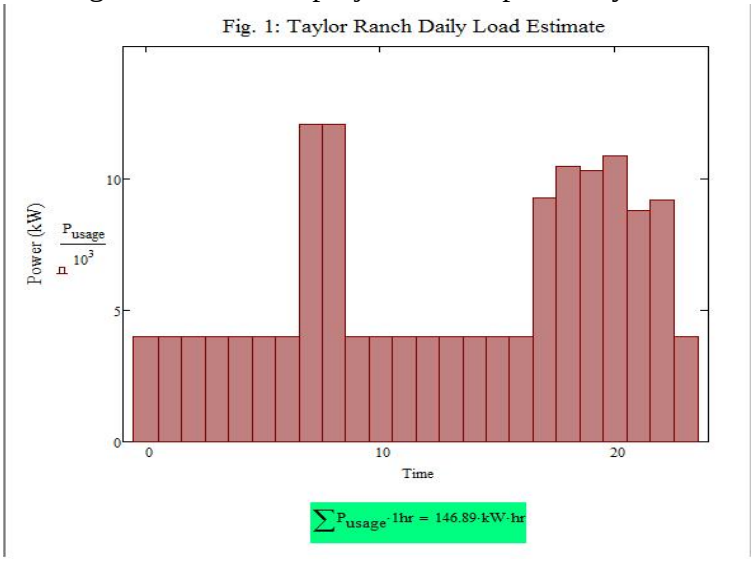
The Taylor Ranch Wilderness Biological Research Field Station is a magnificent opportunity for collaborative research in the preservation and sustainable use of natural resources. In light of recent advances in scientific knowledge and in the ability to communicate worldwide, Taylor Ranch's unique location and resources open a rare and astonishing array of possibilities. Unfortunately, all cutting-edge research depends upon having sufficient electrical power available on demand. The lack of sufficient electrical power is the limiting factor that prevents greater use of Taylor Ranch. Despite the most severe conservation measures already enjoined, there is no room in the incumbent electric power system for any increase in research capability.

The most important needs, identified through extensive interviews with staff and researchers, data collection, and appropriate load analyses, are as follows:

- Increasing the duration, quantity, and timing of Taylor Ranch research activities
- Expanding a heavy scientific equipment load to an aging, overtaxed electrical system
- Obtaining enough electrical power for a reliable, more capable, high-speed data exchange
- Using technology to make Taylor Ranch activities available to researchers worldwide
- Realizing an improved quality of life for on-site researchers, including support of a two-year-old cabin with several rooms that more than doubles the available beds

Analysis of the data projected a consumption level of 150kWh per day expected at summer peak with instantaneous demand peak of 15kW. Figure 1 shows the projected load profile by hour at peak load.



This proposal presents a design that provides these peak levels of electric power with phased commitment created to take the best, responsible advantage of Taylor Ranch's proven renewable energy resources. We employ a careful mix of clean (no water storage) hydroelectric generation and solar power as a base. Peak loading requires a low-emission fossil fuel generator in concert with sufficient energy storage to take advantage of Taylor Ranch's unique load profile. Advanced methods of data acquisition and automated real time control of generation, distribution, and storage enable us to achieve maximum energy efficiency and caretaker convenience. Our design is intentionally compatible with future expansion. Most remote power systems fail for lack of maintenance; we have made a user-friendly phased maintenance system the cornerstone of our design. We have carefully balanced these requirements to optimize the available electric power while remaining good stewards of the environment and maximizing return on the money that we propose to commit.

Hydroelectric generation. Clean, renewable hydroelectric power is the main source of energy at Taylor Ranch. A mountain creek passing through this field station property may provide from 36kWh from a turbine consistently year around. We propose to upgrade the existing 800-Watt generator, taking advantage of a more efficient and reliable turbine generator and employing significantly underused water rights. An improved design from top to bottom provides easier maintenance than the incumbent system: Improved water collection methods, designed by our

civil engineer partner, greater flow, improved storage, and better organized maintenance. With no water storage or dam, this design lacks the dominant environmental faux pas of most hydroelectric generating systems. This larger and more robust hydroelectric generator has a 20-year service life. Transportation and installation are included in the proposal budget. Unlike the aging 800-Watt incumbent system, maintenance of a turbine-based system is minimal, requiring annual inspection of the turbine and regular cleaning of the water collector. Water rights enable future upgrade to 50kWh. Energy storage from this generation system helps mitigate load peaks.

Solar. To supply the necessary stored power to meet peak demand, solar capacity must expand, consistent with preserving the natural beauty of the site. The primary site is the roof of the Taylor Ranch hay shed, a fairly inconspicuous place with a peak 3.6kW generation capacity. Solar flux at Taylor Ranch varies from more than twelve hours per day at maximum panel capacity in summer down to about four hours per day at less than 1kW at low sun angles in winter; energy production range is 43kWh in summer down to 6kWh in winter. These cells have a higher than typical efficiency of 19.7% and provide about 200 Watts per cell. They withstand 2.5cm diameter hail and 80km/hour winds, somewhat worse than any conditions recorded on site. Warranty for the solar collection system is 20 years at rated power output. Transportation of all materials to the site is feasible, sling loaded by helicopter or inside a light plane. Custom mounting hardware is part of the price. Maintenance is minimal, occasionally cleaning the surface and, in winter, removing snow. The site has an easy, fairly inconspicuous, ground-mounted future upgrade capacity of 20kW. Solar generation requires energy storage.

Peak Power Generation and Energy Storage. Load peaks are too great for the solar capacity to overcome. Hydroelectric generation is insufficient to meet load on many evenings. A third energy source is necessary, complemented by sufficient energy storage. We audited all energy needs, including reasonable expansion, and determined a summer peak requirement for nearly 150kWh. With proposed hydroelectric and solar generation capacity, this leaves a need for about 75kWh. In concert with carefully sized battery storage, we propose a 30kW propane generator to meet this need. Replacing the incumbent 3.5kW diesel unit, this larger generator will run about 2.5 hours per day during anticipated peak summer load, programmed to meet peak load while charging batteries. Hydro and solar generation is sufficient to meet all winter peak loads. A large stationary propane tank is currently available on-site, primarily used now as fuel for cooking. Replacing diesel fuel with propane unifies fossil fuel usage to a single, cleaner alternative and would require only a single new gas line to the generator.

Battery energy storage provides the ability to ride through load peaks and to extend the benefits of clean solar energy. In our audit of energy needs, particularly considering the usage pattern shown in Figure 1, we determined it necessary to upgrade the incumbent 10.4kWh of storage to 71kWh of storage as follows: a set of 32 batteries rated at 6 Volts, 370 Amp-hours. This battery storage can handle a 15kW peak without starting the fossil fuel generator. At the expected load profile and discharge rates, their life is about ten years. They fit into the current facilities. Flooded lead-acid batteries provide the best cost per unit of storage and greater lifetime, but require more maintenance. The newer dual-shell designs reduce maintenance sufficiently, so we propose them for this project.

Electrical Grid. Each generating source sends electrical power to one of three Xantrex central controllers located in the existing “power house”, a 4’x8’ building housing also the hydroelectric generator and the storage batteries. These controllers send power to the distribution network to supply all loads. They also monitor and control power in storage batteries and use the dummy load to relieve excess power if necessary. The controllers are

interconnected for reliability.

Distribution to cabins and labs, compliant to electrical code, is already installed as single phase, 120 Volts, 60 Hertz, service at appropriate capacities. Properly rated circuit protection is at each building entrance. The Xantrex electrical controller unit provides electrical protection for distribution circuits and for each line arriving from a generator. Transmission from the solar site to the controllers is at 600 Volts DC. Line losses are minimal at this voltage level. Properly insulated and armored cable is requested in the budget. Our selection of a 48V battery bus keeps cabling almost as simple and light as it is for the incumbent system. Our experience with the incumbent Xantrex controller for more than a decade is that maintenance is negligible.

Data Acquisition System. Since the incumbent system was installed more than a decade ago, advances in data acquisition for control and management of small power systems are more than amazing. Sensors, wireless communication, enormous data storage capacities, improved analysis and reporting techniques, and flexible feedback control create a monitoring and control system that performs much better and is more convenient to use. Real time power management is now available to the small power system owner.

We propose a Data Acquisition (DAQ) System that monitors system operation closely. In response to DAQ information, the fossil fuel generator engages when battery state-of-charge warrants. This system monitors load, coordinating storage, generation, and even dummy load to maintain system stability and preserve system voltage. Detecting problems early and coordinating maintenance is a great feature of this DAQ system. It also stores and organizes information to help plan for future needs of the facility. A coordinated wireless and Ethernet computer communication system is in the budget to support the data transmission needs of such a power management system. As a bonus, off-site researchers studying remote energy systems can investigate the performance of a self-sustaining, remote micro-power system in real time. The wireless system is selected for its compatibility with existing wireless capabilities, making it available as a collaborative resource with on-site researchers and, with satellite connection to the Internet, for off-site communication and research as well.

Maintenance. Most remote power systems fail for lack of maintenance. We propose a phased approach to maintenance that has worked well for us in other remote systems. Daily maintenance includes various tasks such as cleaning the water collector, visual inspection of batteries and components, and checking for alerts generated by the DAQ system. Periodic tasks, such as cleaning the solar panels or changing generator oil are scheduled and alerted. Tasks requiring off-site resources are scheduled, alerted, and automatically arranged. Keeping the maintenance simple is the key. A similar maintenance program that we established on a similarly sized system elsewhere has been working without problems for more than a decade.