

THE YUOK TRIBE'S 'WIRELESS' ELECTRIC UTILITY

Dr. Thomas J. Starrs
Principal
Kelso Starrs & Associates, LLC
14502 SW Reddings Beach Road
Vashon, WA 98070-6814
e-mail: kelstar@nwrain.com

Arne Jacobson
Energy & Resources Group
310 Barrows Hall, MS-3050
University of California
Berkeley, CA 94720-3050
e-mail: arne@socrates.berkeley.edu

ABSTRACT

The Yurok Tribe is designing and implementing a rural electrification project to provide reliable electricity to a remote part of the Yurok Indian Reservation. The project relies primarily on grid-independent alternative energy systems using photovoltaic (PV) or small-scale hydro-electric power. As part of the project, the Tribe is providing routine maintenance and repair services, including the replacement of components as they wear out. In order to finance the maintenance and repair program, the Tribe is implementing a billing system that rewards customers for living within the 'renewable energy budgets' of their alternative energy systems. In effect, the Tribe is developing a 'wireless' utility to provide grid-independent electricity service that is metered and billed in a manner similar to conventional grid-connected service.

1. INTRODUCTION

The Yurok Indian Reservation is located along the Klamath River (a federally-designated Wild & Scenic River) near the coastal counties of Humboldt and Del Norte in Northern California. The 'upriver' part of the Reservation includes an extremely remote and rugged area that is considered the cultural heart of the Tribe's ancestral land area. This area is inhabited by about 120 Tribal member households, including many Tribal elders. The area lacks much of the utility infrastructure most Americans take for granted, including access to utility power and telephone services.

During the past year, the authors have been working for the Yurok Tribe to design and implement a rural electrification project to provide electricity to part of the upriver

Reservation area using sustainable, renewable energy systems. This project — dubbed the Alternative Energy Project — includes the design and configuration of remote power systems for individual Tribal households and village power systems for areas where Tribal households are clustered.

What makes this project particularly interesting is that the Tribe will own, operate, and maintain the alternative energy systems, and will meter and bill for the electricity used by Tribal member customers. In effect, the Yurok Tribe is creating an electric utility without wires — creating the infrastructure to ensure safe and reliable operation of the alternative energy systems for Tribal members, while obligating the Tribal members to cover the cost of maintenance and component replacement. The authors will discuss several of the challenging issues that had to be resolved in designing the program, focusing on the development of a maintenance program that employs Tribal member technicians and a billing mechanism that rewards customers for living within the 'renewable energy budgets' of their alternative energy systems.

2. DESCRIPTION OF THE YUOK TRIBE ALTERNATIVE ENERGY PROGRAM

The purpose of the Yurok Tribe Alternative Energy Project is to bring reliable electricity and telephone services to the remote upriver portion of the reservation. Although approximately 85% of upriver households own at least a small generator set, only 15% of households currently have what they or the Tribe consider 'adequate' electricity service. Similarly, many upriver households use radio telephones, but reception in many areas is poor because of mountainous terrain. Cellular service is available in about 10% of the upriver area.

The Tribe is using a mix of technologies to carry out the rural electrification work. These include a power line extension to serve about a dozen households; two village-scale hydroelectric systems to serve approximately 15 households each; and individual solar and micro-hydroelectric systems to serve the balance of the upriver Tribal households. In addition, the Tribe is developing telephone service in the area through use of a microwave telecommunications network and a micro-cellular telephone node. These facilities will be powered by grid-independent PV systems.

3. SOURCE AND ALLOCATION OF FUNDING FOR THE ALTERNATIVE ENERGY PROJECT

The primary source of funding for the Yurok Tribe's alternative energy project is an Energy Trust Fund that was set up for the express purpose of providing energy services on the Yurok Reservation. The trust fund, which was established following a legal settlement in the 1980s, contains approximately \$1.5 million.

The Tribe is using the Energy Trust Fund to cover the capital costs of the rural electrification and telecommunications infrastructure development effort. However, the Tribal Council has made the decision to require these programs to be self-financing with respect to continuing operation and maintenance. Accordingly, one of the principal challenges facing the Tribe was the development of a maintenance program to ensure the safe and reliable operation of the systems, and a billing program to recover the costs associated with the maintenance program.

4. ALTERNATIVE ENERGY PILOT PROJECT

The Yurok Tribe began the Alternative Energy Project with a pilot project that was implemented during the past two years. During this time, the Tribe installed nine alternative energy systems for residential applications. A tenth system provides electricity to a Head Start school in the upriver area.

The purpose of the pilot project was two-fold. First, the Tribe wanted to use the pilot project to gain experience for the larger electrification effort that is planned for the coming years. Second, the majority of the pilot project systems were installed in households headed by Tribal elders, in an effort to improve their standard of living. In

several cases the elders needed access to reliable electricity in order to use medical equipment.

Eight of the nine pilot project systems consist of a 720 peak watt (W_p) PV array, a 4 kilowatt (kW) sine wave inverter, 700 Amp-hours (A_{hr}) of battery storage at 24 Volts DC, and an auto-starting backup generator. The ninth system has an identical inverter and battery bank, but is powered by a 700 watt, year-round micro-hydroelectric system. The pilot project alternative energy systems were designed in 1996, prior to the development of the maintenance and billing programs described below.

5. DESCRIPTION OF ALTERNATIVE ENERGY SYSTEMS OFFERED

Four different alternative energy system configurations are currently available through the Yurok Tribe's alternative energy electrification program.

The system configurations are described in Table 1. Heads of households are given the opportunity to choose a system that meets their electric energy needs and their ability to pay monthly bills. The heads of households are given technical advice about the capabilities and limitations of the systems through literature and from meetings with trained Tribal Utility staff members, so that they are able to make an informed choice.

TABLE 1: ALTERNATIVE ENERGY SYSTEM CONFIGURATIONS

<i>Power Source</i>	<i>Battery</i>	<i>Inverter</i>	<i>Generator</i>
720 W_p PV	700 A_{hr} @ 24V	4 kW Sine Wave	6.5 kW
360 W_p PV	660 A_{hr} @ 12V	2.5 kW Modified Sine	3.5 kW
Micro-Hydro	700 A_{hr} @ 24V	4 kW Sine Wave	3.5 kW optional
Hybrid Micro-Hydro & 360 W_p PV	660 A_{hr} @ 12V	2.5 kW Modified Sine	3.5 kW

6. OPERATION AND MAINTENANCE PROGRAM

Maintenance for the alternative energy systems is provided through a three tiered system:

Tier I -- Basic Maintenance Technician: Responsibilities include a visual check of the systems, testing the batteries, checking and changing the oil on the backup generator, reading the electric meter, and logging system parameters (battery voltage, inverter status, generator run time). This position is filled by a Tribal member who has completed the Solar Energy International training course and additional training from one of the authors. The Yurok Tribe chose to hire a technician who lives near the systems that are to be maintained, in order to minimize travel related costs. The hours for this positions are estimated at 15 hours per system per year for the solar PV systems, and 18 hours per system per year for the systems that include a micro-hydro unit.

Tier II -- Maintenance Supervisor: Responsibilities include supervising and coordinating the Tier I technician's activities, purchasing parts and supplies, troubleshooting system problems beyond the abilities of the Tier I technician, and assisting in maintenance as needed. The hours for this position are estimated at 5 hours per system per year. Training is the same as the Tier I technician, but the Tier II technician is expected to have more prior experience with alternative energy systems.

Tier III -- Alternative Energy Contractor: The Tribe maintains a working relationship with a licensed electrical contractor who has substantial experience with the design, installation and maintenance of PV and micro-hydro systems. The contractor is called in to address unique system design issues and serious maintenance problems. The hours for this position are estimated at 0.5 hours per system per year (not including initial design and installation).

The use of a three-tiered system helps ensure that basic maintenance is carried out at a reasonable cost, and also gives the Tribe access to an experienced technician to trouble shoot occasional difficult maintenance problems.

7. CUSTOMER BILLING PROGRAM

The Yurok Tribal Council instructed the authors to design a customer billing system that would cover the anticipated costs of operating and maintaining the alternative energy systems (except for the cost of generator fuel, which was the responsibility of each household).

The objectives used in the design of the billing program were as follows:

- Monthly bills should allow Tribal Utility to cover O&M costs;
- Bills should be structured to encourage customers to live within the "energy budget" of their alternative energy system;
- Customers should have several system options from which to choose, with varying levels of service and varying costs;
- Monthly bills should be based on a quantity that is easy to measure (for example, the kWh meter reading);
- The billing system should be easy for the customers to understand; and
- Billing rates should be as low as possible.

The resulting billing program developed by the authors and approved by the Tribal Council has the following characteristics:

- Customers pay a flat rate amount (hereafter referred to as the 'fixed charge' amount) that is equal to the estimated O&M cost of the system.
- The O&M cost includes two components: a fee to cover the salary and expenses of the maintenance technicians; and a payment to cover the anticipated cost of replacing components over a 30-year system life.
- The fixed charge includes an allotment of electricity that the customer can use without any additional charge. The allotment amount is based on an annualized estimate of the renewable energy contribution to the system's total output plus the energy available from running the back-up generator a total of 400 hours per year. Different system designs will have different energy allotments.
- If the customer's use exceeds the allotment, the excess electricity use surcharge is \$0.50/kWh. This high rate is designed to cover the cost of extra wear and tear associated with overuse of the system, particularly shortened battery and generator life.
- Customers are responsible for the cost of fuel for the backup generator. This cost is not included in the billing rates and is paid separately by each customer.

The authors chose to design the billing system around a fixed charge combined with a metered rate because many of the O&M costs are relatively fixed when energy use is within the monthly allotment.

7.1 Living Within an Energy Budget

The monthly allotments of electrical energy act to encourage customers to live within an "energy budget" that corresponds to the capabilities of the alternative energy system. When they exceed the limit set by the monthly

allotment, they are penalized in two ways. First, they are charged \$0.50 per kWh for the excess electricity. Second, they must pay the generator fuel cost associated with running the generator to provide the extra electricity. This double incentive to live within the 'energy budget' is necessary in order to keep wear and tear on the batteries and the generator at a minimum.

7.2 Billing Rates

A breakdown of the fixed charges and electricity allotments for the four alternative energy systems currently available from the Yurok Tribe is presented in Table 2. The fixed charges are based in part on work by Chris Greacen of the Native American Renewable Energy Education Project.(1)

There are four different monthly fixed charges for the four different systems offered. The solar PV systems with the same design have the same monthly electricity allotment,¹ but hydroelectric system electricity allotments vary somewhat depending on the characteristics of the hydro resource. All of the systems have the same excess use surcharge rate of \$0.50/kWh.

The monthly allotments for the solar PV systems allow for moderate use of electricity. Most homeowners have propane appliances, including stoves, refrigerators, water heaters, and clothes dryers. The use of propane reduces the demand on the electrical system. If high efficiency electrical appliances such as compact fluorescent lighting are used, then the solar PV systems in conjunction with the propane appliances can provide an adequate level of residential electricity service.

The monthly allotments for the hydro-electric systems can, in many cases, provide substantially more electricity than the solar PV systems. Some of these systems provide a level of electrification that is comparable to being connected to the utility grid. For comparison, the typical residential electricity use for a family of four in a home that is connected to the utility grid is on the order of 500 kWh per month.²

¹This assumes that the homes have similar solar access. In practice this access varies, but the variation is small enough to ignore for the purposes of calculating the monthly electricity allotments. House sites with poor solar access are not eligible for solar PV systems under the Yurok Alternative Energy Program guidelines.

²This estimate assumes a home in the U.S. that has some natural gas appliances (i.e. all electric homes typically have higher electricity use).

A breakdown of the estimated O&M costs that were used to set the monthly fixed charge rates is given in Table 3. The costs for replacement equipment are amortized over a 30-year lifetime using a 5% discount rate.

TABLE 2: ALTERNATIVE ENERGY SYSTEM BILLING RATES

<i>System Type</i>	<i>Monthly Electric Allotment</i>	<i>Monthly Fixed Charge</i>	<i>Monthly Generator Fuel (estimated)*</i>
720 W _p PV	135 kWh	\$85	\$35
360 W _p PV	70 kWh	\$50	\$35
Micro-Hydro	Varies; 500 kWh typical	\$65**	\$0
Hybrid Micro-Hydro & 360 W _p PV	Varies; 300 kWh typical	\$55	\$15
* Based on annualized average monthly fuel bill for a household that does not exceed monthly electricity allotment.			
** \$70 if optional generator is included.			

TABLE 3: BREAKDOWN OF MONTHLY FIXED CHARGES FOR ALTERNATIVE ENERGY SYSTEMS

<i>System Type</i>	<i>Labor Costs</i>	<i>Replace Battery</i>	<i>Generator O&M</i>	<i>Replace Other Equipment</i>
720 W _p PV	\$27	\$20	\$20	\$18
360 W _p PV	\$27	\$7	\$10	\$6
Micro-Hydro	\$31	\$13	\$0	\$21
Hybrid Micro-Hydro & 360 W _p PV	\$31	\$6	\$9	\$9

8. UTILITY OWNERSHIP OF ALTERNATIVE ENERGY SYSTEMS

The Yurok Tribe has chosen to retain ownership of the energy systems installed under the Alternative Energy Project and to operate the systems as described in the preceding sections of this paper. This decision is based on a

desire to ensure that the systems are properly maintained over a projected life of 30 years. The billing program should ensure that the funds are available to replace system components when they are needed and to pay for maintenance services by trained, qualified Tribal member technicians.

While there are some very positive aspects to this arrangement, some problems are created by the fact that the system users (i.e. the customers) do not own the systems. The most obvious potential problem is the overuse of the system's capacity to deliver electricity. This is addressed by the billing system's monthly energy allotment and excess use energy surcharge.

However, there are other things that a customer can do or not do that affect the alternative energy system's life. Actions by the customer that can help maintain the life of the system include reporting problems promptly, ensuring that the generator always has adequate fuel to operate, and refraining from tampering with system equipment.

The Yurok Tribe would like to ensure that the customer is an asset, not a liability, to the Tribe's alternative energy maintenance program. To accomplish this the Yurok Tribal Council has approved measures including the financial incentives contained in the billing program, a customer education program, and a contract between the Tribal Utility and the customer that includes penalties for misuse of the system.

The customer education program is used to provide information about energy efficiency and other topics related to optimizing the value of the alternative energy systems. The Tribe is implementing the program by distributing literature and through informal sessions between the customers and the maintenance technicians.

The Yurok Tribe is also working to establish and maintain a sense of trust between the Tribal Utility and the customer. Customers must feel that they are "getting their money's worth" in services when they pay bills. This sense of trust will have an important impact on the customers' treatment of the alternative energy systems.

All of these efforts are aimed at extending the life of the system components and on helping the customers to maximize the value of the systems.

9. ALLOWING FOR FUTURE GROWTH IN ALTERNATIVE ENERGY SYSTEMS

The Yurok Tribe recognizes that it is important to allow alternative energy systems to grow as the needs of the household change over time. Homeowners can add energy generating and battery storage capacity to the systems at their homes under the following conditions:

- The additions must be approved by the Yurok Tribe.
- The work must be carried out by a qualified technician.
- The work must comply with the appropriate codes, including the National Electrical Code.

When changes are made, the monthly energy allotment will increase to reflect the increased generating capacity and the monthly fixed charge rate will increase to reflect any additional labor costs associated with the new equipment. The homeowner is responsible for replacing the new equipment when it fails.

10. DISCUSSION

The authors have identified several key lessons that can be learned from the Yurok Tribe's experience to date with the alternative energy 'wireless utility.'

10.1 Discussion of Billing Rates

The fixed charge rates for the alternative energy systems are higher than expected. This is true even though the rates are only designed to cover the O&M costs for the systems. The rates would be even higher if they also included the amortized capital cost for the systems. There are two main reasons for the high costs.

First, the fixed charge rate includes O&M labor costs for tasks that are generally carried out by the owner of an alternative energy system. Most alternative energy systems in the United States are owned by the end user, and the labor cost for basic maintenance that they carry out themselves is assumed to be zero. For a utility-owned system this basic maintenance is carried out by a technician. This may increase the quality of the maintenance, but it also increases the cost. While the wages of the technician make up the bulk of this extra cost, travel costs and administrative costs are also significant.

The second major component of the fixed charge rate is the cost of replacing system components. The battery bank and backup generators make up the majority of the replacement costs. These costs are very difficult to predict, as it is unknown how long the components will last

in a utility-owned and maintained alternative energy system. The component of the fixed charge for replacing equipment is based on typical equipment lifetimes for similar systems. These lifetimes may be optimistic if equipment is overused in a utility owned operation.

The fixed charge rates will be revisited each year and adjusted as necessary.

10.2 Experience With Operation and Maintenance of the Pilot Project Alternative Energy Systems

The Yurok Tribe has maintained the alternative energy pilot project systems for six months using the three tiered maintenance system described in Section 6. Prior to the implementation of this maintenance program, the systems were maintained through the efforts of the homeowners, a Tribal staff member, and contractors to the Yurok Tribe.

The billing program is in the process of being implemented. To date, customers in the pilot project have not paid bills for the use of alternative energy systems. This had lead to over-use of the systems, as the end user's only incentive to live within the system's "energy budget" is the cost of the generator fuel.

As a result, the labor costs during the first six months of the maintenance program were approximately twice as high as the amounts given in Section 6 (labor hours) and in Table 3 (labor costs). These additional costs can be broken into two categories. First, there are additional materials and labor costs associated with carrying out overdue maintenance tasks. Second, there are start up labor costs associated with training the technician and providing customer education services. The training process costs include actual instruction hours as well as the extra time that it takes the technician to carry out new and unfamiliar tasks. The customer education costs are associated with the time that the technician spends talking with customers about energy efficiency practices and system performance. We expect that these additional labor costs will drop over time to the levels indicated in Table 3.

10.3 Comparing Micro-Hydro to Solar PV

The hydroelectric system in the pilot project has proved to be a much higher value to the customer than the 720 Wp solar PV systems have been. The 700 Watt continuous power input from the hydro system allows for a monthly energy budget of 450 kWh at a cost of \$65 per month. This is a far greater value than the 135 kWh for \$85 per month that is available with the 720 Wp solar PV systems.

Micro-hydro systems will be used for future off-grid electrification on the Yurok Reservation wherever possible. However, because not all of the Tribal member house sites have a good, year around hydro resource, PV will continue to play a role in future electrification efforts.

11. CONCLUSIONS

The Yurok Tribe is working to provide electric service to Tribal members in a remote part of the reservation using off-grid alternative energy systems. The authors have worked with the Tribe to develop maintenance and billing programs for this wireless utility.'

The three-tiered maintenance system is designed to provide basic maintenance at a reasonable cost, while also allowing for the use of an experienced technician on an as-needed basis. The billing program design provides a funding mechanism for the maintenance. It uses a monthly limit on electricity use along with an excess use surcharge as incentives to the customer to live within the alternative energy system's "energy budget." These components are critical parts of a program to provide safe, reliable, and long-lasting electric service to Yurok Tribal member households.

Important lessons learned from experience with the Alternative Energy Project include the following:

- It is possible to create a billing system that is simple, yet reflects both the fixed and variable costs of renewable energy system operations. Furthermore, this billing system provides incentives for users to operate the systems in ways that maximize electricity services to the user while not overusing the system.
- O&M costs for utility operated off-grid alternative energy systems are higher than expected. These costs are reflected in the fixed charge rates.
- Initial labor costs are high due in part to start-up learning on the part of the technician and the customers.
- Micro-hydroelectric systems should be used for off-grid electrification instead of solar PV when the appropriate hydrologic resources are available.

ACKNOWLEDGMENTS

The authors thank the Yurok Tribal Council for the opportunity to work with the Tribe on this project, and Tribal Planner Zef Murguia for his collaboration in the performance of this work. The authors also thank John Busch, Jim Williams, Chris Greacen, and the rest of the staff of the Native American Renewable Energy Education Project for initiating the work that led to this project.

REFERENCES

- (1) Greacen, Christopher E., *Community Context and Technology Options in the Yurok Tribal Electrification Project* (Master's Thesis), University of California, Berkeley (1997)