Moving Toward Energy Sustainability at the Marblemount (Skagit) Ranger Station

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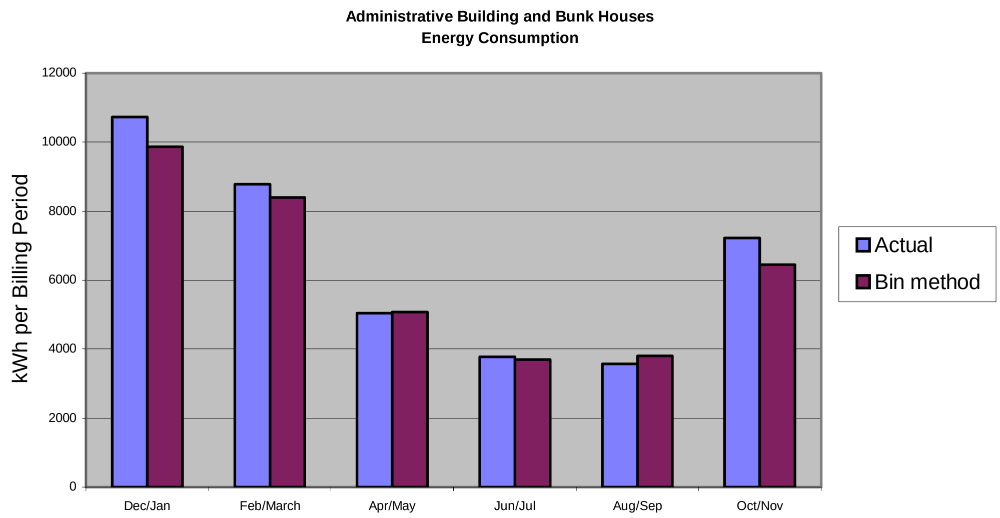
Executive Summary

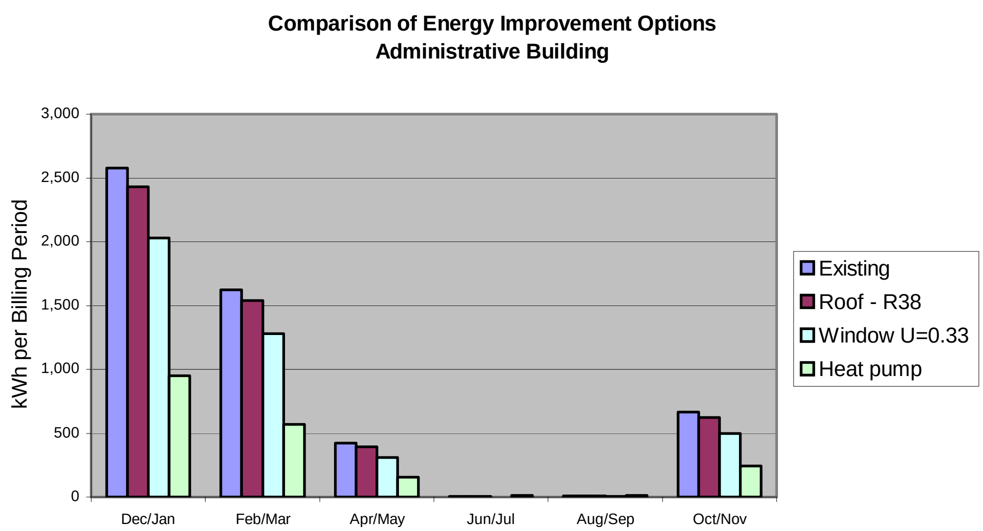
This report analyzes energy consumption patterns at the National Park Service's Marblemount (Skagit) Ranger Station in Marblemount, Washington, and recommends building improvements and upgrades that will reduce energy consumption at the Ranger Station, thereby enhancing the prospect of renewable energy practice. Additionally, daylighting opportunities are identified. The report addresses the following points: first, it presents data on the energy use of particular buildings at the Ranger Station; next, it describes the computer model that gauges the actual energy requirements for each building; then, it modifies the computer model in order to assess the effects of building envelope improvements on energy consumption; and finally, it compares the actual energy consumption patterns with the computer modeled energy-savings predictions and presents recommendations for improvements.

Since there are about thirty buildings at the Marblemount Ranger Station, an energy study of every building would present a very extensive task. Hence, it is more economical to study a few representative buildings and then complete a thorough energy analysis of these. The buildings chosen should either be similar to other buildings, have especially large energy needs, or have potential for significant energy improvements. Furthermore, to be considered as a representative building for this analysis, both the building envelope (such as walls, roof, and windows) and the occupancy and usage pattern should be similar to the other buildings at the Ranger Station. Newer structures are eliminated from this analysis, since it is assumed these meet current, strict building codes and therefore are energy efficient with less potential for building envelope improvement. Based upon the foregoing criteria, the following four buildings are the subject of this research: the Administrative Building (1001), the Wilderness Center (1018), the Residential Building (1014), and the Automotive and Maintenance Building (1004). Since the Administrative Building shares an electrical meter with two Bunk Houses and the Automotive and Maintenance Building shares an electrical meter with the Fire and Resources Building, these buildings are also included in the study.

Once the buildings are selected for analysis, a computer model is developed that allows for the assessment of energy consumption patterns. This model is based upon an "Alternate Bin-Method" that also affords the opportunity to predict the potential energy savings of specific building improvements. For the most part, the modeling compares reasonably well with the actual energy consumption data. The following graph demonstrates the accuracy of the computer model; it illustrates the comparison of the actual average electrical energy consumption to the computer-modeled energy consumption for the Administrative Building and Bunk Houses. For these buildings, heating is accomplished by electrical resistance heaters.



Once the validity of the computer model is confirmed against the actual energy consumption data, the model is altered to reflect the changes in building composition that result from a building upgrade. The building improvements considered in this analysis are roof (attic) insulation, high-performance windows, and heat pumps, as well as garage doors for the Automotive and Maintenance Building. (The comparison is completed for the heating energy consumption since the building modifications affect the heating requirements only.) The different upgrades are then compared to the model of the current building configuration in order to evaluate the annual savings in energy consumption. The following graph represents an example of the variation in heating requirements for the Administrative Building with the three upgrades considered separately (note that a similar analysis is completed for all four buildings in the energy analysis):



The computer model demonstrates that the energy efficiencies of many of the buildings at the Marblemount Ranger Station are in need of improvement. Although some building improvements are costly and entail long payback periods, there are some options that appear economically feasible at the present time. Heat pumps, for example, would have immediate and far-reaching impacts; consequently, they may be good choices for several buildings at Marblemount, including some buildings not included in this analysis. Although their initial costs are large, once installed the heat pumps could bring a total savings of about $1,975 and 39,705 kWh annually for the four buildings considered in this study. On average, the heat pumps reduce the annual electricity requirement for heating purposes by about two-thirds.

Caulking and weather-stripping all the buildings is recommended as well, even though these improvements are not treated in the computer model. Indeed, these are inexpensive and easy upgrades that are certain to have impacts on the amount of infiltration in the buildings, thereby lowering the heating requirements.

In addition, roof insulation and window upgrades should be considered on a case-by-case basis, since their benefits vary according to building. For example, roof insulation may be effective for the Bunk Houses and Residential Buildings, but not in the larger buildings, such as the Administrative Building and Wilderness Center; it would not be cost-effective in these cases since the payback periods are very long. Likewise, windows should be considered for the Bunk Houses.

The construction of the Automotive and Maintenance Building and the unusual usage pattern of the Wilderness Center create unique circumstances that need to be addressed on an individual basis. The Automotive and Maintenance Building, with its four large garage doors, is subject to significant conductive heat loss and infiltration. To solve this problem, it would be useful to consider replacing the garage doors with new, high performance, insulated garage doors. Some high performance garage doors are equipped with full-section-view window inserts, which would increase the amount of natural light in the building and contribute to a more pleasant working environment. On the other hand, the Wilderness Center, with its occasional employee meetings, would be well served by replacing the current wood stove with a more efficient, low-emission model. A new stove, sized appropriately to fit the main room, would not only considerably reduce the amount of wood required for burning and the amount particulate matter in the air, it would provide more pleasant heating for its occupants.

It is important to carefully and thoroughly consider the cost-effectiveness of building improvements before beginning the upgrades. Otherwise, building changes may not be as effective as possible. A case in point is the recent upgrade of the residential buildings’ windows in which old, single-glazed windows were replaced with double-glazed ones. Although this was certainly an improvement over the previous windows, upgrading to high-performance, low-emission windows, rather than to basic double-glazed windows, would have provided even more energy savings with only about 1 to 2 years added to the payback period. Not surprisingly, future upgrades should be considered thoroughly and cautiously. For example, consideration of high-performance windows should be made for other residential buildings, like 1009 and 1010. It is quite possible to significantly improve energy efficiency and establish a sustainable energy practice at Marblemount, provided that multiple improvement options are weighed and then decisions are made accordingly.

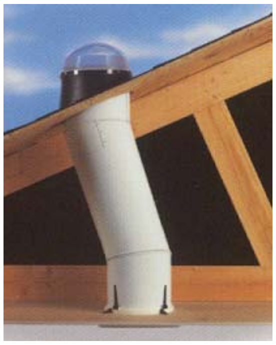
The following table summarizes the payback periods on the upgrades.

Administrative Building	All upgrades have very long payback periods (42 to 59 years), because the building is significantly heated by people and office equipment, and some upgrades have already been completed.
Bunk Houses	All upgrades appear reasonable attractive, because the payback periods are moderate (14-23) years.
Wilderness Center	All upgrades have significant, though not unreasonable, payback periods of 24 to 26 years
Residential Building 1014	Two upgrades, windows and heat pump, have very long payback periods (38 to 53) years, because of the inconsistent use of the building and the previous upgrading of the windows. However, the roof upgrade has a reasonable payback period of 19 years
Automotive and Maintenance Building	Installing new garage doors would appear to be energy-cost-effective, with a payback period of about 18 years.

In addition to the building modifications, consideration of replacing lighting, equipment, and appliances with high efficiency devices would reduce the base load consumption and improve energy consumption. At first, these would shift the energy consumption from base load to heating due to lowered internal heat gains. However, since heat pumps have been shown to significantly reduce the electrical energy consumption due to heating, the overall savings from a combination of high efficiency lighting and equipment and a heat pump could offer significant reductions in the overall electrical energy consumption.

In addition to the building and heating system modifications, the National Park Service should consider measures to increase daylighting in some of the buildings at the Marblemount Ranger Station. Daylighting is the use of sunlight to illuminate the interior of the structure. Natural light provides a full spectrum of light allowing the eyes to see real colors. Many studies have shown that natural light increases occupant satisfaction and productivity and reduces the number of absentee days, since the natural light provides a healthier, more pleasant environment. Hence, the initial investment in daylighting measures may be recovered in increased productivity and less absenteeism. Natural light should be brought into a room mainly as diffuse light.

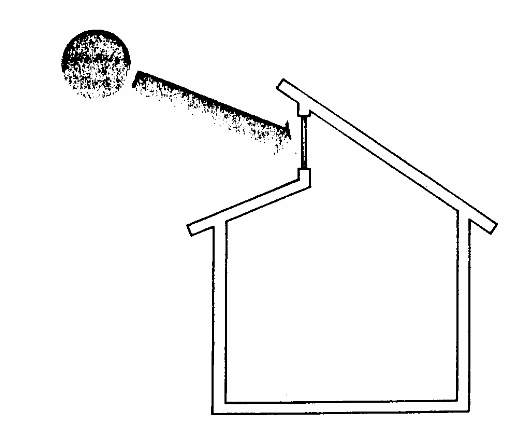
The following four types of daylighting measures are considered as potential natural light sources at the Marblemount Ranger Station: solar tubes or pipes, clerestories, skylights, and light shelves. A solar tube is a small device installed in the roof. A solar tube consists of a collecting device on the outside of the roof, a tube or pipe for channeling the light down to the building, and a diffuser which diffuses the bright light throughout the room. A Solar Tube is shown in the following illustration.



Solar Tube

Solar tubes are applicable to all buildings at Marblemount. However, care must be taken if installing in the Wilderness Center to avoid excessive shading from the large trees on the south side.

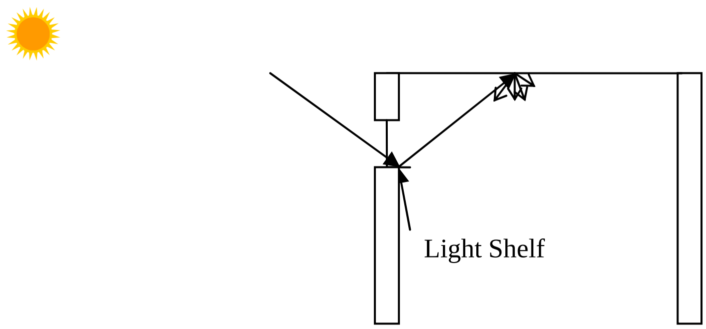
A clerestory is an upper portion of a wall that contains windows that supply natural light to a building. Clerestories are windows that project up from the roof surface and are installed on the south-facing wall to maximize the annual sunlight brought into the work space. A schematic of a clerestory is shown below. The only building in this analysis that is suited for a clerestory is the Automotive and Maintenance Building due to it large south-facing wall (or east-west orientation).



Clerestory

Skylights perform the same functions as the clerestories and solar tubes: they bring in more natural light. Since the thermal performance of windows is generally lower than that of a roof/ceiling, it is highly recommended to install skylights with low heat loss coefficients in order to minimize the additional heat loss. Additionally, more sunlight enters the building if the skylight is installed on a south-sloping roof. Installing skylights is applicable to all buildings.

Unlike the three daylighting options discussed above, a light shelf is installed in a wall of a building. A window above the shelf allows sunlight to strike the surface of the light shelf. This light is reflected by a mirror onto the ceiling of the interior creating a diffuse light deep into the workspace (see figure below). Generally, a light shelf should be installing in a south-facing wall. Hence, light shelves are applicable to the Automotive and Maintenance Building and the Administrative Building.



Light shelf

Implementing any of the daylighting measures could improve the working environment and create a more pleasant atmosphere. Priorities for improved daylighting are given in the table below.

Priority	Building	Daylighting Approach
High	Automotive and Maintenance	Skylights, and perhaps lightshelves, to bring light into the work areas, which at present receive very little sunlight.
High	Wilderness Center	Solar tubes to bring sunlight into the main room, which is poorly lighted at present.
Moderate	Administrative Building	Solar tubes to bring light into interior rooms and rooms with few windows.