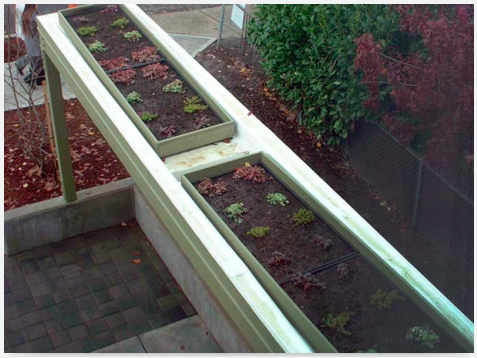
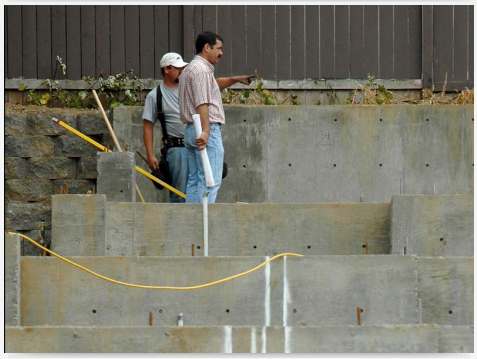




Reach Community Development, Inc.
33rd & Powell Rowhouses

Six units of affordable housing in inner SE Portland for first-time, lower-income home-buyers. The homes feature structurally insulated floor and roof panels, hydronic heating, and tankless water heaters among other energy efficiency measures to achieve PGE Earth Advantage certification, which requires 15% energy use reduction beyond code. The outside of the townhouses are distinguished by ecoroofs over the home's porches and sheds.

Project Highlights

- **Ecoroof**
- **Structural insulated panels**
- **Hydronic heating**
- **Low VOC paint**
- **Water efficient toilets**
- **Formaldehyde free plywood cabinets**
- **Energy efficient appliances**

Portfolio Contents

- **Final Report**
- **Monitoring & Verification**

Project Website (External Link)

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

Portland Office of Sustainable Development
G/Rated Green Investment Fund

Grantee Final Report

PROJECT INFORMATION

Name of Primary Contact: **Kevin Kraus**
Company or Organization: **REACH Community Development**
Address: **1135 SE Salmon St.**
City, State & Zip: **Portland Oregon 97214**
Phone: **503-231-0682** Fax: **503-236-3429**
E-mail: kkraus@reachcdc.org

PROJECT DETAILS

Project Name: **33PO**
Project Owner: **33PO, LLC**
Project Address: **3630, 3634, 3638, 3642, 3646, 3650 SE 33rd.**
City, State, ZIP: **Portland, Oregon 97202**
Directions to Site: **SE Powell east to SE 33rd, turn south on SE 33rd**
Date Project Started: **March 6, 2006**
Date of Completion: **October 31,2006**

Design and Construction Team

Architect or Designer: **Lundin Cole Architects**
General Contractor: **Oregon Construction, LLC**
Landscape Architect: **None**
Structural Engineer: **WDY, Inc.**
Civil Engineer: **None**
Mechanical Engineer: **Design Build–Tri-Temp Control/ Wolcott Plumbing**
Electrical Engineer: **Design Build–White Lightning Electric**
Interior Designer: **Tracy Simpson**
Environmental Building Consultant: **Earth Advantage**
Energy Modeler: **None**
Additional: Geotechnical–**Alder Geotechnical Services**

Building Details

If building has mixed use, please include the sq. ft of each type of use
Gross Floor Area: **6,730 sqft**

Building Type
[ ] Single-family Residential
[ ] Multi-family Residential
[ ] Commercial
[ ] Industrial
[ ] Institutional
[ ] Mixed-Use
[X] Other--Rowhouse

Site Conditions (check all that apply)

[X] Previously Undeveloped Land
[ ] Previously Developed Land
[ ] Brownfield Site
[ ] Preexisting Structure(s)

Project Type

[ ] Renovation
[X] New
[ ] Addition

Green Products & Materials: Must include projected performance, efficiency ratings, equipment ratings or product certifications for all green building products outlined in Exhibit 1, for example, FSC wood, Energy Star Appliances, Green Seal etc..

1. All appliances are Energy Star rated
2. SIP's pane roofs provide R44 insulation value
3. Lighting system is entirely Energy Star/fluorescents.
4. Eco-roofs-plantings on front exterior roofs help reduce run-off.
5. Onsite drywells allow for all site run-off to be infiltrated into the ground on-site.
6. Takagi instant water heaters used for domestic and heating purposes.
7. Shaw PET carpet made from recycled materials.
8. Rodda Horizon paint is Greenseal certified
9. All insulation materials used were Greenseal certified.
10. Advanced framing techniques were used.

Green Venders & Suppliers Used
Rodda Paints
Shaw Carpet
Tri-County Temp Control
Standard TV and Appliance
Axis Construction
Structures NW (SIP's panels)
Island Landscaping
Weston Solutions (Green Grid Trays for Eco-roofs.

PROJECT HIGHLIGHTS

List Innovative Sustainable Technologies & Practices
See above items 1- 10

Project Costs
Land Acquisition: $150,456
Site Clearing/Deconstruction: $-0-
Site Development: $18,670–water meters/fire hydrant, etc.
Public Improvements: Included in construction #
Design Fees: $50.000
Permits: $13,463
System Development Charges: Waived
Construction: $941,833
Green Technologies: $51,800
Other Costs: $88,194–soft costs, realtor fees and carrying costs
Total: $1,314,416

Project Cost by measure (as listed in Exhibit 1, Green Building Practices and Features) Attach additional pages with the following format to accommodate additional measures as needed.
NOTE: Prices are for all six units/

1. Measure Eco-roofs
   Materials-green grid trays, soil, plantings and wood trim
   Cost: $4,900

2. Measure-SIP's panels vs conventional framing
   Materials-SIP's panels
   Cost: $15,000

3. Measure-Appliances
   Materials-Energy Star rated
   Cost: $2,400

4. Measure-Plumbing for heating
   Materials-Tankless water heater and hydronic furnace
   Cost: $18,000 over conventional equipment

5. Measure-Fresh air changes
   Materials-Bath exhaust fans and dampered inlet air pipe into furnace
   Cost: $6,700

6. **Measure-Paints and adhesives**
   Materials-Low VOC
   Cost: $0

7. **Measure-Flooring**
   Materials-VCT and Marmoleum/recycled carpet
   Cost: $0

8. **Measure-Light Fixtures**
   Materials-Energy Star rated
   Cost: $0

9. **Measure-Toilets**
   Materials-Caroma dual flush
   Cost: $3,000

10. **Measure-Cabinets**
    Materials-Non Urea formaldehyde plywood
    Cost: $1,800

Financial Savings & Benefits

Energy:
Hard Costs: **SIPS, ventilation, appliances and HVAC $42,100**
Projected Or Actual (Circle One) Operational Cost Savings: **@$400 per unit per year**
Incentives: Grants, Tax Credits, Below Market Loans: **GIF, Green Communities**
Other:

Water:
Hard Cost: **Toilets $3,000**
Projected: Savings: **@$100 per unit per year**
Incentives: Grants, Tax Credits, Below Market Loans: **GIF, Green Communities**
Other:

Stormwater:
Hard Cost Savings and/or Cost Tradeoffs: **N/A City requirements**
Projected Or Actual (Circle One) Operational Cost Savings: **???**
Incentives: Grants, Tax Credits, Below Market Loans:
Other:

Materials:
Hard Costs: **Cabinets $1,800**
Projected Savings: **Long term health??**
Incentives: Grants, Tax Credits, Below Market Loans: GIF, Green Communities
Other:

Environmental Benefits

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

Annual or Modeled Energy Savings (beyond code): **48%**
Materials Savings: **0**
Annual CO_2 Emissions Savings: **1545 lbs/yr**
Annual Water Savings (beyond code): **???**
Construction Waste Diversion (% and by weight):
Annual Reduced Rainwater Runoff (beyond code): **100%**
Enhanced Habitat (amount of restored or new): **None**
Other:

Community Benefits:

Less resources used to construct, better energy efficiency on all levels for long term health of the environment. Built for long term health of the owners.

DESIGN & CONSTRUCTION

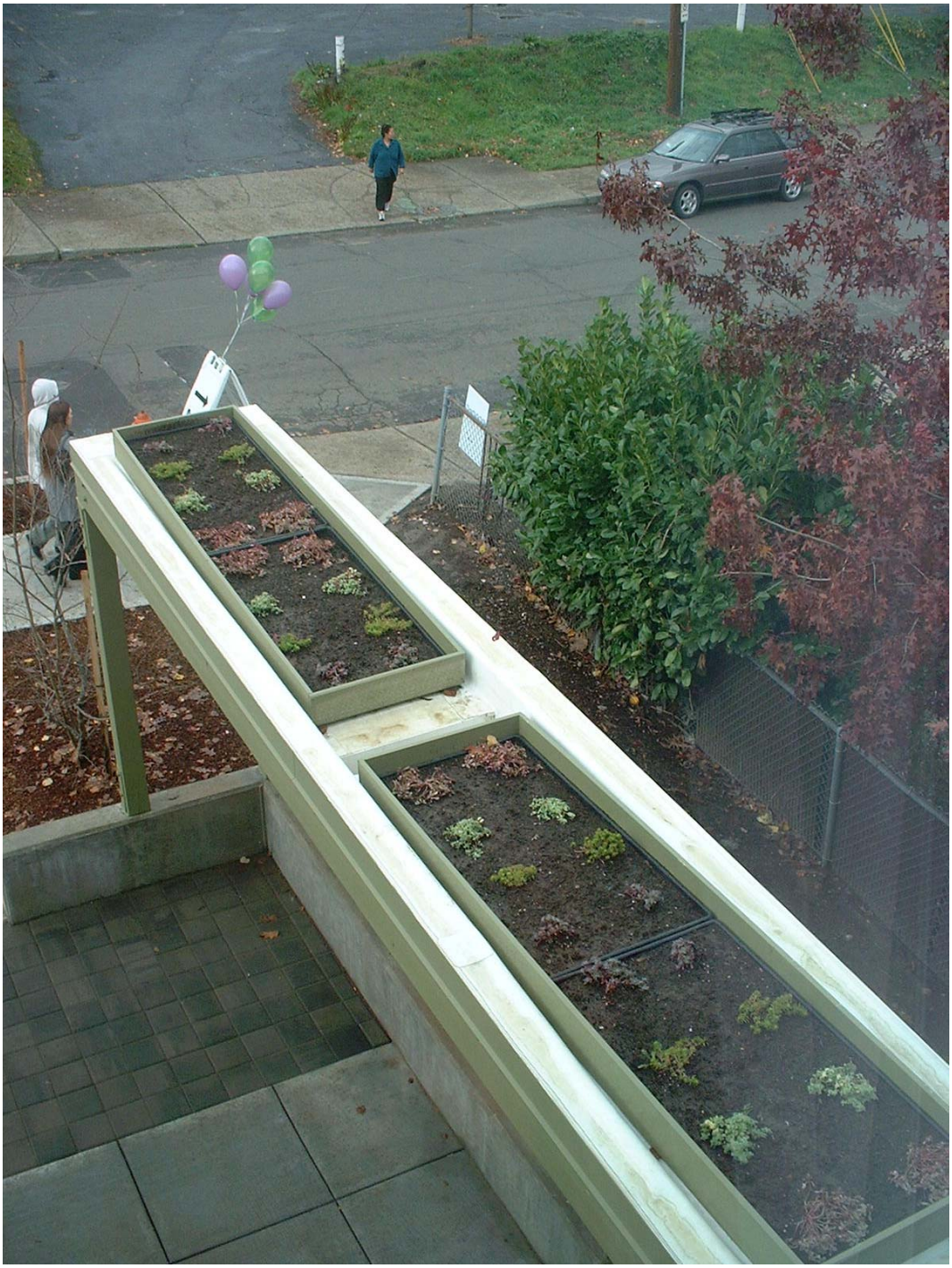
Provide a short description of how the green technology or practice was incorporated into the project process. What were the qualitative and quantitative (measurable) objectives and why? If possible, describe by phase: Pre-Design, Design, Construction, Operations and Maintenance.

See project costs for the list of items included in the project. We set out to build units that would qualify for the Earth Advantage program and to provide the best units we could for the environment and end user. We chose the items we included for their high impact and mid-range costs.

All went as planned during construction. Five of the six homeowners have been tutored in the maintenance, care and systems for their homes. The 6th unit will not participate in returning phone calls and emails.

IMAGES AND GRAPHICS

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



BUILDING CERTIFICATION

If project has received LEED, Earth Advantage, or other Green Building certification, please describe.

All six units are Earth Advantage Certified and will be LEED-H Silver certified.

LESSONS LEARNED

Describe key outcomes from this project. How has the project has changed from its original scope and why? Would you recommend the green technology or practice to other projects? Were there any zoning or building code related issues that affected the project?

Building green does add additional cost to a project. There is a strong market out there for reasonably priced green units. The grant money received did not fully cover the costs of the green building features. Many features have become common place in the market and do add a premium cost to the project. Other feature definitely cost more.

Questions? Please contact Kyle Diesner, 503-823-4166 or Terry Miller, 503-823-7418 at OSD. Thank you for taking the time to share what you've learned!

GIF Project M&V Plan and Report: REACH Community Development at SE 33rd & Powell

July 30, 2009

FINAL REPORT

Prepared by:

The Cadmus Group, Inc.
720 SW Washington Street
Suite 400
Portland, OR 97205
(503) 228.2992

With Team Members:

Geosyntec

Prepared for:

Portland Bureau of Planning and Sustainability

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1. Executive Summary

REACH Community Development, Inc. has pioneered affordable housing and supportive programs that address complex challenges facing communities. As part of their portfolio, REACH built six units of affordable housing in inner southeast Portland for first-time, lower-income homebuyers.

One of the main objectives of this project was to provide lower operating cost for home owners through use of highly efficient systems and environmentally friendly, durable materials. The project was certified through Earth Advantage and received a Leadership in Energy and Environmental Design (LEED) Silver certification from the U.S. Green Building Council as part of the LEED for Homes pilot project. It was originally proposed to be completed in September 2006, but was completed and ready for sale on October 24, 2006.

Key green measures in this project included integrated components such as hydronic heating from on-demand water heaters and rainwater harvesting used for irrigation. In addition, structural insulated panels (SIPs), ecoroofs, ENERGY STAR appliances, and water saving devices were incorporated into the design.

The energy analysis began with a detailed counterfactual eQUEST model for the REACH townhomes using architectural drawings and based on the Oregon Energy Code. The evaluation team calibrated an energy-efficient version model based on final building and operational characteristics, including energy billing data. The final step examined the specific end-use savings and global savings attributable to the as-built homes compared to the modeling outputs. The results indicated gas savings of 21% and electric savings of 28% compared to homes built just to code.

The evaluation team reviewed all the water-using fixtures and appliances in the homes to determine which ones exceeded the efficiency requirements of applicable standards. All the fixtures and one appliance were more water-efficient than required by the standards, and included dual flush toilets, faucet aerators, and low flow showerheads. One unit provided an estimate of weekly water use, through which the evaluation team calculated water savings at 26% compared to code.

The REACH project originally included several stormwater control features intended to reduce runoff which were scaled back due to budgetary constraints. The primary measure removed was a rainwater harvesting system for on-site irrigation. The measures which were installed included a dry well system for on-site rainwater retention and infiltration, ecoroofs on each unit near the carport and front of house, and pavers with permeable edging in the center of the driveway. The evaluation team determined the remaining impervious fraction for the site, and calculated a runoff reduction of 72%, equal to 21,718 ft^3 per year.

Overall, the project's original vision was achieved in regard to reducing operating costs through efficiency and environmentally-friendly methods. The design, construction, and operation of these six units have produced significant reductions in gas, electric, and water usage, as well as stormwater runoff reduction.

2. Project Description

General Project Characteristics

Since 1982, REACH Community Development, Inc. has pioneered affordable housing and supportive programs that address complex challenges facing communities. REACH has gained local, state, and national acclaim for innovation and responsiveness to difficult urban issues. REACH's portfolio includes single-family homes and large apartment buildings, new construction, and substantial renovation. As part of their portfolio, REACH built six units of affordable housing in inner southeast Portland for first-time, lower-income homebuyers. This new construction project, in the Creston-Kenilworth neighborhood, is located at SE 33rd and Powell Boulevard. A view of a typical unit is shown in Figure 1.

One of the main objectives of this project was to provide lower operating cost for home owners through use of highly efficient systems and environmentally friendly, durable materials. Key measures of this project included integrated components such as hydronic heating from in-line water heaters and rainwater harvesting used for irrigation. In addition, structural insulated panels (SIPs), ecoroofs, ENERGY STAR appliances, and water saving devices were incorporated into the design. Due to REACH's efforts, the project was certified through Earth Advantage and received a Leadership in Energy and Environmental Design (LEED) Silver certification from the U.S. Green Building Council as part of the LEED for Homes pilot project.

Figure 1. Front View of SE 33rd and Powell Townhomes

This project was originally proposed to be completed in September 2006. It was actually completed and ready for sale on October 24, 2006.

Proposed Green Features

The project included a variety of green features and practices. A set of measures was accepted by the Bureau of Planning and Sustainability (BPS) for funding under the Green Investment Fund (GIF).

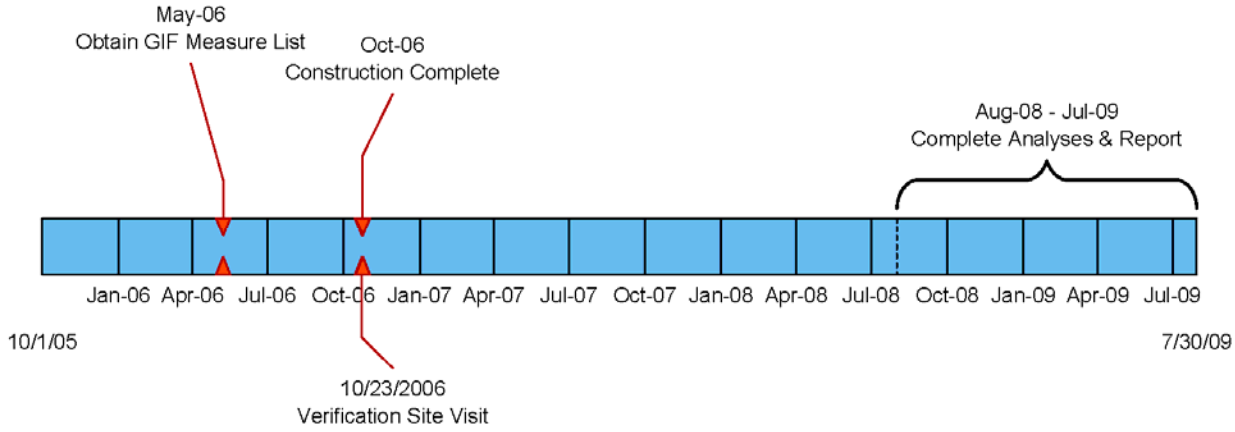
The most significant green features proposed included a hydronic heating system with forced-air, SIPs, on-demand water heaters, and rainwater harvesting used for irrigation.

M&V Scope and Schedule

In accordance with the priorities identified by the BPS, the monitoring and verification (M&V) focus was on energy use and water use, although a limited stormwater analysis was also performed. The Cadmus Group (Cadmus), Portland State University (PSU), and Geosyntec performed the M&V for this project. Cadmus focused on the review of the green features installed and conducted the energy and domestic water analysis. PSU contributed to the energy analysis by developing a counterfactual model to simulate the building's energy usage. Geosyntec had the lead for the stormwater analysis.

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

Figure 2. M&V Schedule



3. Verified Green Features

Cadmus and Geosyntec scheduled and performed a detailed site visit to verify that the green measures were incorporated into the housing units. As shown in the checklist in Table 1, we reviewed the proposed measures to verify that they were present and properly installed. We also noted additional green or energy-efficient features installed that were not included as part of the Green Investment Fund (GIF) grant. Measures included in the GIF are noted in the second column of the table.

For measures that involved the use of recycled material or environmentally-friendly products, the measures were visually verified when possible. In other cases, either Kevin Kraus, REACH Community Development Coordinator, or the general contractor (Oregon Construction) provided documentation or confirmed the use of the material or product (e.g., low VOC paint).

Table 1. Checklist for Site Visit

Proposed Measures	GIF Measure?	Installed	Comments
Exterior			
Rainwater harvesting system for yard and lawn care	Yes	No	GIF funding less then requested and this measure was cut from the budget.
Rainwater retention and infiltration onsite	No	Yes	Dry well system installed
Ecoroof over pump shed	Yes	No	Developer indicated they had agreement with BPS to delete this measure
Ecoroof over porches	Yes	Yes	Near carport and front of house
Fiber Cement Board Siding with Rainscreen	No	Yes	On two sides: West and South face.
Turf Paver Parking	No	Yes	Reduced area from planned. Strip of pavers down the center of the driveway.
Permeable pavers	No	Yes	1/2 of the proposed area was installed to reduce budget.
Building Envelope			
Structural Insulated Panels - (Expanded Polystyrene, EPS) core for roof	Yes	Yes	Located in roof. R-44. 10" thick.
Eco - flooring (type)	No	Yes	PET carpet recycled grade. Manufacturer: Shaw
Low VOC and allergen-free materials and finishes used throughout interior	No	Yes	Rodda Paints: Horizon GreenSeal
ENERGY STAR windows	No	Yes	Vinyl, Argon filled. U-value: 0.34 to 0.35
Concrete slab on first floor	No	Yes	
Wall Insulation	No	Yes	R-21, Fiberglass insulation
Energy Efficiency			
On-demand water heaters	Yes	Yes	Takagi (T-K1S) Gas. 190K BTU (max) - DWH and Space
Forced air hydronic heating on the main floor	Yes	Yes	Takagi (T-K1S) Gas. 190K BTU (max) - DWH and Space
ENERGY STAR Appliances (see below)	No	Yes	See Below
In-wall hydronic units (bedrooms and bath) - zoned	Yes	Yes	
Automated forced fresh air system.	No	Yes	Automated forced fresh air system. Runs 7 hours

Proposed Measures	GIF Measure?	Installed	Comments
			at night.
Exhaust fan	No	Yes	Low Sone: 1.5
Other			
Low-flow showerheads/faucets	No	Yes	Low-flow showerhead of 2.0 gpm (better than code of 2.5). All faucets have an aerator of 0.5 gpm.
Low-flow toilets	Yes	Yes	Dual Flush Caroma Carelleve 0.8/1.6 gallons per flush
Cabinets and countertops (low-toxics)	No	Yes	Formaldehyde - free.
Construction waste and recycling program - 60%	No	Yes	Achieved 96%
Metering/Measurements			
Cadmus/Geosyntec: GIF verification			Site Visit 10/24/06
Cadmus/PSU: Energy performance v. counterfactual			eQUEST/REMRate/Survey/Billing data
Geosyntec: Annual municipal water use v. counterfactual			Survey/Billing data
Blower door testing to measure air infiltration			Achieved 0.18 ACH
Earth Advantage certification			Passed and completed
Other: LEED for Homes			Silver rating
Energy Efficient Appliances			Model Number or Brand Name
Dishwasher			ENERGY STAR Whirlpool
Refrigerator			ENERGY STAR GE
Clothes washer			Not installed. Hook-ups only.
ENERGY STAR fluorescent lighting system			Manufacturer: Seagull

4. Energy M&V

Project and Counterfactual Characteristics

This GIF project consisted of six townhomes with relatively similar floor areas, floor plans, and construction details. The energy M&V started with the creation of a simulation model reflecting the as-built townhomes and a counterfactual model based on minimum code requirements. Table 2 compares the energy-efficiency measures of the homes as-built and verified through our site visit with the measures that would have been installed if the homes were designed to just meet to the Oregon energy code using conventional practice (the "counterfactual").

Table 2. Comparison of Energy-efficiency Measures

Measure	Code Requirement (Counterfactual)	Project As-Built
Windows	U-value 0.40 (OR Code)[1]	U-value 0.34
Ceiling Insulation	R-38 (OR Code)	Structural Insulated Panels (SIPs) R-44
Space Heating	Gas Furnace, 80% AFUE	Hydronic heating with on-demand water heaters
Water Heating	40-gallon tank water heater, EF = 0.59	On-demand water heater, EF=0.84
Appliances	Standard	ENERGY STAR Appliances

The evaluation team's energy modeling approach is discussed next. Because of limitations in the modeling software, when we analyzed the homes it was not possible to model all the energy-efficiency measures, particularly the use of the on-demand water heater for hydronic heating.

Analysis Approach

The energy analysis approach started with the development of a detailed counterfactual eQUEST model for the REACH townhomes using architectural drawings and based on the Oregon Energy Code. Portland State University provided assistance in developing this initial model.[2] The next step involved creating the energy-efficient version of the calibrated model using building characteristics from the final design of the townhomes. The third step was calibration of the energy-efficient model using billing data collected over one year to produce yearly consumption estimates (heating, lighting, etc.) consistent with the billing data, and then applying that calibration data to the counterfactual model. The final step involved comparing the outputs of the two models to determine the specific end-use savings and global savings attributable to the homes as built.

Earth Advantage also performed testing to achieve certification as part of the LEED for Homes pilot project. LEED for Homes is a voluntary rating system that promotes the design and construction of high performance "green" homes. As part of the LEED for Homes certification, Earth Advantage performed blower door tests to determine air leakage, commissioned exhaust

[1] Standard practice is ENERGY STAR (U-value 0.35) – Energy Trust of Oregon

[2] The initial modeling was conducted as part of a building energy modeling class taught by Dr. David Sailor.

fans, performed a combustion air test in each utility room, and used REMRate software to develop a Home Energy Rating System (HERS) rating for the townhomes.

Description of Simulation Model and Other Analysis Tools

Energy Simulation Model

eQUEST is a public domain model supported as a part of the Energy Design Resources Program, which is funded by California utility customers and administered by Pacific Gas and Electric Company, San Diego Gas & Electric, and Southern California Edison, under the auspices of the California Public Utilities Commission.

eQUEST's calculation engine is the well-known DOE-2 model. DOE-2 is also in the public domain and is the most widely used and accepted building energy analysis program in the U.S. DOE-2 relies on building profile data, including building layouts, construction characteristics, energy usage behavior, conditioning systems (lighting, HVAC, etc.), and weather data to perform an hourly simulation of the building and to estimate energy consumption. In eQUEST, the energy-efficiency measure wizard allows users to explore various measure configurations while accounting for measure interaction effects.

Blower Door Testing

This test by Earth Advantage represents a way to determine the natural air leakage of the townhomes. This information is important in determining the energy consumption of the homes for heating and cooling and is a factor in the indoor air quality and longevity of the structure.

The test involves assembling a temporary frame in an exterior door, installing a large powerful fan, and depressurizing the interior volume of the home. From the pressure difference between indoors and outdoors, the pressure at the fan opening, and the airflow rate through the fan, it is possible to calculate the overall air tightness of the home in terms of the natural air changes per hour (ACH). The tests were scheduled to be conducted on all townhomes by an Earth Advantage Technical Specialist, and indicated a natural leakage rate of 0.18 ACH.

Key Energy Analysis Inputs, Assumptions, and Data

After the homeowners occupied their townhome for one year, a year's worth of utility billing data was requested. Electric, gas, and water billing data for 2007 were collected from three of the six units. The energy billing data—electricity and natural gas—were used to calibrate the eQUEST model according to the energy use of the townhome, averaged between the three units.

Project Model Development

The evaluation team developed a baseline eQUEST model of the townhomes. The inputs to the model were taken primarily from information provided by the architectural drawings supplied by REACH Community Development, using Oregon Energy Code standards for certain features (such as roof insulation) or where no information from the developer could be determined. In the

case of home sealing, the evaluation team applied the default eQUEST value of 0.40 ACH as a representation of standard practice.

Next, a model was created by including the energy-efficiency measures from the as-built townhomes and re-running eQUEST on the revised building design. As noted above, the evaluation team used the energy billing data to calibrate the eQUEST model to produce approximately the same energy use as the average billing data. The primary adjustment for electric energy use involved setting the appropriate level for average plug load. The original PSU-developed model set the plug load at 0.3 watts per square foot. Upon review, the evaluators reset this value to 0.45 watts per square foot, which provided a better match for the average billing results. No effort was made to calibrate gas billing data to the eQuest model.

The resulting as-built calibration data were then used to calibrate the baseline model. Once both models were calibrated, the difference between the baseline and the as-built models represented the net energy savings for the modeled building.

Envelope Model Design

The eQUEST Schematic Design Wizard mode was used to input the basic design data. Multi-family low rise building type (exterior entries) was selected among the alternatives. Building drawings were converted from a PDF document to AutoCad and vertices were traced out into the eQUEST model. The total building area was subdivided into twelve shell components based on six units of two stories each, using the appropriate as-built square footage for each unit. U-value inputs of structures in the baseline model, such as walls and floors, were to building code standard. After creating the building footprint and zoning, the building envelope parameters and building load data were entered. The front and back views of the townhomes developed in eQUEST are shown in Figure 3 and Figure 4.

Figure 3. eQUEST Model Front View

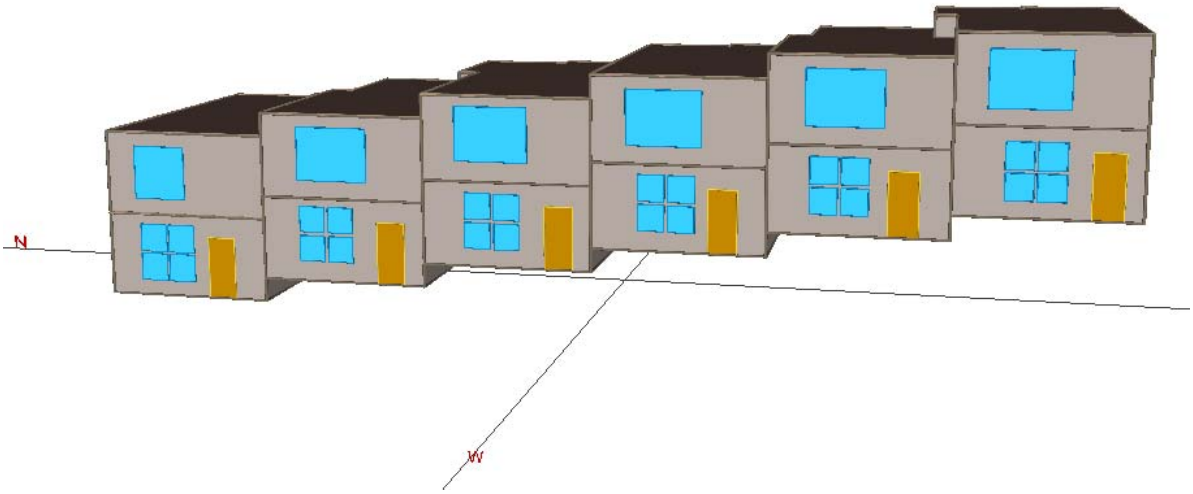
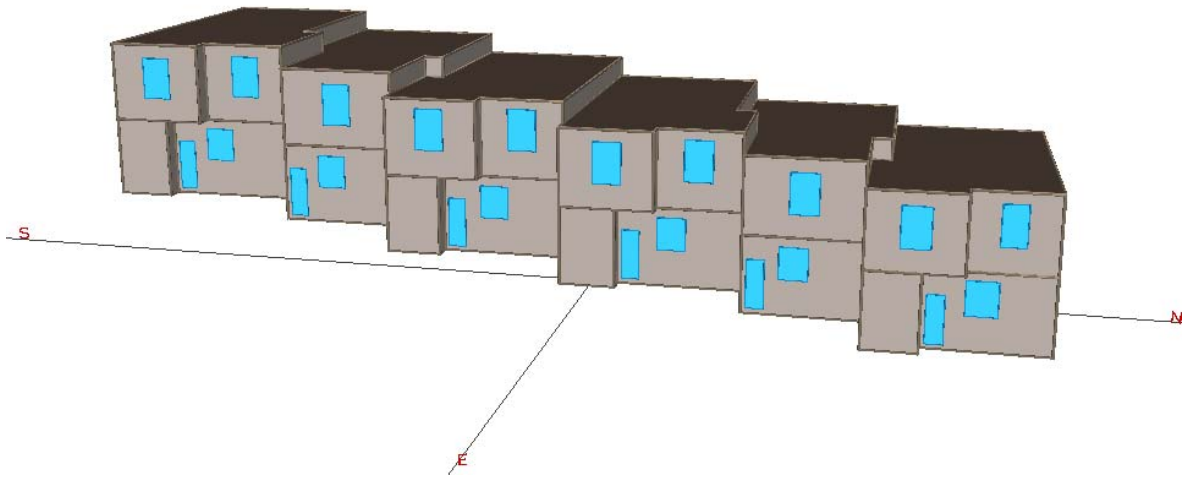


Figure 4. eQUEST Model Rear View



Counterfactual vs. As-Built

Once the baseline envelope design was completed, the energy-efficiency measures were designed into the model. eQUEST cannot represent all the potential technologies, such as hydronic heating. However, it was possible to design assumptions into the model that best fit and represented most of these technologies. With the exception of the on-demand water heater for the hydronic heating system, the stated technologies were incorporated into the eQUEST model. For the on-demand water heater for hydronic heating, the evaluators adjusted the model to use hot water coils as the heating method and set the boiler efficiency to 84%, the efficiency of the on-demand water heater. Table 3 presents the energy-efficiency measures that were included in the as-built model.

Table 3. Energy Efficiency Measures Integrated in eQUEST Model

Measure	Code Requirement (Counterfactual)	Project As-Built
Windows	U-value 0.40 (OR Code)	U-value 0.34
Ceiling Insulation	R-38 (OR Code)	Structural Insulated Panels (SIPs) R-44
Space Heating	Gas Furnace, AFUE=80%	Hydronic heating
Water Heating	Tank water heater	On-demand water heater
Appliances	Standard	ENERGY STAR Appliances
Infiltration	0.40 ACH	0.18 ACH

Energy Consumption and Savings Results

Following the calibration of the model based on the as-built homes billing data, the same calibration adjustments were made and the model was rerun using the counterfactual (code)

building characteristics. The billing data for the as-built homes and the model estimates for the as-built and counterfactual buildings were compared. The resulting curves for natural gas and electric usage are shown in Figure 5 and Figure 6.

Figure 5. Natural Gas Usage Comparison

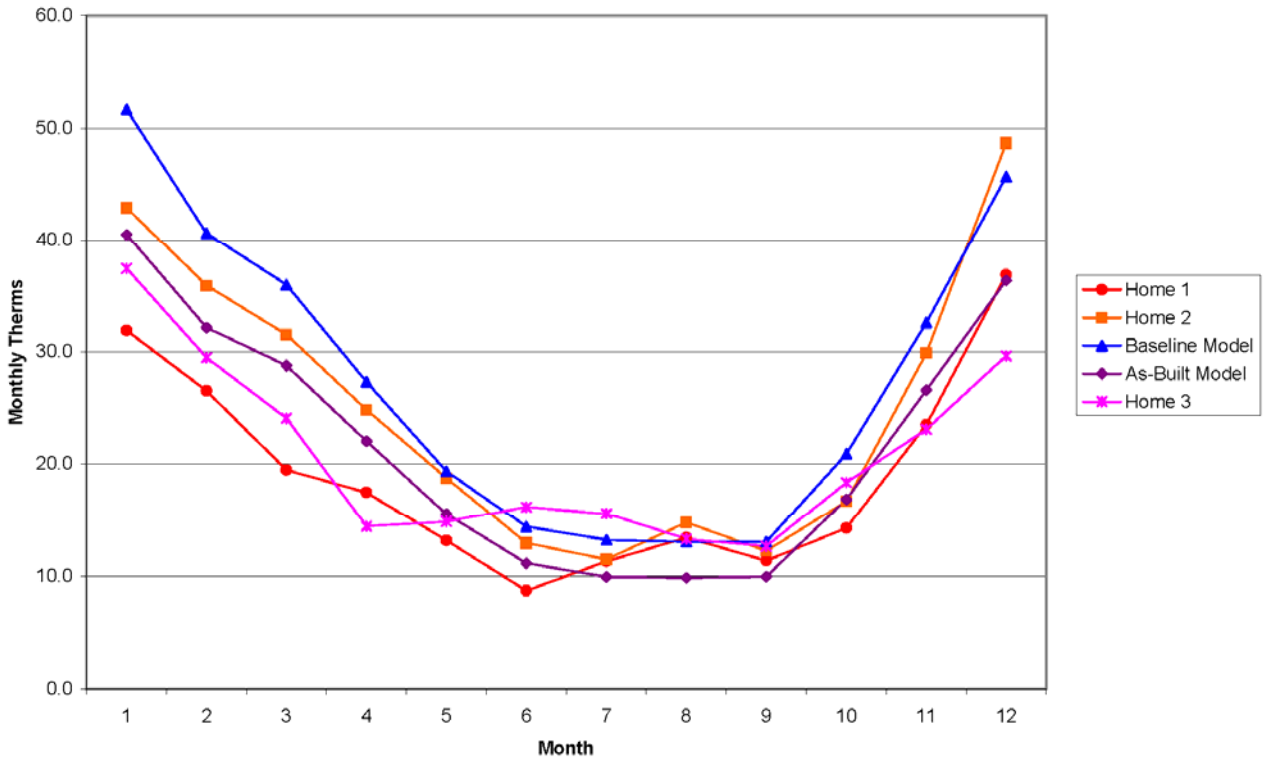
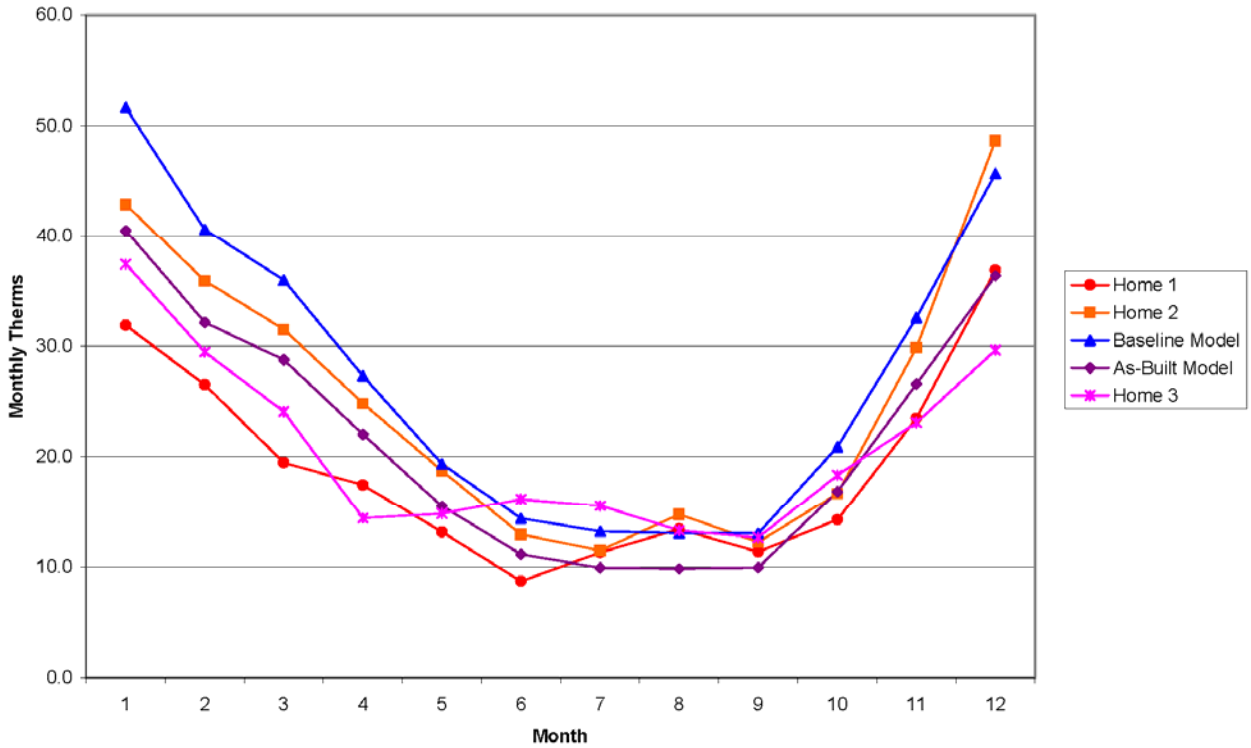


Figure 6. Electricity Use Comparison



The comparisons between modeled and actual energy usage indicate that the as-built model results provide a reasonable approximation of the average usage for the actual units. The model energy use was averaged over the square footage among the six townhomes. For the most part, the as-built model energy use reflects that average with results between the actual billing data for the two identically-sized units. The total natural gas analysis shows a strong correlation between the model results and as-built unit usage, except for unexplained increases throughout the summer months that culminated in a spike in use in August for at least two of the units. All three units experienced a similar phenomenon, which could not be explained by weather-related effects. A review of Portland Heating Degree-Days (HDD) from 2005 to 2008 indicates that August 2007 experienced 7 HDD, compared to an average of 9. However, the results for September 2007 suggested there should have been a higher than average demand, with 116 HDD compared to an average of 83 HDD, but the gas usage spike occurred in August. The evaluation team was unable to resolve the discrepancy.

The electric usage analysis also indicates that for the most part the as-built modeled electric use fell either at or between the billing data for the two units. Any differences between the modeled use and average from the three units would represent a change in the base plug load. Adjusting this value would have no effect on the energy savings, because the plug loads would be identical between both baseline and energy efficient models.

For Home 2, the billing data indicated a spike and then sharp drop in April and May. The evaluation team believes that this resulted from a meter reading error that assigned more electric

use in April that should have been applied to May. The average usage between these two months would indicate a more normal behavior. The usages for Home 2 and Home 3 also indicate a moderate August increase in line with that observed with natural gas usage.

The final step after performing calibration and analyzing the resulting data involved calculation of energy savings. The difference in usage between the counterfactual and as-built eQUEST models resulted in annual gas savings of 409 therms and annual electric savings of 8,520 kWh for the entire building, as indicated in Table 4. The average townhome unit should save 68 therms and 1,420 kWh on an annual basis.

Table 4. Energy Saving Analysis Results

End Use	Baseline Usage (MBTU/year)	As-Built Usage (MBTU/year)	Energy Savings (MBTU/year)	Energy Savings % of total
Space Heating	99.22	83.25	15.97	16%
Water Heating	58.28	33.34	24.94	43%
Total Gas	196.63	155.72	40.91	21%
End Use	**Baseline Usage (kWh/year)**	**As-Built Usage (kWh/year)**	**Energy Savings (kWh/year)**	**Energy Savings % of total**
Lighting	14,830	3,710	11,120	75%
Total Electric	30,870	22,350	8,520	28%

The evaluation team examined each gas efficiency measure to determine which represented the majority of the savings. We expected the majority of the savings from the tankless water heater. For comparison, the team looked at an annual water heating usage value derived from a conditional demand analysis for Puget Sound new single-family construction. These data were calibrated from billing data in the context of developing end-use energy consumption values in a recent Resource Potential Study for Puget Sound Energy. The evaluation team assumes these annual water heating values would be comparable for the Portland and Puget Sound areas.

The calculations in the Puget Sound project were based on 3.4 occupants per household, resulting in tankless water heating savings of 71 therms. The REACH Community Development project was assumed to have two occupants per unit. By adjusting the projected savings on a per occupant basis, we estimated the tankless water heater would save 43 therms per unit. However, the tankless water heaters were installed on the exterior of the units, which would result in some losses through the piping insulation. This would reduce the potential gas savings that could be achieved.

In addition, we projected savings of 7 therms from the ENERGY STAR dishwasher, based on engineering calculations from the ENERGY STAR rating and Puget Sound water heating energy use intensity data. The window and ceiling insulation measures were expected to provide small savings, due to the small differential from code. The evaluation team expected most of the remaining savings would result from the infiltration control measures that reduced the number of air changes per hour from 0.40 to 0.18.

5. Water M&V

Project and Counterfactual Characteristics

The evaluation team reviewed all the water-using fixtures and appliances in the homes to determine which ones exceeded the efficiency requirements of applicable standards. All the fixtures and one appliance were more water-efficient than required by the standards. Table 5 shows the water-efficient fixtures and appliances, along with the efficiency requirement of the standards and the actual rated efficiency of the fixture or appliance.

Table 5. Efficiency of Water-Using Equipment

Equipment	Water Efficiency Standard	Actual Water Efficiency
Faucet aerators	2.2 gpm	0.5 gpm
Low-flow showerhead	2.5 gpm	2.0 gpm
Caroma dual-flush toilet	1.6 gpm	0.8 / 1.6 gpm
Whirlpool ENERGY STAR dishwasher	9 gallons per cycle	5 gallons per cycle

Analysis Approach

Given the small number of fixtures and appliances that are more water-efficient than required by standards, the analysis approach was relatively straightforward. The team contacted the homeowners to obtain an estimate of the average number of fixture uses, flushes, and dishwasher loads per week, and received a response from only the homeowner in Home 2.

The team also obtained the requirements of the standards for these products. 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 then estimated by multiplying the number of cycles per year of the dishwasher times the difference in the water usage of the installed unit and a unit just meeting the standard.

Two of the owners (including the one who provided water use data) also signed a utility bill waiver that allowed us to obtain from the City of Portland Water Bureau the quarterly municipal water meter readings. These data were obtained for the first year-and-a-half of occupancy. This information allowed us to compare the water savings from these appliances to the total consumption.

The average American home uses 87 gallons per day per occupant[3]. The evaluation team reduced that by the uses not applicable to this site, including lawn watering, pools, garbage disposal, and car washing. Based on the end use estimates from the EPA, we reduced the estimated baseline water use per occupant to 58.5 gallons per day. There were three people living in Home 2 during the M&V period, resulting in an estimated baseline water use of 64,058 gallons per year (176.4 gal/day).

Results

The estimated water savings from use of the efficient fixtures and appliances are shown in Table 6. Water savings ranged from 430 to 4,420 gallons per year by fixture or appliance, or from 0.7% to 7% of total estimated baseline water consumption using the estimate above. Overall savings were estimated at 35 gal/day, or 20% of calculated baseline consumption.

However, the actual annual water use from billing data for Home 2 was only 36,767 gallons. With the addition of the calculated savings, that would represent a total annual baseline usage of 49,534 gallons (or, 45.2 gallons per capita per day), 23% below the baseline estimated from the secondary source. Due to the degree of difference, the evaluation team chose to set the baseline equal to the value determined through billing data. Relative to their estimated baseline usage without the efficient fixtures, the savings for this household were estimated to be 26%.

Table 6. Water Savings from Home 2

Fixture / Appliance	Weekly Usage	Annual Water Savings (gal/year)	Total Water Savings (gal/year)	Baseline Household Water Use (gal/year)	Savings, % of Baseline Water Use
Caroma dual flush toilet	45 flushes	1,872	12,767	49,534	26%
Whirlpool dishwasher	2 loads	430			
Low flow showerhead	15 showers	2,730			
Bathroom faucet aerator	75 uses	3,315			
Kitchen faucet aerator	100 uses	4,420			

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

6. Stormwater M&V

Introduction and Purpose

The REACH project included several stormwater control features intended to reduce runoff. Due to budgetary constraints, the stormwater reduction components of the project were scaled back. The developer's original plan included a rainwater harvesting system to use for on-site irrigation. However, budget constraints resulted in the removal of this measure. This chapter summarizes the remaining stormwater features and provides a description of their expected performance.

Stormwater Features and Rainfall

Each of the six REACH homes included the following stormwater features:

- Dry well system for on-site rainwater retention and infiltration
- Ecoroof on each unit near the carport and front of house
- Pavers with permeable edging in strip down center of driveway

The selection and design of stormwater features is based in large part upon the precipitation characteristics of the location where they will be used. Our analysis neglected the impact of pavers with permeable edging because those were installed on a slope, which results in stormwater runoff running over the pavers rather than draining into the ground. The analysis of the stormwater system components in the following section 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 7 displays the annual rainfall totals used in the analysis; Figure 8 shows the temporal distribution of Portland rainfall.

Figure 7. Portland Yearly Rainfall Totals (PDX Rain Gage)

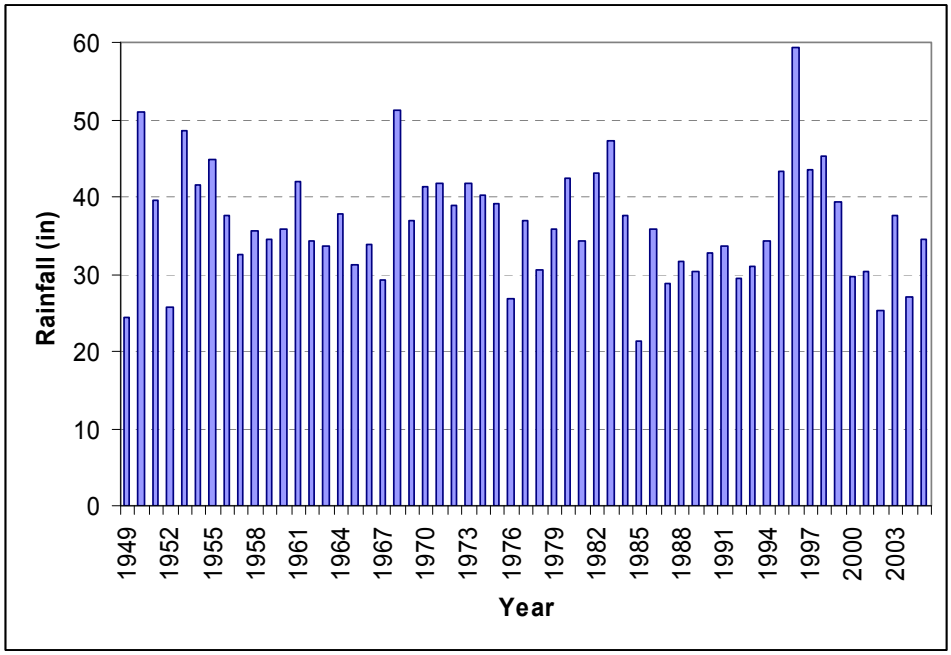
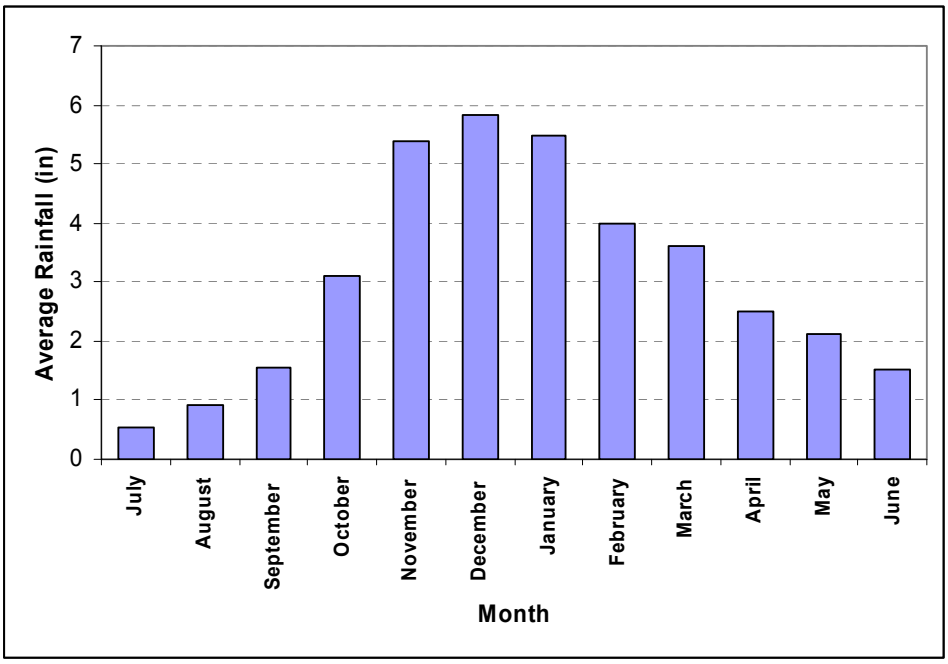


Figure 8. Portland Average Monthly Rainfall



Site Reduction in Stormwater Runoff

In order to estimate the effect of the stormwater management system on reducing stormwater runoff, an average annual stormwater runoff volume was estimated for the project as if it did not have the stormwater features, using the Rational Equation (Novotny and Olem, 1994):

$$Q = R_v \times I \times A \qquad (1)$$

where

Q = runoff (cubic feet),

I = rainfall (3 feet annual average),

A = drainage area (square feet), and

R_v = mean annual runoff coefficient (dimensionless).

The runoff coefficient is a unit-less value that represents the expected fraction of rainfall that results in runoff. It is primarily a function of the amount of impervious cover in the urban watershed. The evaluation team calculated the amount of impervious cover using site data in the following manner:

- Roof Area – 53% of lot impervious and draining to drywell
- Driveway and Front of Lot – 27% (5% pervious – square planting areas between driveways and mini-ecoroofs; 22% impervious and draining to City stormwater system)
- Backyard – 20% pervious

The runoff coefficient was then calculated using the Simple Method (Schueler, 1987), a linear runoff coefficient equation based on a wide range of stormwater-monitoring data which is suitable for this level of analysis.

$$R_v = 0.90 \times (\textit{impervious fraction}) + 0.05$$

Without the stormwater features, the impervious fraction is estimated to be 80 percent, based on the roof, driveway and sidewalk area, resulting in a runoff coefficient of 0.77. Therefore, the total runoff volume is estimated as 29,956 cubic feet[4] on an average annual basis for the entire project without the stormwater components included. A similar calculation was made for the volume of runoff prevented by the planting areas and ecoroofs at around 1,872 ft^3, on average, per year. The drywell is also expected to prevent approximately 19,846 ft^3 of stormwater runoff in an average year. The expected reduction in stormwater runoff from using the ecoroofs, planting areas, and drywell, therefore, is 21,718 ft^3 per year, or an average annual reduction in stormwater runoff of about 72%.

[4] Runoff = 0.77 × 3 ft rain × 12,968 sq. ft. = 29,956 cubic feet of runoff

Due to the storage capacity of the dry well it is probable that only very large storms would result in additional stormwater runoff above the calculated value from the project site.

Conclusions

The external stormwater features (planting areas and ecoroofs) of the REACH project are functioning properly and should result in a small portion of rainfall infiltrating through the permeable areas, as well as much of the rainfall falling on the ecoroofs being returned to the atmosphere. The most effective way to improve the performance of the REACH stormwater system would be to implement a rainwater harvesting system using a cistern. Use of the collected rainwater would provide the additional benefit of reduced purchases of City water, helping offset the costs of the collection system.

While a modeling assessment of the drywell performance is outside the scope of this project, the drywell was constructed to meet the City of Portland standards and is expected to prevent stormwater runoff from leaving the project site except during very large storm events. The stormwater volume reductions achieved with the ecoroofs when combined with the expected performance of the drywell should result in stormwater volume reductions even higher than the LEED goal of 30 percent reduction (US Green Building Council, 2005). The REACH project has effectively met the commitments made to incorporate effective stormwater controls into the project.

7. Construction and Demolition Waste

Starting with GIF projects funded in 2006, awardees were required to submit to Cadmus the material description, weight, and disposal or recycling receipts for all C&D waste. This project was funded in 2005, and therefore, this requirement did not apply.

However, the evaluators did receive a waste report from the REACH Community Development's contractor, Oregon Construction Company, LLC. The waste hauler, AGG Enterprises, reported recycling 27.35 tons out of 28.39 tons of mixed solid waste, for a 96% recycling rate. This information was not verified by the evaluator for the reasons stated above.