EARTH ADVANTAGE COMMERCIAL PROGRAM

FINAL REPORT

Fire Station 16

January 9, 2002

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EXECUTIVE SUMMARY

The purpose of this report is to present the final results of the energy analysis conducted for the Fire Station 16, in Portland Oregon. The building is a 5,600 square foot 24-hour fire station. This report provides information on the energy savings possible with the efficiency measures considered for the project. This analysis was performed by PAE Consulting Services and Portland General Electric (PGE) for PGE's Earth Advantage Commercial program.

A building is considered Earth Advantage if it uses 20% less energy annually than if it were designed to meet the minimum requirements of the State of Oregon Energy Code, (Chapter 13 of the 1998 Oregon Specialty code). If it uses 30% less energy, it is eligible to be considered an Earth Advantage Gold building.

This analysis compares alternatives against the code baseline. The baseline building design meets the Oregon Energy Code without exceeding the code. The baseline is described beginning on page 3. The analysis methodology is described beginning on page 5.

The PGE Savings Summary Chart, Table 1, page 2, tabulates the energy usage and cost results for each individual EEM evaluated. Ten energy efficiency alternatives were considered for Fire Station 16 building after discussion by the team, as listed below. Energy savings results for eight of these are listed in the Table 1 Summary. All of the potential energy efficiency measures are described beginning on page 8. Incremental costs for these measures were not available at the time of this report, but will be provided by the team. The energy cost savings presented are based on current published rate tariffs. The owner may wish to consider proposed and speculative changes in rates in considering the future energy costs and savings.

- ☑ Daylight Control of Interior Lighting
- ☑ Efficient Interior Lighting
- ☑ Efficient Windows with Thermal Break
- ☑ Efficient Envelope Insulation
- ☑ Packaged HVAC Systems with Above Code Efficiency
- ☑ Occupancy Sensor Control
- ☐ Service Call Lighting Shutdown
- ☑ Economizer
- ☑ Automatic Blinds in Meeting Room
- ☐ Insulation in Wall Between Apparatus Bay and Residence Area

An interactive model was prepared including the measures checked above. The interactive analysis allows overlapping energy savings effects to be considered. For example, daylighting and efficient lighting both reduce lighting energy at the same time, and the interactive savings are less than the sum of the individual savings.

The interactive energy savings is 28,500 kWh, and a negligible increase in natural gas usage, for a total combined 97 mmBtus. This is 20.7% total energy savings compared to the baseline, enough to meet the Earth Advantage target. Changes to the building in design or construction may affect the final total savings.

TABLE 1 SAVINGS SUMMARY CHART

Final Results January 9, 2002

Portland Fire Station 16																
			ANNUAL CONSUMPTION							ENERGY AND COST SAVINGS						(4) SIMP. PAY-BACK
		Incremental Cost (1)	Electric			Natural Gas		Total		Electric		Natural Gas		Total		
		$	KWH	kW (2)	Cost $ (3)	therms	Cost $ (5)	10^6Btu	Cost $ (3)	KWH	Cost $	therms	Cost $	10^6Btu	Cost $	YR
EEM #	Baseline Building	---	82,161	22.3	5,751	1,881	1,840	468.5	7,592	---	---	---	---	---		---
1	Daylighting Controls	1,040	74,722	20.3	5,231	1,917	1,874	446.8	7,104	7,439	521	(36)	(34)	22	487	2.1
2	Efficient Lighting	0	75,912	21.2	5,314	1,966	1,920	455.7	7,233	6,249	437	(85)	(79)	13	358	-
3	Eff. Windows w/ Thermal Break	3,525	70,936	19.0	4,966	1,710	1,681	413.1	6,646	11,225	786	171	160	55	945	3.7
4	Efficient Envelope Installation	3,000	82,459	21.8	5,772	1,580	1,559	439.4	7,331	(298)	(21)	301	281	29	260	11.5
5	Package Systems	1,350	79,762	20.1	5,583	1,881	1,840	460.3	7,424	2,399	168	-	-	8	168	8.0
6	Occupancy Sensor Control	1,320	75,466	22.3	5,283	1,962	1,916	453.7	7,198	6,695	469	(81)	(76)	15	393	3.4
8	Economizer	1,500	78,685	22.3	5,508	1,882	1,841	456.8	7,349	3,476	243	(1)	(1)	12	242	6.2
9	Automatic Blinds-Meeting Rm.	7,015	76,099	20.2	5,327	1,812	1,776	441.0	7,103	6,062	424	69	64	28	489	14.4
	Interactive	18,750	53,408	15.1	3,739	1,890	1,849	371.3	5,587	28,753	2,013	(9)	(8)	97	2,004	9.4

Notes:

1) Incremental costs are estimates based on previous projectsor conversations with the design team.

2) kW is the highest monthly peak electricity demand that occurs during the year.

3) Electricity cost is estimated based on Portland General Electric's schedule 83-S, effective October 1, 2001
Natural gas cost is estimated based on Northwest Natural's schedule 3, effective October 1, 2001.

4) Simple payback is the incremental cost of an alternative divided by its total annual energy cost savings.

BASELINE BUILDING DESCRIPTION

The following information outlines the baseline building model inputs for Fire Station 16. The energy analysis project included 5,600 square feet of space. The building is located in Portland, Oregon which is in Oregon Energy Code Climate Zone 1.

Oregon Energy Code was used to establish the baseline construction values according to the State of Oregon Non-Residential Energy Code, 2000 Edition, Chapter 3.

Building Envelope

Roof Type:	All Areas	S.P. membrane, 3" polyurethane, ¾"
Wall Type:	Exterior Walls	face brick, building paper felt, ½" plywood, R-6 effective batt insulation (R13 derated for metal 2x4 on 16" o.c.), 5/8" gypsum board,
Floors:	All Areas	12" soil, 8" concrete slab, carpet & fiber pad

Building Envelope Summary Table

Component	Oregon Energy Code	Baseline	Sq. Ft.
Roof	R-19	R-19	5,661
Wall Frame	R-13	R-13	4,759
Windows, Vertical			1,410
Overall U-Value	0.54	0.54	
Shading Coeff.	0.57	0.57	
% Glazing	<30%	23%	
Skylights			12
Overall U-Value	1.23	1.23	
Shading Coeff.	0.57	0.57	
% Glazing	<6%	0.2%	

Occupancy Schedule

The main schedule allows for full occupancy between 10pm and 6am for all sleeping areas. The remainder of the schedule allows for 50% occupancy in all areas, except between 4pm and 6pm when the building is considered to be completely vacant. This period of time represents typical service calls.

Zoning

Four air handling units are defined serving a total of 16 zones. The residence room system serves 7 zones (1659 ft^2), the residence day use system serves 4 zones (1338 ft^2), the apparatus bays system serves 4 zones (2041 ft^2), and the meeting system serves one zone (634 ft^2). Zones are selected to allow areas with different load conditions to be adequately analyzed.

HVAC System

The residence room, residence day, and meeting systems are modeled as packaged single zone units with direct expansion cooling and furnace heating. The apparatus bay system provides only heating using a unit heater.

HVAC Summary Table

Residence, Office and Meeting Room Systems

Component	Code	Baseline
Heating System	74%	74%
Cooling System	8.5 EER	8.5 EER
Heat Setpoint	n/a	70
Cool Setpoint	n/a	75
Unoccupied Heat Setpoint	55-70 °F	63
Unoccupied Cool Setpoint	70-85 °F	80
Supply Air Setpoint-Heating (max.)	n/a	105
Supply Air Setpoint-Cooling (min.)	n/a	55

Apparatus Bay System—Heating Only

Component	Code	Baseline
Heating System	74%	74%
Heat Setpoint	55-70	55

Ventilation

In the office and living areas, outside air ventilation is set at a base of 20 cfm/person at design airflow. Outside air ventilation is not set for the electrical, turnout, apparatus, and storage zones. The number of people per area was provided by the architect.

In the addition, outside air in the residence room system is set at 43% of the design airflow, the residence day system outside air is set at 29% of the design airflow, and the meeting system outside air is set at 42% of the design airflow.

Lighting

The lighting power density (LPD) is set at 1.2 W/s.f. for all office areas, which is the maximum allowed by the Oregon Energy Code for office space. The LPD for all other areas in the building are also set at 1.2 W/s.f.

Miscellaneous Equipment

The zones in the building are modeled with a plug load ranging from 0 to 5.0 W/s.f. Most residential, and office function area are modeled as using 1 W/s.f. Corridors and storage are set at 0 W/s.f. The kitchen and electrical room are set at 5.0 W/s.f.

ENERGY ANALYSIS METHODOLOGY

Modeling Methodology

The energy analysis of this project was performed using accepted, standard engineering calculation procedures and the computer program PowerDOE, which is based on DOE 2.2. DOE-2.2 is the latest privately supported extension of DOE2, the microcomputer version of DOE-2, the mainframe energy consumption simulation program jointly developed by Lawrence Berkeley Laboratory and Los Alamos National Laboratory for the U.S. Department of Energy. DOE-2 is a program designed to determine the energy consumption behavior of proposed and existing buildings utilizing an hour-by-hour simulation procedure.

Although every attempt has been made to model the actual building conditions and while DOE-2 is generally accepted as the most accurate energy simulation program available, the predicted energy consumption should not be interpreted as an absolute prediction of the actual usage. Actual conditions may differ from the original assumptions due to unpredictable variables such as changes in occupancy schedules, equipment selection and installation, building construction and operation, and weather variations from a typical year.

Modeling of the Energy Efficiency Measures

A computer model is developed from design plans and specifications using the Oregon Energy Code, or common practice. This model is referred to as the "Baseline."

To evaluate each EEM, a copy of the baseline model is modified according to the design data specific to that EEM. For example, to evaluate a glazing measure, the baseline glass thermal and shading data (U-value and shade coefficient) would be replaced by data specific to the proposed glass. The energy consumption and cost results for this measure are then compared with the Baseline results to determine the energy savings associated with this particular option. This process may be iterated several times in order to determine the most cost-effective glass option.

Each identified EEM is evaluated separately. A selection of measures is then combined into a unique model and analyzed together to account for the effect of interactions between measures. The final energy result of the interactive analysis is compared to the original "Baseline" to determine whether the project meets the energy savings requirements of the PGE Earth Advantage program.

Economics

The cost-effectiveness of all energy efficiency measures is normally evaluated by using a simple payback analysis. Simple payback indicates how many years it will take to recover the capital cost of installing an EEM by the predicted annual energy cost savings, without consideration of inflation or interest rates. The simple payback values are included for the benefit of decision-makers considering which alternatives to include in the project.

Energy Costs

Energy costs are currently in a state of change. The rates used in this analysis are the currently published rates. The owner of the facility may wish to explore the impact of proposed and speculative rate changes on future energy costs and potential savings.

Electricity

The new facility will likely be served by Portland General Electric according to Rate Schedule 83, secondary voltage. This rate, effective October 1, 2001, results in a significant increase in electricity costs. This rate was estimated at $0.07 / kWh to update the modeled results conducted under the old 32, Level II rate.

Natural Gas

Natural gas will likely be provided by Northwest Natural according to Rate Schedule 3. This tariff was updated with a substantial increase in cost, effective October 1, 2001.

Modeled charges were update to reflect the same customer charge and the new higher per therm cost as follows.

Customer Charge:	$7.00 / month
Energy Charge:	$0.93367 / therm

DESCRIPTION OF ENERGY EFFICIENCY MEASURES (EEMS)

EEM 1 – Day Lighting Controls

This EEM proposes to implement daylighting controls in the Fire Station to reduce the energy consumed for lighting. The controls will automatically dim light levels in daylit rooms to maintain a minimum comfortable light level at 2.5 feet above the floor.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. Daylight sensors were placed in the dining/dayroom, meeting room, apparatus bay, and the kitchen. The sensors were placed at 2/3 of the room's depth into the room, and otherwise centered in the room. The ballasts were set as "continuous" dimming, with the capability of turning down to 10%. The controls will maintain a light level of 45 foot-candles. The EEM was run and compared to the baseline model.

Baseline Assumptions:

No daylighting sensors are implemented in any room.
Lights are on from 6 am to 10 pm.

EEM Assumptions:

Daylight sensors in dining/day room, meeting room, apparatus bay, and kitchen.
Lights are dimmed as daylight conditions allow.
Minimum light level in all rooms = 45 foot-candles

EEM 2 – Efficient Lighting

This EEM proposes to implement an efficient lighting scheme in the new Fire Station.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The lighting power density was set to 1.0 W/ft^2 for each applicable space

Baseline Assumptions:

Lighting Power Density: 1.2 W/ft^2 per Oregon Energy Code.

EEM Assumptions:

Lighting Power Density: 1.0 W/ft^2

EEM 3 – Efficient Windows with Thermal Break

This EEM examines the effects of using windows and frames with superior thermal characteristics to the code requirements, for all vertical and horizontal glazing. A drawing of the thermal break can be seen in Figure 1.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The upgraded U-value for the proposed window-system was entered into PowerDOE and compared to the baseline model. The upgraded glazing's center of glass U-Value is 0.30. Aluminum frames with a thermal break will be used on the upgraded glazing system. Standard calculations from the ASHRAE 1997 Fundamentals Handbook were used to derate the center of glass U-Value and calculate the glazing system's overall resistance to heat transfer. The shading coefficient for the improved glass equals the code maximum shading coefficient.

The shading coefficient of the building's skylights were improved over code minimum levels in accordance with the architecturally specified glass.

Baseline Assumptions:

Vertical Glass
- U-Value: 0.54 Btu/h-ft^2-^{o}F
- Shading Coefficient: 0.57

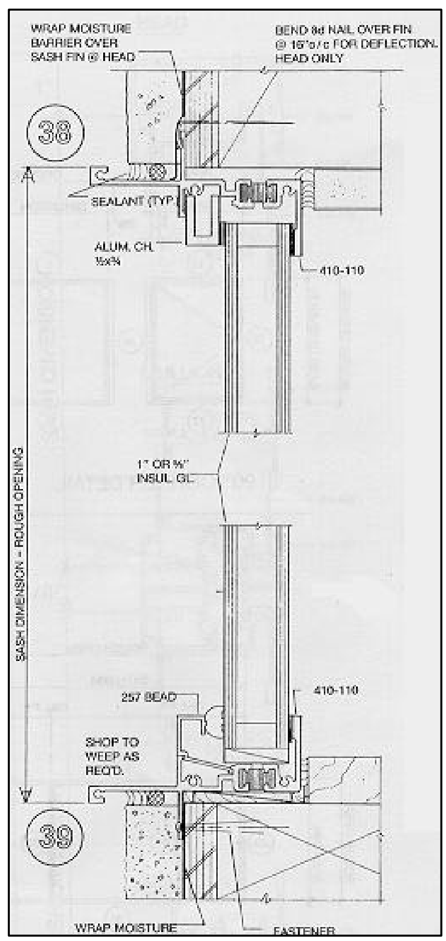
Skylights:
- U-Value: 1.23 Btu/h-ft^2-^{o}F
- Shading Coefficient: 0.57

EEM Assumptions:

Vertical Glass:
- U-value: 0.41 Btu/h-ft^2-^{o}F
- Shading Coefficient: 0.2

Skylights:
- U-Value: 1.23 Btu/h-ft^2-^{o}F
- Shading Coefficient: 0.35

Figure 1. Window Detail:



EEM 4 – Efficient Envelope Insulation

This EEM investigates the energy savings achieved by increasing the roof and wall insulation values above the Oregon Energy Code requirements.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The upgraded U-value for the proposed roof and wall U-Values were entered into PowerDOE and compared to the baseline model. The improved wall and roof constructions follow:

Wall construction: (U=0.044)
1. Outside Air Film
2. 3.5" Clay Masonry
3. Building Paper
4. ½" Plywood
5. R-19 Batt Insulation Derated with 16" OC 6" Metal Studs (Derated to R-7.1)
6. 5/8" Gypsum Board
7. 2" Airspace
8. Inside Air Film

Roof Construction: (U=0.018)
1. Outside Air Film
2. Metal Roofing
3. 7/16 O.S.B.
4. 11-1/4" Polystyrene
5. 7/16" O.S.B.
6. Inside Air Film

Baseline Assumptions:

Wall U-Value: 0.13 Btu/h-ft^2-^{o}F
Roof U-Value: 0.05 Btu/h-ft^2-^{o}F

EEM Assumptions:

Wall U-Value: 0.044 Btu/h-ft^2-^{o}F
Roof U-Value: 0.018 Btu/h-ft^2-^{o}F

EEM 5 – Packaged Systems

This EEM investigated the benefits of implementing high efficiency DX-Cooling units in the air handlers serving the residence occupancy area, residence use area, and meeting hall.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The Cooling Energy Input Ratio (EIR) was adjusted to reflect an overall improvement in system efficiency. The EER of the improved units is 10.7. This translates into a DOE EIR of 0.32 Btu/Btu. This model was run and compared to the baseline.

	Capacity	EER	EIR
Baseline Assumptions:			
All Three AHUs	34-42 kBtuh	8.5	0.4
EEM Assumptions:			
All Three AHUs	34-42 kBtuh	10.7	0.32

EEM 6 – Occupancy Sensor Control

This EEM proposes to implement occupancy sensors in the residence areas, office apparatus bay. The occupancy sensors will turn the lights off in these areas when the rooms are unoccupied. This was approximated by turning off lighting for a two hour period every day in these areas.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The lighting schedules for the "Residence Use" areas and "Apparatus Bay" were turned to a minimum value every day during the assumed service call (from 4pm to 6pm). The lighting schedules were also reduced for these areas by 50% of the maximum for an average of 4 hours each day.

Baseline Assumptions:

Residence Use Lights on from 6 am to 10 pm
Apparatus Bay Lights on from 6am to 10 pm

EEM Assumptions:

Residence Use Lights	Off from 4 pm to 6 pm 50% of maximum for 4 hours each day On other times
Apparatus Bay Lights	Off from 4 pm to 6 pm On other times

EEM 7 – Service Call Building Shut-Down

The building has system for turning lights on in the bunk rooms, common area, and apparatus bay when a service call comes in. After a short period, the lights will turn back down. This is part of the service call, or TABS system, to facilitate the response of the fireman to calls. One concept considered was to use this system during the day to turn off lights, and to turn down HVAC set points when the system indicates that all firemen have left. Further review of the anticipated shortness of many service calls and the number of calls when only some firemen would leave, led to the decision to not try to control the set points, and turn off lighting in this way. Instead, EEM 6, Occupancy Sensors are relied on to provide space by space control of lights, and HVAC set points will be left at normal values. No separate savings results are presented for this measure.

EEM 8 – Economizer

This EEM proposes to implement an economizer cycle in all three air handlers. The economizer cycle uses favorable outside air conditions to reduce the amount of cooling that is required to maintain space temperature in the building. The baseline building does not incorporate an economized because the Oregon State Energy Code only requires economizers on units with capacities greater than 180,000 Btuh. The largest AHU serving the Fire Station is about 43,000 Btuh.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. The Outside Air Economizer Cycle was enabled and the control set to Outside Air Temperature. The high limit was set to 75° F.

Baseline Assumptions:

Outside air is controlled to a fixed fraction of the flow rate.

EEM Assumptions:

Ecomomizer cycle is active when outside air is less than 75° F.

EEM 9 – Automatic Blinds in Meeting Room

EEM 9 incorporates motorized blinds in the meeting room that respond to sunlight levels in an attempt to reduce the cooling load.

Modeling Strategy

This EEM was modeled using PowerDOE energy analysis software. A shading schedule was developed to represent the effects of automatic shading.

Baseline Assumptions:

No shading implemented in meeting room.

EEM Assumptions:

Shading Schedule Implemented:
Automatic blinds to decrease shading 70% any time target solar heat gain levels are exceeded.

Maximum Solar Heat Gain Schedule Implemented:
Max Solar gain from November to March: 100 Btuh/sq ft
Max Solar gain from April to October: 15 Btuh/sq ft

Probability of reopening the shades when light levels are favorable: 100%

EEM 10 – Insulation between Apparatus Bay and Residence Area

This measure involves including batt insulation in the wall cavity between the apparatus bay and the rest of the facility. The measure was considered an option because the Oregon Energy Code does not explicitly require insulation between semi-heated spaces, such as the apparatus bay, and fully conditioned areas, such as the residence and office areas. The latest year 2000 version of the Oregon Energy Code does provide guidance in the text that such insulation should be included, and the Oregon Office of Energy clarified that this is highly recommended, even if technically not required by the letter of the law. The preliminary analysis did not show substantial savings from this measure. The insulation is part of the current design. According to the Oregon Office of Energy, this type of insulation should be considered standard practice. So, no savings results are presented in Table 1, and the measure is not included in the interactive model.