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Balancing Energy Options in Stehekin, Washington

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PREPARED BY:

Jessica G. Kirchhoffer and Philip C. Malte
Department of Mechanical Engineering
University of Washington
Seattle, Washington 98195-2600
Phone: 206.543.5486
E-mail: malte@u.washington.edu

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Jessica G. Kirchhoffer and Philip C. Malte
Department of Mechanical Engineering
University of Washington
Seattle, Washington 98195-2600

Executive Summary

This report is based on the Masters of Science (Mechanical Engineering) Thesis of Ms. Kirchhoffer completed June 2003. The report covers a two years study of the energy options available in Stehekin, Washington, a remote and isolated community not served by a major electrical grid. Stehekin lies at the northern tip of Lake Chelan, in a valley set between peaks of the North Cascades Mountains. Stehekin is a gateway to North Cascades National Park and is itself a National Recreation Area administered by the National Park Service. Electricity is provided by a local hydroelectricity facility and three diesel generators operated by the Chelan Public Utility District (PUD). Although the electricity rate paid by the Stehekin community is about double that paid on the main parts of Chelan PUD grid, the PUD indicates an annual loss of about $50,000 on its Stehekin operation. Part of this loss is caused by the remoteness of Stehekin, through much of it arises from the high cost of running and maintaining the diesel generators. Typically, the diesel generators run a couple times of day during the summer and almost constantly during the winter. In addition to the high cost of running the generators, the diesel generators are a source of noise and air pollution.

The purpose of this study is the exploration and analysis of energy options for Stehekin that would allow the diesel generator use to be curtailed. The study has been conducted by considering the electricity use patterns for Stehekin, followed by the examination of both demand-side and supply-side solutions. Demand-side solutions involve energy conservation and fuel switching. Switching to propane for domestic water heating and space heating would decrease the demand for electricity. Additionally, space heating with low-emission certified wood stoves would reduce the demand for electricity. Although wood is the traditional heating fuel of Stehekin, ups and downs in National Park Service policy on woodcutting may have diminished enthusiasm for this fuel. Supply-side solutions involve both central and distributed electricity storage, upgrading the existing hydroelectricity plant, solar PV, and wind turbines. Central electricity storage using flow batteries or upgrading of the existing hydroelectric plant, coupled with conservation and fuel switching may offer the best long term solution for Stehekin. Both the flow battery system and the hydroelectric upgrades carry a price tag in the low $200,000 range.

Electricity load information for Stehekin is taken from a 1992 report prepared for the NPS, in which 1988 and 1989 data were used. These data used a sample day from each month. For season from April to October, termed the high season, the averaging of the 1988-89 data indicates a base load of 95 kw and the peak load of 200 kw. However, it is also known that for a busy holiday weekend, the load can significantly exceed the 200 kw value. For the season from November to March, termed the low season, the base and peak loads obtained from the averaging of 1988-89 sample days are about 115 and 180 kw, respectively. February, however, exhibited peak load exceeding 200 kw. Although these data are 15 years old, they should reflect the present electricity load situation. The permanent population of Stehekin has been relatively steady, and though more tourists appear to be visiting Stehekin, fuel switching may be providing a countering effect with respect to electricity use. This view is supported by the decline in diesel fuel consumption between the 1992-95 and 2000-01 periods.

The hydroelectric plant is rated at 205 kw. However, based on typical actual water flow rates, the hydroelectric power output varies from 183 kw in the summer (early) to 108 kw in the winter. This hydroelectric output is unable to meet the summer and winter load peaks. Additionally, it is not quite able to meet the winter base load. Thus, a significant part of this study has been focused on upgrades to the hydroelectric facility. First, it is noted that the hydroelectricity plant is unable to provide a constant 60 cycles per second (cps) frequency in the electricity. On one of our visits, the frequency fluctuated to a value of around 59 cps. The variation in the frequency essentially eliminates the tying of distributed generation and storage systems into the Stehekin grid. It also prevents modern energy efficient appliances with microprocessor controls from being fully utilized in Stehekin. A new water jet deflector and control system on the Pelton wheel turbine of the hydroelectric plant should bring the frequency into compliance. The cost is about $30,000. Second, it is noted that the efficiency of the Pelton wheel turbine / electrical generator system is 63%, which is quite low. By upgrading the Pelton wheel to a two-jet system, from the present single jet system, the efficiency could be brought up to 76%. This would increase the typical winter and summer power outputs to 130 and 221 kw, respectively. Cost would be about $200,000. This includes the upgrade of the jet deflector / control system. An upgrade to a four-jet system, costing about an additional 10%, would bring the winter and summer power outputs up to about 135 and 230 kw, respectively. These upgrades would appear to cover the winter base load and all of the summer loads except possibly those occurring on busy tourist days.

Adding conservation and fuel switching into the picture improves the ability of the upgraded hydroelectricity system to meet the load. Conservation, including building insulation upgrades and the use of efficient appliances, is estimated to reduce the average load by about 10%, or 15 kw. Based on results on energy use in the 1992 report, we have estimated that fuel switching could reduce the winter load by about 30 kw and the summer load by about 50 kw. The greater value is assigned to the summer, because of significant use of hot water by tourists in the summer and its switch from electricity to propane. If these demand-side energy reductions could be realized, favorable margins would exist between the upgraded hydroelectricity output and the Stehekin load. For the summer the situation would be a hydroelectric output of either 221 or 235 kw for normal maximum stream flow (17 ft^3/s) versus an average peak load of 135 kw based on conservation and fuel switching, while for the winter the output would be either 130 or 135 kw for normal minimum water flow (10 ft^3/s) which just matches the average peak load.

A supply-side approach with a total price tag of about $300,000 is the flow battery for central storage of electricity. This could store 100 kwh of electrical energy, which could be used to cover the load during peak demand periods. The battery system would be charged during the base load time of day. An additional power output of 50 kw for 2 hours, when added to the present hydroelectric outputs, would bring the winter output to 158 kw and the summer (early) output to 233 kw. The main drawback of the flow battery appears to be its lack of establishment, that is, it is an emerging commercial technology. The remoteness of Stehekin may work against its use there at this time.

This study also focused significantly on the potential of solar PV for Stehekin. An off-grid solar PV system rated at 960 watts was purchased and installed on the roof of the Stehekin Visitors' Center. The system, consisting of eight 120-watt panels, panel mounting framework, combiner box, charge controller, eight 98 amp-hour gel deep cycle batteries, a 24 volt / 2.5 kw inverter, and battery rack with DC disconnects, had a price tag of $9280. The NPS installed the system, so that cost is not included in the $9280. From July of 2002 to February of 2003, the system was monitored for the solar flux input, the PV voltage and current output, and the battery voltage. Based on the 120 watt power rating of each panel and the panel total area, the solar-to-electric energy conversion efficiency is 12.3%. However, as the panels heat up on a sunny day, their power drops by about 0.5% for every degree C of temperature rise above 25 degrees C. Additionally, losses occur in the power electronics and battery pack. Our measurements showed the system could nearly reach 10% efficiency when connected to a significant load. If the load is too small, the capacity of the solar PV system is not well utilized and the controller commands the PV panels to run near the open circuit condition with low current (and low power) output. Our measurements for the month of August indicate a daily solar energy input to each of the 1 m^2 panels of 5900 watt-hours. Using this value and assuming the 10% system efficiency leads to daily electrical energy generation of 4.7 kwh for the 8-panel (8 m^2) array. With the array tilt angle set near optimum for each period of the year, solar energy input to the panels should vary between 4000 and 7000 watt-hours/m^2 over the months of April to October, corresponding to a daily electrical energy generation of 3.2 to 5.6 kwh for the 8-panel array.

The addition of about ten 1 kw solar PV systems could overcome the present shortfall of the hydroelectric system in meeting the average peak load in the (early) summer. These systems would require battery storage, since the time of the peak load (morning) does not coincide with peak solar flux (early afternoon). Cost would be about $10,000 per system, or about $100,000 for the 10 arrays. These figures assume installation by the purchaser.

Finally, we examined wind energy. This was done based on data available from the fire weather station located at the Stehekin airport. These data indicate a wind resource inadequate to justify the installation of wind turbines in the Stehekin Valley. However, wind data were not available for the lake shore, where summer afternoon winds can be brisk. Ridgelines above the valley probably offer a good wind resource, but the installation of wind turbines there could carry significant view shed impacts and unwanted construction impacts.

Recommendations reached from this study are as follows:

- Solving the problem of the fluctuations in the frequency of the electricity should be tackled as soon as possible, since this problem prevents other solutions, such as distributed generation and storage, and efficient appliances.
- Demand-side conservation and fuel switching should be strongly promoted, since they need to be part of any long term solution.
- The National Park Service should stick to a stable policy on woodcutting. Additionally, a short study should be commissioned comparing the air pollution impacts of business-as-usual diesel generator use against increased burning in low-emission certified wood stoves.
- Solar PV should be considered part of the solution, since the Stehekin solar energy resource appears to be very good (except in deep winter). Especially, solar PV should be encouraged for new summer loads, particularly those for cooling and daytime work activities. Additionally, solar PV could be attractively coupled to the charging of electric utility vehicles.
- Perhaps most important, the National Park Service and the Chelan Public Utility District should strive to reach an agreement whereby it becomes feasible to upgrade the hydroelectric plant, increasing its efficiency from the current 63% into the 76-79% range. This would enhance the environment of Stehekin Valley by curtailing diesel noise and pollution. It would not add impact to Company Creek. The cost of $200,000$^+$ is not all that high, especially if energy solution burdens could be shared. The benefits are significant. The hydroelectric upgrade, if coupled with conservation and fuel switching, and with well sited solar PV and distributed storage, could eliminate the use of the diesel generators except for emergency use.

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