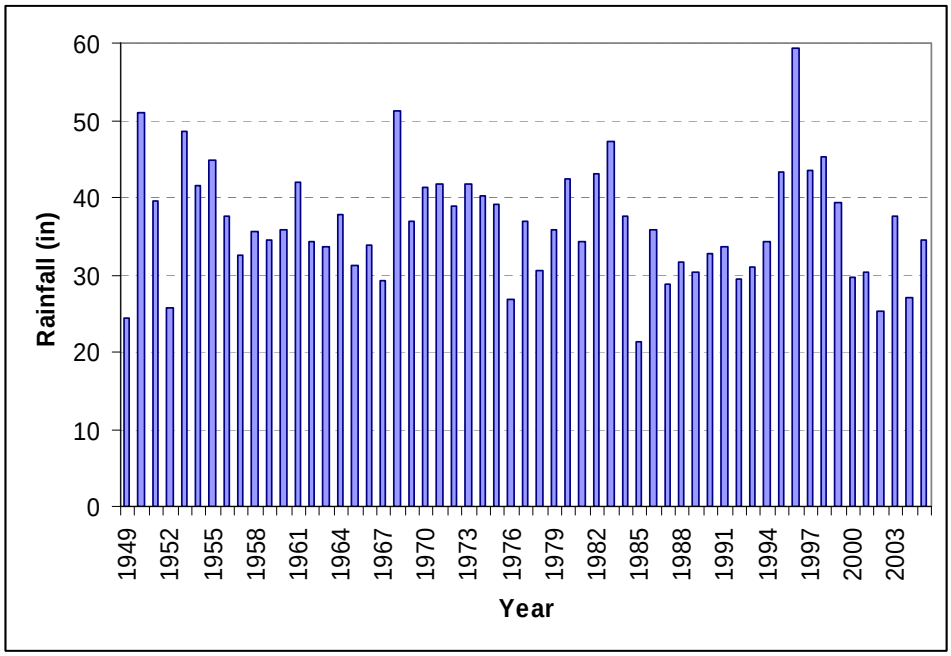
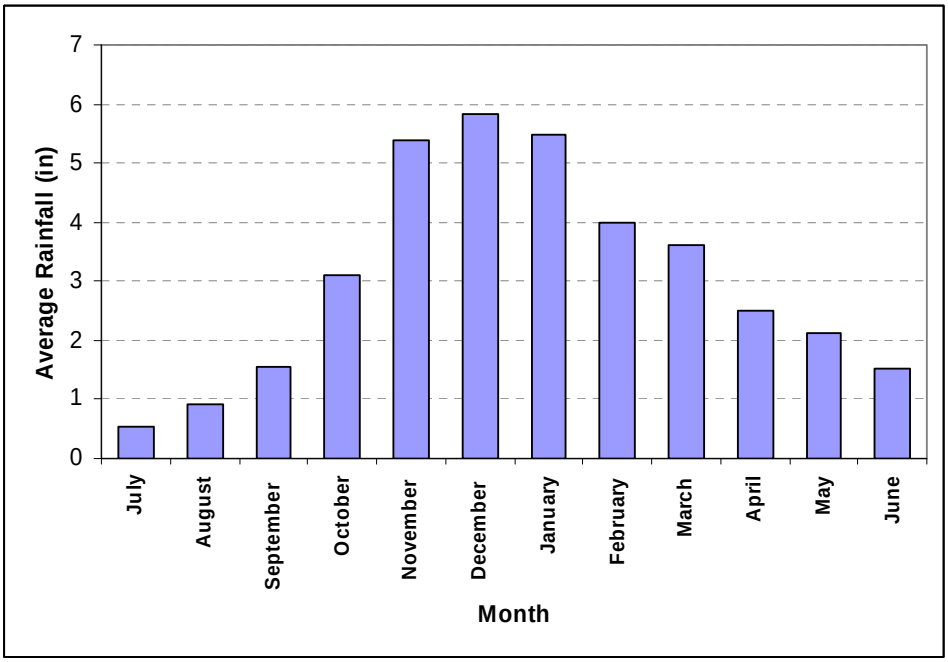


Figure 6. Portland Average Monthly Rainfall



Site Inspection

A site inspection of the project (Figure 7) was conducted in the afternoon of June 11, 2007. Photo 1 shows the rooftop area with planter boxes. All rainfall that hits the rooftop is directed to the 4 inch drain in the middle of the roof. There is no screen on the drain to ensure it does not clog with small detritus from the roof garden. Photo 2 shows the storage tank located in the sun room on the southwest corner of the house. Photo 3 shows the pump, filter, and piping system. The tank is open so that any debris that makes it through the drain can be easily scooped out. The filter is cleaned about once per week with washing / back flushing.

Figure 7. Stormwater M&V Inspection

Photo 1: Rooftop with planter boxes

Photo 2: Rainwater storage tank

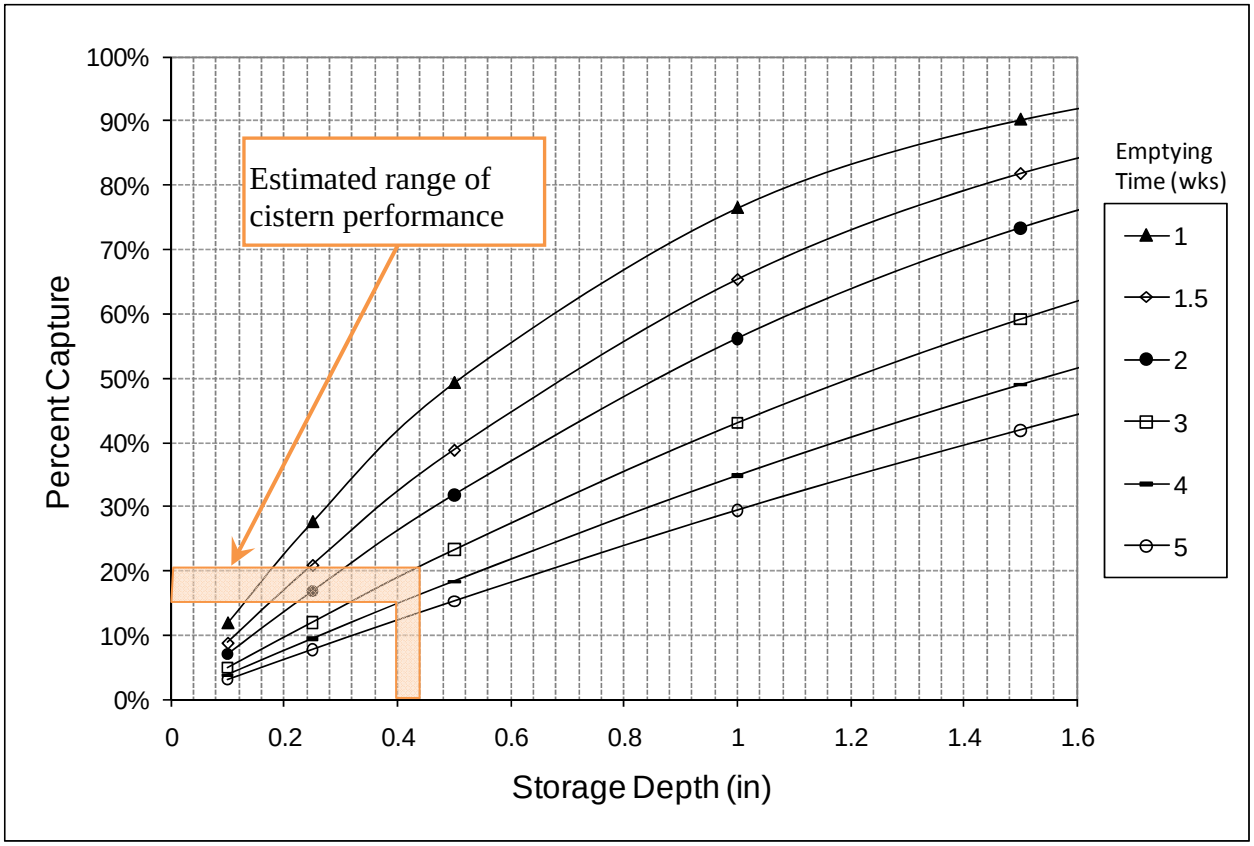
Photo 3: Rainwater/river water pump, filter, and distribution system

Rainwater Harvesting System Assessment

Captured stormwater is used to irrigate the roof garden as well as the potted plants in the sun room. To provide ballast for the floating house, the tank is maintained at about ½ full during the summer by supplementing with river water. The tank is emptied prior to anticipated rainfall events. During warm weather the entire 300 gallon tank is emptied in about 1 week. During cooler weather the tank takes several weeks to empty since only inside potted plants are watered.

Given a drainage area of 600 square feet, the tank when empty can capture approximately 0.8-0.85 inches rainfall, but since the tank is kept approximately half full the available capacity is about 0.4-0.42 inches. Considering back-to-back storms and assuming an average weekly drain time of 3-4 weeks during the wet season, the cistern is likely capturing about 15-20% of the average annual rainfall on the roof of the house. The percent capture curves shown in Figure 8 were generated by long-term, continuous simulation of runoff storage and release using the U.S. EPA SWMM model and the period of record summarized in Figure 5.

Figure 8. Average Annual Cistern Capture Efficiency



Conclusions

The Urbansun project includes a progressive rainwater harvesting system designed to capture roof runoff for indoor and outdoor irrigation use. Runoff reductions associated with the system are estimated to be approximately 15-20% of the average annual volume. Considering that the house is a floating home where rainfall would reach the river whether the house is there or not, the overall benefits associated with these runoff reductions is relatively small. However, every gallon of harvested rainwater replaces a gallon of city water that otherwise would have to be purchased. The innovative use of river water to supplement the harvested rainwater allows for 100% of Urbansun's irrigation demand to be met without municipal water, thereby lowering the strain on the City's water treatment and distribution system.

7. Construction and Demolition Waste

All GIF projects starting with those funded in 2006 are required to document construction and demolition (C&D) waste. The program requires recycling 100 % of this waste.

The complete list of GIF materials requirements are:

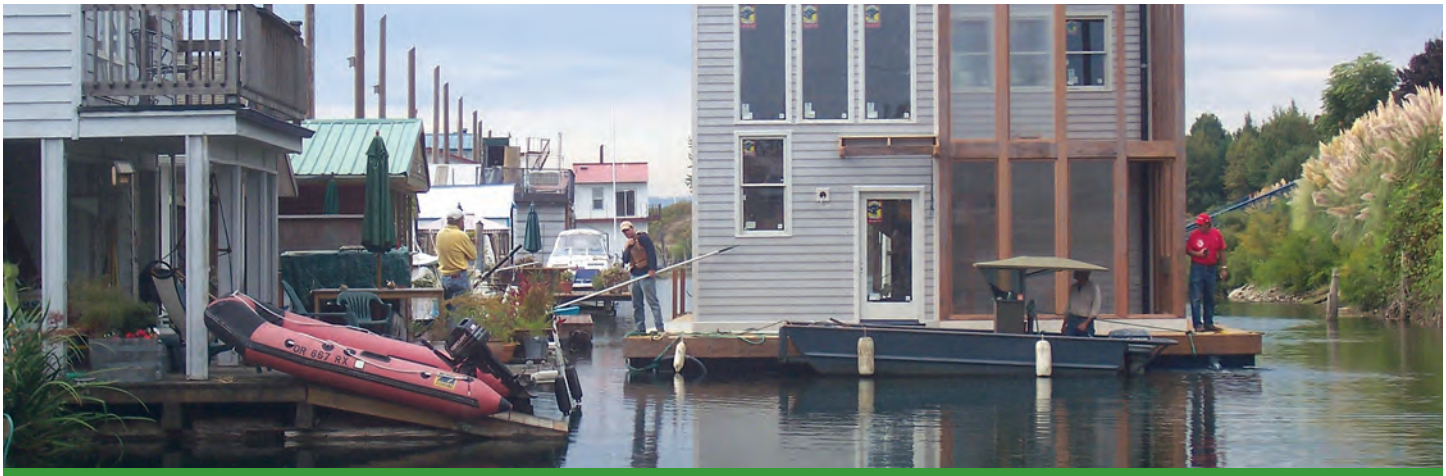
- 100% construction & demolition waste recycling (starting in 2006)
- 30% materialsuse reduction
- Design and construction practices that enable deconstructability and reuse of 80% of building materials
- Use of materials with recycled content such that the sum of post-consumer recycled content plus one-half of the post-industrial content constitutes at least 10% of total value of project materials
- Use salvaged, refurbished or reused materials, products or furnishings for at least 5% of building materials (by cost)
- Design for easy and accessible garbage and recycling collection for building residents and tenants.

The owners of the Urbansun home provided seven receipts for material that had been recycled. Material description, weight, and disposal method are listed in Table 7.

Table 7. Recycling Chart

Receipt	Material	Pounds	Dollars	Method
Pacific land cleaning & Recycling Center #1	wood	800	$16.00	recycled
Pacific land cleaning & Recycling Center #2	wood	380	$10.00	recycled
Pacific land cleaning & Recycling Center #3	wood	480	$10.00	recycled
Pacific land cleaning & Recycling Center #4	yard debris	240	$10.00	recycled
Metro Central Station #1	yard debris	580	$19.00	recycled
Metro Central Station #2	MSW	440	$24.00	recycled
Metro Central Station #3	yard debris	880	$25.00	recycled
Totals		3,800	$114.00	

The Urbansun home recycled a total of 3,800 pounds of material: 1,660 pounds of wood, 1,600 pounds of yard debris, and 440 pounds of miscellaneous solid waste.



URBANSUN HOME

A Floating Model of Sustainability + Net-Zero Energy Goals

The owners of this floating home turned hard work, diligent research and great ideas into an energy-efficient home that also minimizes its impact on the surrounding Columbia River. The home incorporates both straightforward passive design principles and high-tech solutions to harness solar energy and maximize energy efficiency. Homeowners Steven and Kathryn Gray have set the stage for taking advantage of future improvements in wind and other sustainable energy generation technologies to provide even more efficiencies down the road. Their goal is to eventually take advantage of all cost-effective sustainable energy sources.

A Net-Zero Energy Use Goal

One of the Gray's goals was to build a home that on average uses no energy from the power grid. As part of a 2008 Solar Oregon Net Zero study of efficient homes, the home's Energy Use Index (EUI) for the year is 7.2 (compared to 46 EUI nationally). The total annual energy use is about 3,000 kWH short of net zero; the best near-term opportunity for achieving net zero is to double the solar PV array by an additional 2.2 kWH system. Even now, their home exports energy back to the grid during certain months of the year.

The Grays, owners of Urbansun Design, used a variety of approaches to create and conserve energy. They started with a set of passive design features to help reduce energy use. These include solar orientation, a two-story solarium/greenhouse, staggered 2x4 framing, high-efficiency appliances and highly effective R-60 cellulose insulation in the ceilings and R-30 in the walls and floors. The Grays also used multiple green building materials, including reclaimed wood, PaperStone countertops and cork and bamboo flooring. They recycled 95 percent of the construction debris.

Steve and Kathryn researched renewable energy systems to identify the best technology available, including solar photovoltaic and small-scale wind and hydro power systems. They ultimately installed a 2.2 kW photovoltaic (PV) solar power system that offsets

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42 percent of their annual energy consumption. They also installed a solar thermal system with rooftop collectors to heat water in an 80-gallon storage tank, with a 55-gallon back-up electric water heater. And they used integrated HRV-hydronic coil forced-air system to assist with space heating. All together, these systems reduce energy usage by about 65 percent compared to an average home of the same size, according to an energy analysis conducted by the Cadmus Group. And the Grays report that energy savings are in fact even greater than those projected in the analysis. After accounting for electricity exported back to the power grid, the Gray's saved over $600 per year in electricity bills during the first year after construction. They anticipate even higher savings after installing more energy-efficiency features in the home.

In addition to using the sun's power to generate electricity, the Grays researched the potential for installing a micro-hydro or wind energy system. Based on an evaluation of wind speeds, water velocity and river current data by energy consultants, the Grays found that a hydro system would not be cost effective. Steve and Kathryn believe that solar-based technologies are the best near-term opportunity to achieve net-zero energy use.

The Grays also considered installing a micro-wind turbine to generate electricity and have researched current and historic wind pattern data for the area. They found that the typical wind patterns likely aren't capable of energy-effective power generation using today's micro-wind systems. However, they believe micro-wind technologies could be a viable, sustainable source in the next five years and will continue to monitor micro-wind developments.

The Grays have installed a moderately-sized (2.2 kWH) solar PV system for a residential application and have room to expand the on-site electricity generation in the future. In the meantime, they're cutting energy use by over 65 percent and plan to implement more conservation practices; then buy green energy to meet their remaining needs. This home has been mentioned in several publications, and was featured as the home of the month in *Smart Home-Owner* magazine in 2008. Steve and Kathryn give tours of the home's sustainability design features.

Making the Columbia River Healthier

The Grays invested in a variety of features to reduce their water usage and limit the impacts of water runoff on the Columbia River. First, they used water-saving appliances. Their Dualmax dual flush toilet, Whirlpool clothes washer, and KitchenAid dishwasher reduce water use by about 8.5 percent over average home appliances. Second, they've installed a stormwater collection system that provides water for all external irrigation and green house irrigation. Rainwater flows from rooftop planter boxes and impervious surfaces through a single 4-inch drain in the center of the roof and into a 300-gallon storage tank/cistern. The water is then filtered and pumped to reuse for irrigation. This helps reduce water use and also eliminates metals and other pollutants found in stormwater from entering the river, making for a healthier Columbia. Because the Urbansun floating home sits right on the river, these benefits are immediate.

Energy and Water System Financial Savings and Benefits

Costs	
▪ Solar PV System	$18,320
▪ Solar Hot Water system	$6,305
▪ Hydronic space-heating with solar pre-heat & HRV	$4,900
▪ Irrigation and water storage systems	$4,700
▪ Energy-efficient appliances	$2,100
▪ Dual-flush toilets and low-flow showerheads	$ 820
TOTAL	$37,145
Offsetting Grants and Rebates	
▪ Solar PV System	$13,480
▪ Solar Hot Water system	$4,100
TOTAL	$17,580
Projected Operational Cost Savings	
▪ Electricity –approximately 65% annually	$625/year

Resources

Urbansun Design Solar Homes
▪ www.sunsmarthomes.com

Energy Trust Incentives
▪ www.energytrust.org

Solar Hot Water System
Mr. Sun Solar ▪ www.mrsunsolar.com

Energy Star Ratings ▪ www.energystar.gov

National Oceanic and Atmospheric Administration (NOAA)
National Climatic Data Center
▪ www.ncdc.noaa.gov/oa/ncdc.html

Project Partners

EnergyTrust of Oregon

Environmental Services City of Portland
working for clean rivers

Portland Water Bureau
FROM FOREST TO FAUCET