Optimizing the Energy Performance of Fire Stations

Technical Brief

What are the Primary Measures?

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Completed in 2003, the Center for Neighborhood Technology uses 52% less energy compared to ASHRAE 90.1-1999, saving nearly $10,000 each year. The project demonstrated that by using affordable, state-of-the shelf technologies energy savings can be cost effective.

Fire stations require energy to keep the occupants comfortable and to enable them to execute their tasks efficiently. By virtue of their 24-hour / 7 days per week operations, fire stations are usually energy intensive buildings. This brief outlines the design methodology involved in designing a new fire station or major renovation of an existing fire station to optimize energy performance. The brief provides designers with the most effective energy efficiency measures and corresponding cost-benefit analysis for fire stations in Seattle.

Daylight dimming involves the use of daylight sensors to control artificial lighting levels based on the availability of daylighting in the space.

Efficient equipment is the selection of ENERGY STAR rated equipment. Equipment that has earned the ENERGY STAR rating helps eliminate wasted energy through special power management features.

Efficient lighting is the selection of ambient light fixtures with lower lighting power density combined with the use of appropriate task lighting.

Optimized envelope is optimizing the thermal (insulation and infiltration) performance of the opaque envelope (walls, roof and window frames) for both heating and cooling seasons.

City of Seattle Department of Planning & Development

Optimized glazing is optimizing the glazing performance (thermal, visual, and daylighting) for both heating and cooling seasons

Optimized HVAC involves the use of heat recovery coils and improved HVAC equipment thermal efficiency. Other technical briefs provide additional, specific design assistance on HVAC technologies.

Optimized orientation is optimizing the orientation of the building form and sizing of window-wall ratios on different facades to augment both optimal envelope thermal performance and optimal glazing for both heating and cooling seasons.

Optimized shading is selecting shading devices based on a balance of solar penetration, daylighting and envelope thermal performance for both heating and cooling seasons.

Optimized thermal mass is changing the envelope, floor and slab constructions from frame to heavy weight masonry while keeping the R-value constant to mitigate the effect of very hot and very cold weather on the building's indoor temperature.

"Shoebox" energy model is a preliminary energy model of the building in the form of a shoebox, while using the actual floor area, climate, use pattern, and utility rates for the projects. The shoebox energy model is calculated during the schematic design phase before the building form has been determined, and can be used to inform early design decisions to optimize energy performance.

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Why is improved energy performance important to the City?

Buildings in the US consume 42% of country's energy and 60% of electricity. Furthermore, buildings generate 35% of the carbon dioxide, 49% of the sulfur dioxide, and 25% of the nitrogen oxides found in the air. Recognizing this, Mayor Nickels launched the City's Climate Action Plan, and adopted the U.S. Conference of Mayor's "2030 Challenge." The Climate Action Plan identifies the following action items that the City will take to increase energy efficiency and use of clean energy technologies:

- Fleets and Facilities Department will increase its focus on energy efficiency in City facilities, hiring a dedicated energy specialist and adding resources for implementing cost-effective conservation measures for both electric energy and natural gas conservation.
- Department of Planning and Development will expand the green building market, and increase the Green Building Program's focus on energy efficiency - particularly natural gas conservation.

The 2030 Challenge requires that by 2030 all new buildings are designed to be carbon neutral. The City's near-term commitments toward achieving the 2030 Challenge are:

- New construction of City buildings shall be designed to and achieve a minimum delivered fossil-fuel energy consumption performance standard of 50% of the U.S. average for that building type as defined by the U.S. Department of Energy.
- Renovation projects of City buildings shall be designed to and achieve a minimum delivered fossil-fuel energy consumption performance standard of

50% of the U.S. average for that building type as defined by the U.S. Department of Energy.

- All other new construction, renovations, repairs, and replacements of City buildings shall employ cost-effective, energy-efficient, green building practices to the maximum extent possible.

In support of these goals, Fleets and Facilities has identified that all new construction and major renovations of neighborhood fire stations should be designed to optimize energy performance and exeed the Seattle Energy Code with a focus on natural gas conservation. In addition to the environmental benefits of reduced greenhouse gas emissions, this strategy reduces the fire station's operational cost and serves as an educational model for the community.

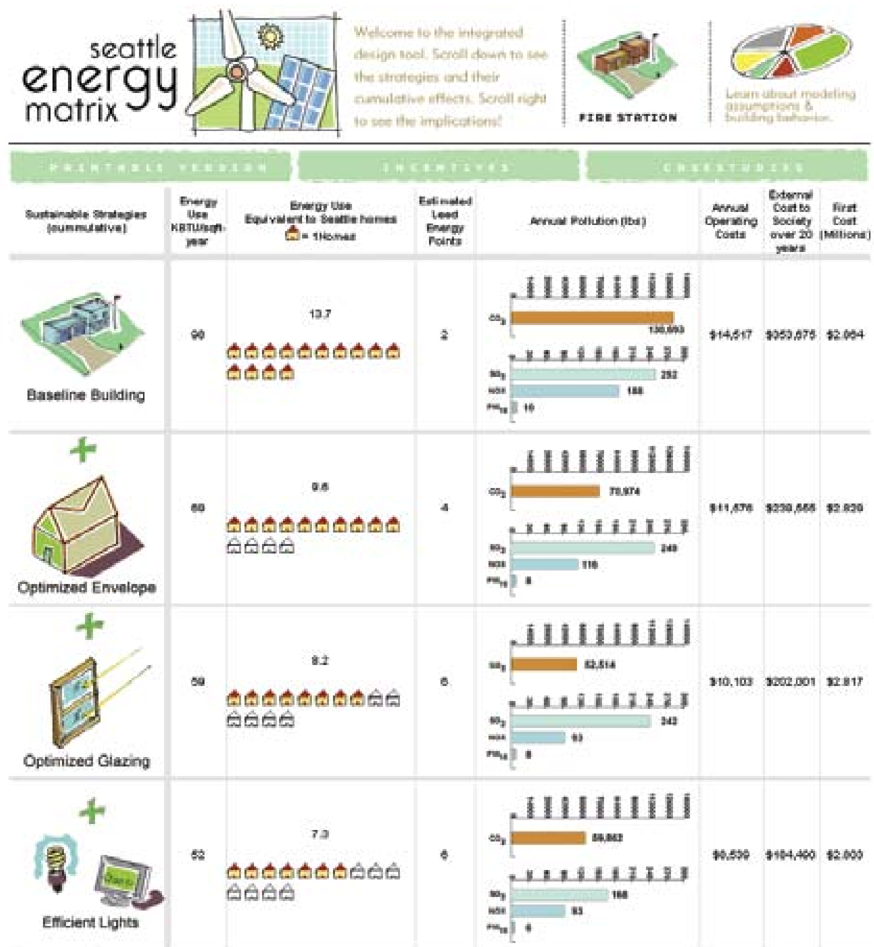
The 2006 Seattle Energy Code, effective July 2007, will result in a net energy savings of 10% beyond the 2004 Seattle Energy Code, and maintain the City's goal to achieve up to 20% enhanced energy efficiency beyond the current version of ASHRAE 90.1 (2004).

Design Tools

Implement: Seattle's Sustainable Building Tool

The City of Seattle's "Implement" Sustainable Building Tool is available to the project teams. Implement is a practical how-to-tool that assists in implementing the City's Sustainable Building Policy by providing integrated design tools and best practice information for project type including neighborhood fire stations.

Implement has been designed to provide general trends and relative importance of strategies to guide design decisions. Each energy efficiency measure was analyzed for performance, costs implications, and annual energy savings. RS Means data (2004) was used to estimate first costs and operating costs, but not maintenance costs. Implement offers a hierarchy of strategies for design team to consider during schematic design. The analysis shows that achieving exceptional energy savings can be achieved cost effectively through optimization of insulation and glazing, and energy efficient lighting design. Additional ideas and strategies are suggested throughout this brief.



The City of Seattle's Implement Sustainable Building Tool illustrates cumulative benefits gained from implementing sustainable strategies, and energy savings and changes in capital costs associated with each energy efficiency measures.

Energy Simulation

To optimize energy performance the Seattle Energy Code a different code compliance path will probably be necessary. The Department of Planning and Development requires all commercial buildings meet the Seattle Energy Code. The Seattle Energy Code is prescriptive in nature and prescribes minimum performance standards for different building elements and systems. The prescriptive path is suitable for projects that aim to meet code. However to demonstrate energy performance that exceeds code requirements, the performance based compliance path should be used. This method accounts for the interaction between the different energy efficiency measures and allows trade-offs between the energy performance of the different building elements and systems.

Energy modeling using simulation tools is required to understand the effect of the interaction between the selected strategies on the building's performance. These tools are also best suited to:

- demonstrate energy efficiency beyond code using the performance based compliance path,
- demonstrate energy savings to qualify for utility incentives from Seattle City Light and Puget Sound Energy, and
- calculate operational savings and payback period associated with corresponding capital costs.

Start Early with "Shoebox" Energy Modeling

At the early stages of design, detailed knowledge of energy modeling software is not necessary. Some architecture firms have in-house staff familiar with energy software "wizards" such as the eQUEST Schematic Design Wizard. These simplified interfaces can build a shoebox model in a matter of minutes. Then, energy efficiency measures (EEM) may be analyzed using a second Wizard called the "EEM Wizard" in eQUEST.

Energy Simulation Tools

Detailed modeling should begin in the design development phase by a team member with expertise in energy modeling. Alternately, design teams can take advantage of the energy modeling assistance offered by Seattle City Light through the Energy Smart Services Program.

Hourly analysis simulation programs are required for energy analysis and energy efficiency strategy development. eQUEST, EnergyPLUS and HAP are some of the more popular energy modeling tools that can be used in the design process. eQUEST and DesignBuilder can be used for shoebox modeling during schematic design and design development phases, by the design team in-house. Detailed modeling can be carried out in the design development and construction documentation phases by an experienced energy modeler using eQUEST, DesignBuilder or HAP.

Energy Simulation Tools

eQuest is the most popular energy modeling tool used on the west coast eQUEST. It is available free of charge, and is a graphical interface for the hourly energy simulation program DOE2 developed by the Department of Energy. Available at http://doe2.com/equest/

EnergyPlus is the next generation of DOE2; it has recently been developed by the Department of Energy. It is more a comprehensive program than its predecessor and has additional modeling capabilities for strategies including: natural ventilation, thermal comfort, water use analysis, and radiant heat transfer. Available at http://www.eere.energy.gov/buildings/energyplus/. DesignBuilder is the furthest developed of a number of interfaces for EnergyPLUS, and is a shareware product. Available at http://www.designbuilder.co.uk/

HAP developed by Carrier Air Conditioning includes an HVAC systems design focus so many mechanical engineering firms already use it to select equipment. HAP's energy analysis capabilities have the following limitations: no 3D building viewing capability, no CAD input files, limited prototype buildings library, and limited shading modeling. Available at http://www.commercial.carrier.com/commercial/hvac/general/1,,CLI1_DIV12_ETI496,00.html

Green Building Studio is one of a few tools that convert 2D CAD drawings into inputs suitable for eQUEST. Available at http://development.greenbuildingstudio.com/About.aspx

The interaction between different energy efficiency measures will affect the design parameters that are within the arena of different consultants. For example, a reduced window-wall ratio will improve the envelope thermal performance by virtue of its smaller glazing area, but will result in higher lighting loads due to the reduction in daylight levels. Taking an integrated design approach coupled with beginning energy modeling and analysis early during schematic design is critical to optimizing energy performance.

Designing High Performance Fire Stations

This section describes steps to take during each design phase that will optimize energy performance for the neighborhood fire stations that are new construction or major renovation projects. Fire stations by virtue of the program size are skin-load dominated buildings with energy consumption primarily dictated by the influence of the exterior climate on a building's envelope. Energy efficiency strategies for skin-load dominated buildings in Seattle should concentrate on improving the envelope thermal performance and optimizing the solar loads. Lighting loads are another major component in the energy profile for fire stations and window-wall ratios should be configured for optimum envelope and lighting load trade-offs.

Pre-Design

During this stage, the energy savings goal should be discussed with the city's representative, along with the implications for integrated design. To make sure that exceptional energy savings can be achieved, the whole design team should plan to invest additional effort in analysis during the schematic design and design development phases. The following activities should be integrated into these two phases:

Schematic Design

- "Shoebox" energy modeling performed by the architect or a savvy mechanical engineer.
- Study HVAC system design options.
- Identify source for hourly weather data for the local neighborhood (see To Learn More).
- Determine the shading availability for the project site using a conceptual 3D tool like SketchUp (http://www.sketchup.com/). Alternately, the Lighting Design Lab provides technical assistance and can help design teams understand the shading availability on the site using a physical site model.

Design Development

- Create a physical model to confirm passive solar and daylighting design.
- Use results of early studies to determine "right-sized" building loads and select HVAC scheme.
- Develop a full energy model to confirm energy savings.

Inputs for the "Shoebox" Energy Model		
Insulation	Roof: Walls: Slab on grade: Infiltration:	U = 0.034 (apparatus bay), U = 0.050 (for rest)" U = 0.062 R-10 0.40 air changes/hr
Windows	Glazing: Window to wall ratio: Shading	"U = 0.40, SHGC = 0.35/0.40" varies due to specific function none for baseline
Internal Loads	Occupancy: EPD: LPD: Ventilation: Daylighting:	18 people 1 W/sq ft 1 W/sq ft 20 CFM / person None
HVAC System (except apparatus bay)	 Supply Fan: Mechanical Efficiency: Drive Efficiency: Motor Efficiency: Return Fan: Mechanical Efficiency: Drive Efficiency: Motor Efficiency: Economizer Control: Lower temp. limit: Upper temp limit: Heat Recovery:	**VAV + Economizer & Zone Reheat Systems** Vanes 4 in. Med Eff 0.55 0.95 0.85 Vanes 2 in. Med Eff 0.55 0.95 0.85 Temperature (outside air) 40 F return air temperature None
HVAC System (apparatus bay)	 Furnace Efficiency:	Unit Heater 0.8
HVAC Water Side	Chilled COP: Builder Efficiency: Pumps:	4.5 0.8 fixed speed
Water Heating	 EIR:	**Electric** 0.75

Schematic Design

At this phase the fire station site and building programs are available to the design team. Based on this information and using a shoebox energy model, the energy profile of the building can be obtained. The design team can then identify energy efficient measures by targeting the high energy end uses.

1. Create a baseline shoebox energy model with square footage, occupancy, schedules of operation and space use characteristics inputs based on the schematic design. Refer to the **Inputs for "Shoebox" Energy Model** table for inputs regarding envelope efficiency, glazing, Lighting Power Density (LPD), and HVAC systems.

2. Simulate the shoebox model to obtain the energy profile per end use.

Measures to Consider during Schematic Design			
Measures	New Construction	Renovation	Historic Renovation
High Performance Insulation	Yes	Maybe	Maybe
High-Performance Glazing	Yes	Maybe	N/A
Efficient Lighting	Yes	Yes	Yes
Optimize Orientation	Maybe	N/A	N/A
Shading Overhangs	Yes	Maybe	N/A
Thermal Mass (Masonry)	Yes	Maybe	Maybe
Efficient Mechanical	Yes	Yes	Yes
Passive Solar	Yes	Maybe	Maybe
Mixed Mode HVAC	Yes	Maybe	Maybe
Radiant Heating/ Cooling with DOAS	Yes	Maybe	Maybe
Demand Controlled Ventilation	Yes	Maybe	Maybe

3. Identify a list of energy efficiency measures based on project scope, the energy profile, and the building parameters that the design team is willing to consider. Figure 3 shows a list of measures the design team should consider; it will probably be necessary to go beyond Implement's recommended efficiency values for measures to achieve exceptional energy savings. Refer to the Implement website (click on energy efficiency measure's icon) for information on optimum efficiency values for the selected measures. For example, if high efficiency wall insulation in one of the energy efficiency strategies identified by the team, select the optimum high efficiency R-value identified in Implement.

4. Setup runs in the energy model for the each of the energy efficiency measures identified by the team. Most of the measures identified in Implement and in this brief can be modeled using the Energy Efficiency Measure Wizard in eQUEST.

An analysis of the model's energy efficiency measures run results will show the order of magnitude of energy performance associated with each of the strategies identified by the design team. This exercise will aid in identifying the most effective energy efficiency measures for the project. The fire station design team can then start integrating the selected strategies into the schematic design. The next step would be to optimize the efficiency of the various strategies during Design Development.

Design Development Phase

With the fire station design more concrete at this point, the shoebox model must be replaced with a full-fledged "proposed design" energy model based on design development drawings and actual project site conditions. Begin by creating a baseline energy model using Seattle Energy Code requirements as inputs. Modify the model to include the energy efficiency measures selected in the schematic design phase. A physical model and/or daylight simulations can be used to test the results of architectural glazing studies and the energy model results in the last phase. The performance of the proposed energy model can be compared to the baseline at any point during the design process to determine the performance in energy efficiency beyond code.

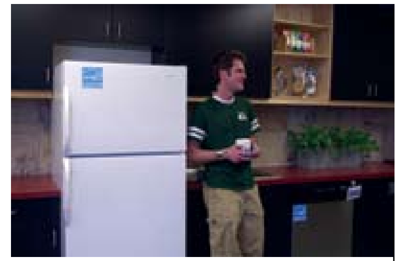
The next step would be to optimize the efficiency of the various measures. An increase in efficiency of a measure will result in improved energy performance. However, this relationship is not linear. Since there are first costs associated with improved efficiency, it is important to identify the optimal efficiency points. For example, improving the wall efficiency beyond R-19 may not exhibit a substantial improvement in energy savings observed so far. Using the specifics provided by Implement is a great first step. Then, the following optimization runs can be used to identify the optimum efficiency for different measures integrated into the project.

- Include localized weather and site shading information in the model.
- Based on first costs, verify that the range of efficiency values listed in Implement will be feasible for the design team to explore. The efficiency values include R-values for walls, U-values and visible transmittance values for glazing systems, HVAC efficiencies, lighting power densities, lighting controls, etc.
- Simulate different scenarios using the efficiency ranges identified.
- Analyze simulation results and compare with baseline model to identify the combination of measure efficiency values that optimize energy performance for the project.

Any new strategies that are considered by the project team during design development must be analyzed and optimized using the energy model before integrating into the design.

Construction Documents Phase

At the end of the construction documents phase when most of the design is in place, update the energy model to include any changes in the envelope and systems design, changes in occupancies, space and program configurations, and all other inputs that affect energy performance. Simulate and obtain the energy performance of both the final design model and the baseline code model. The performance beyond code is the difference between the baseline model energy use (Seattle's minimum requirements) and the proposed model energy use.



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Energy measures range from ENERGY STAR® appliances like the ones featured to an ice storage tank buried on the east side of the building to serve the building's radiant cooling system.

Energy Performance Case Study: Center for Neighborhood Technology

Completed in October 2003, the Center for Neighborhood Technology (CNT) is a historic renovation project that achieved a LEED-NC Platinum rating. The building uses 52% less energy per square foot compared to ASHRAE 90.1-1999. CNT established a project goal to demonstrate that a green renovation can be achieved at an affordable cost by using "state-of-the-shelf" technologies. CNT demonstrated that simple, cost effective choices can result in substantial energy savings. The renovation was completed on a conventional budget of $82 / square foot.

The project team optimized the insulation in the walls and roof to improve thermal comfort. Since it is located in Chicago, CNT's roof insulation averaged R-30 and wall insulation R-19, both with fiberglass batts plus 2 inches of rigid board insulation. A high efficiency lighting system with a lighting power density of 0.8 - 0.9 watts per square foot was integrated with daylight design. The lighting system components include T8 lamps, high efficiency electronic ballasts, light sensors in bathrooms, and wiring / lighting controls in common areas such that one, two, or three lamps could be used separately or together, as needed. Large skylights and operable windows decrease the need to operate the artificial lights and mechanical ventilation. Low walls and partitions create an open space and allow daylight to penetrate deeper into the work space.

A hybrid ventilation system maximizes natural ventilation through operable windows, and mechanical ventilation rates are controlled by CO_2 sensors. The HVAC system components include variable speed drives, high efficiency fan motors and zone controls. An ice storage tank provides cooling for the building through a radiant system. Hot water is provided by a high efficiency water heater.

Other energy efficiency measures include ENERGY STAR appliances and reflective ENERGY STAR roofing. Five percent of the CNT's energy is supplied by solar panels

"By saving on building operational and maintenance costs, CNT is able to use more of its raised dollars on programming and less on its facility."

installed on the roof, and half of purchased energy is supplied through Renewable Energy Certificates (green-tags).

The energy efficiency measures generate nearly $10,000 in annual energy cost savings. The project team attributes their success to researching alternatives upfront and striving to use simple, affordable solutions. In 2004, Mayor Daley honored the project with the Chicago GreenWorks Award for Outstanding Non-residential Project.

To Learn More

Incentives and Technical Assistance

Seattle City Light (SCL) Energy Smart Services Program

Of the different types of incentives offered by SCL to promote the design of energy efficiency buildings, the Custom Incentive Program is the most beneficial for fire station projects working towards exceptional energy performance that exceeds code requirements. SCL also offers technical assistance services including in-depth energy analysis of custom incentive opportunities conducted by a consultant hired by the project team. The energy analysis may be used for developing custom incentive proposals, selecting energy conservation measures for analysis, identifying the Seattle Energy Code baseline for the project, adjusting the baseline to reflect selected energy efficiency measures, calculating the value of savings to SCL, and calculating incentives and writing a custom incentive report.

Incentives will cover incremental cost up to 70% of the total cost of introducing energy efficiency measures. Additionally, if the design team hires an energy consultant, SCL will cover 100% of the agreed upon analysis costs for new facilities upon review and approval of the energy analysis report. For existing buildings a facility assessment is required based on which the design team can apply for SCL custom incentives funding. SCL will provide free facility assessment services and reimburse up to 100% of the agreed upon energy analysis cost in a phased manner.

- Refer to the Energy Smart Services Program manual, Section 2D and Section 3 for detailed application process and incentives information. (http://www.seattle.gov/light/Conserve/Business/ProgramManual/)
- For Seattle City Light Energy Analysis and Modeling visit http://www.seattle.gov/light/conserve/business/cv5_ncp.htm#Assistance
- For Seattle City Light Facility Assessments for Performance, Operations, and Safety visit http://www.seattle.gov/light/conserve/business/cv5_ora.htm

Puget Sound Energy (PSE)

PSE provides technical assistance and incentives to help Seattle customers increase natural gas conservation through a broad array of programs, financial incentives (grants and rebates), and tools. The grant programs include customized rebates to fund energy efficiency projects and direct funding for energy efficient new construction (non-residential). Rebates are streamlined incentives for specific energy efficient products that are available for over a dozen measures with over 100 options. PSE tools include an online energy audit; Energy Interval Service, a web-based application that provides access to usage data from your meters; Energy Smart information Library; and, links to other web sites for Energy Efficiency information. For more information call Toll Free at 888-225-5773 or visit http://www.pse.com/solutions/ForBusiness_EfficiencyPrograms.aspx.

Seattle City Light Contact

Renovation Projects
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Lighting Design Lab (LDL)

Located in Seattle, the Lighting Design Lab is funded by the regional utilities to transform the Northwest lighting market by promoting quality design and energy efficient technologies. The LDL has operated throughout the Pacific Northwest since 1989, and accomplishes its mission through education and training, consultations, technical assistance, and demonstrations. Contact LDL staff at 206-325-9711 or learn more at www. lightingdesignlab.com.

The following free consulting services are provided to projects by the LDL:

- Daylighting Consultations
- Model Studies and Documentation in Test Facilities
- Limited Computer Modeling/Simulations
- Expected Energy Savings Calculations
- Product Evaluations and Technical Review
- Coordination of Utility Incentive Programs with Specific Projects
- Glazing Specifications Review/Extensive Sample Library
- Integrated Design Services through BetterBricks

Seattle Daylighting Lab

Seattle Daylighting Lab, which is a part of the LDL provides integrated lighting information and tools for assisting with daylighting design decisions. Seattle Daylighting Lab has mirror-box overcast sky and heliodon sun simulators as well as digital photographic and light flux metering equipment for the analysis of lighting levels using physical models at all stages in the design process. Contact the Seattle Daylighting Lab by calling Toll Free at 877-604-6592 or learn more at www. daylightinglab.com.

Regulations, Guidelines and Design Resources

- For the Seattle Energy Code visit http://www.seattle.gov/DPD/Codes/Energy_Code/Overview/default.asp and information about the 2006 Seattle Energy Code Update is available at http://www.seattle.gov/dpd/Codes/Energy_Code/Overview/DPDP_019122.asp
- Seattle Energy Code Hotline offering technical backup service to answer Energy Code questions is available by calling 206-684-7846 between 1:00 and 4:15 pm. Prepare your question, call this number, and then ask for "Energy Technical Backup."
- "Implement: Seattle's Sustainable Building Tool" provides a basic tool to evaluate energy efficiency measures, visit http://www2.ci.seattle.wa.us/Implement/
- BetterBricks provides services to help building professionals find resources that will help them create more energy effective buildings, visit www. betterbricks.com.

Local Hourly Weather Sites

- Weather Underground: http://www.wunderground.com/weatherstation/WXDailyHistory.asp?ID=KWASEATT55&day=22&year=2007&month=3&graphspan=6month
- Puget Sound Clean Air Agency: http://www.pscleanair.org/airq/windrose/default.aspx

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