Renewable Energy Options Feasibility Study – Starr Ranch/Longhorn Munitions Superfund Site

November 2010

Cover photos:

Inset: Exterior and interior of the Starr Ranch Facility, located in the Caddo Lake Wildlife Refuge in Karnack, Texas

Background: View of Caddo Lake from the Starr Ranch Facility

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1 INTRODUCTION

Under the U.S. Environmental Protection Agency's (EPA) Office of Brownfields and Land Revitalization, the Longhorn Munitions / Starr Ranch facility was selected for technical assistance under SRA International's Brownfields Analytical and Technical Support Contract (EPA Contract No. EP-W-07-023). In support of this project, SRA International (SRA) was tasked to provide assistance to the U.S. Fish and Wildlife Service (FWS)—performing technical and economic analyses to determine appropriate renewable energy options for the refurbishment and revitalization of the historic Starr Ranch building located within the Caddo Lake National Wildlife Refuge in Karnack, Texas. This report documents the analyses completed in support of the Starr Ranch facility, and recommends energy technology measures for providing off-grid power to the site in an efficient and environmentally conscious manner.

1.1 EPA Brownfields Program

Under the EPA's Office of Brownfields and Land Revitalization, the Brownfields Program empowers states, communities, and other stakeholders to work together to prevent, assess, safely clean up, and sustainably reuse brownfields. A brownfield site is real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or the potential presence of a hazardous substance, pollutant, or contaminant. Technical assistance may be provided to entities in need of support to revitalize brownfield properties into productive and useful facilities.

1.2 Starr Ranch Project Background / Site Description

The Caddo Lake National Wildlife Refuge (NWR) is located adjacent to the U.S. Army Longhorn Munitions Facility, and was once part of the facility. The munitions facility was used as one of the primary locations in the country to manufacture dynamite (TNT) for bombs in World War II. For the next 50+ years, the facility was used for a variety of munitions manufacturing operations. In 1988, the Army facility was used to destroy the first U.S. missiles under the U.S.-Soviet nuclear arms treaty. As a result of decades of munitions production, the site became contaminated with by-products of manufacturing processes.

In 2000, 7,500 acres of the Longhorn Munitions Facility were established as the Caddo Lake National Wildlife Refuge. The Refuge was established for the purpose of migratory bird and other fish and wildlife management, conservation, and protection. The Refuge is also designed to protect one of the highest quality old-growth bottomland hardwood forests in the southeastern United States. Along the Refuge shoreline of Caddo Lake are wetlands that are designated under international treaty as "Wetlands of International Importance." Prior to being obtained by the U.S. Army in 1941, the area now managed by the Refuge was home to early Texans during the era of the Texas Republic and a variety of uses. One of these early Texas pioneer families was the Starr family, who maintained a small house on the shore of the Caddo Lake. This historical building has fallen into severe disrepair, and is the subject of this report.

The Friends of Caddo Lake National Wildlife Refuge (a community-based support organization) and other local entities have expressed a strong interest in rehabilitating the Starr Ranch building. Discussions are ongoing as to whether the structure should be demolished and re-built, or remodeled to make it habitable again. The facility would be used for short-term stays by the public, as well as longer term occupancy by visiting scientists and researchers conducting studies and collecting data within the Refuge. SRA was tasked with developing a feasibility study for providing electrical power to the Starr Ranch facility in an environmentally conscious, efficient, and cost-effective manner. This report summarizes the analyses and results of this study.

1.3 Technical Assistance Overview

The technical assistance provided to the Caddo Lake National Wildlife Refuge includes technical and economic analysis support in the areas of building load profile estimation, renewable energy technology screening, renewable energy system conceptual design and specifications, and economic feasibility assessment. In completing these tasks, the goal was to provide the FWS with current and accurate information on the costs of developing a renewable energy based off-grid electrical supply, and the economic value of pursuing this off-grid approach. Specifically, the analyses completed under this study were performed through the following six work assignment tasks:

- Task 1: Conduct Project Site Visit and Interviews with Key Stakeholders
- Task 2: Develop "Power Needs" Checklist
- Task 3: Identify Possible Renewable Energy Technologies, Applicable Regulations and any Applicable Financial Incentives
- Task 4: Finalize Renewable Energy Options Recommended for Starr Ranch Facility
- Task 5: Develop Renewable Energy Options Conceptual Design for the Starr Ranch Facility
- Task 6: Develop Feasibility Study of Conceptual Design Technology Package

These tasks were completed by SRA with assistance from Caddo Lake NWR personnel, EPA staff, and Friends of Caddo Lake representatives. All information and analyses in this report are based upon data provided by project participants, industry standard costs and modeling procedures, and current regulatory requirements as of November 2010. The information and results presented in this report may be subject to change based on changes in market conditions, regulatory or legislative initiatives, and/or technology advances.

The following report sections summarize the work assignment tasks completed for this project, and provide recommendations for next steps towards development of an off-grid electrical supply project for the Starr Ranch facility.

2 PROJECT SITE VISIT AND INTERVIEWS WITH KEY STAKEHOLDERS (TASK 1)

In this section, we provide an overview of the project site visit, which occurred on December 9, 2009. Activities conducted during the site visit include the project kick-off meeting (i.e., onsite interviews with key stakeholders) and a tour of the Starr Ranch site to evaluate renewable energy potential. Findings generated from the project site visit are described in detail in subsequent sections of this report. In addition, a complete summary of Task 1 was delivered to EPA as a stand-alone report in December 2009, titled: *Longhorn Munitions Plant Starr Ranch Renewable Energy Feasibility Assessment*.

The onsite project kick-off meeting commenced at 9:00 AM on December 9, 2010. Representatives from U.S. EPA Region 6 (Diana Hinds and Karen Peyke), FWS (Mark Williams and Paul Bruckwicki) and SRA International, Inc., (Joe Bourg) were present.

FWS representatives summarized the Starr Ranch facility refurbishing project and provided a briefing on the site's aging and inefficient electrical infrastructure. FWS introduced two proposals for the Starr Ranch facility refurbishing project: the first, to tear down the existing structure to its foundation and rebuild the structure on its original site footprint to salvage whatever materials and structures are still usable and restore the facility to its original condition and historical design. Regardless of how the structure is rebuilt, the building footprint and cubic feet of interior space would be nearly identical; therefore it was determined that neither option would materially impact the overall sizing of the renewable energy system.

The kickoff meeting participants also discussed overall site characteristics, potential constraints and opportunities for siting of renewable energy equipment, the current condition of the facility, site preparation requirements, and the applicability of various renewable energy technologies. It was agreed among all parties that designing the energy infrastructure for the Starr Ranch facility would incorporate off-grid renewable energy technologies.

A site tour was conducted of the existing structure at the Starr Ranch. SRA staff surveyed the site for locations to place renewable energy equipment, possible obstructions to solar photovoltaic / solar thermal equipment, opportunities for passive solar design strategies, and other opportunities and constraints of siting renewable energy equipment. The technical site visit (e.g., site walk-through) was divided into three components: 1) building interior survey, 2) building exterior survey, and 3) building perimeter survey.

Photos 2-1 through 2-5 illustrate site conditions.

Photo 2-1. EPA and FWS Starr Ranch Project Team (Paul Bruckwicki, Diana Hinds, Karen Peyke, L/R Mark Williams)

Photo 2-2. Starr Ranch Residence — Exterior

Photo 2-3. Main Living Area with Fireplace

Photo 2-4. Bedroom #1

Photo 2-5. View of Caddo Lake from Boat Ramp Adjacent to Starr Ranch Residence

The building interior survey revealed a structure that is in disrepair, but appears to be structurally solid. The building has only three small rooms that would be considered “interior” rooms—a main living area (Photo 3), a bedroom (Photo 4), and a small bathroom (no photo). These three rooms account for an interior space of 675 square feet, and would comprise the entirety of the conditioned space and the majority of electrical loads upon completion of the re-building process (see Section 3 for more detail). The rock walls that have southern and eastern exposure to the sun (see Appendix C, existing left side and existing rear elevations) could serve as an excellent thermal mass and supplement the heating needs of the building during the winter.

The building exterior survey indicated few sources of electrical loads. Those found include an electrical outlet and possibly lights for the screened-in front porch, and an electrical outlet and lights for the screened-in second bedroom. Neither of these screened areas will be subject to space conditioning. In addition, there is a separate, 185-square-foot outbuilding that was previously used as a kitchen. However, this structure is slated to be demolished; demolition of the kitchen structure will also provide more winter sun exposure to the rock walls if the thermal mass option is incorporated into the building design.

The orientation of the roof does not allow for placement of solar photovoltaic or solar thermal panels without compromising significant output; solar panels will need to be placed adjacent to the building in an area with no sun obstructions to the south. SRA suggested that the solar photovoltaic panels could be installed on the eastern side of the existing building, and that the panels could be integrated as the roof component of a shade structure. This shade structure would provide a cool place to gather outside during the summer for meals and socializing. A FWS representative asked if the Texas Smoker/BBQ unit already at the site could be placed under the panels. Mr. Bourg indicated that it could, as the panels would be high enough off the ground and above the smoker/BBQ’er to not be impacted by its heat. Solar panels do lose efficiency as the surface heat on the panel’s surface increases. However, the stove pipe would likely need to be modified to ensure that the smoke blows up and away from the panels. This is to ensure that soot and ash emitted from the stove pipe does not build up on the panels, which would impact their performance.

During the site visit, SRA presented a worksheet template that would allow participants to build the project's energy budget, and led a discussion of energy usage options for the facility. EPA walked the participants through a quick review of the work plan, and focused on next steps to move the project forward. EPA noted that the key deliverable from these next steps would be an "Energy Infrastructure Design Guideline" (now referred to as the "Conceptual Design" document) that could be used by the selected architects and engineers as an input into the redesign of the building.

3 "POWER NEEDS" CHECKLIST AND LOAD ANALYSIS (TASK2)

The first technical element of the renewable energy system sizing process is to develop an electrical load profile for the Starr Ranch facility. The electrical profile defines the daily, monthly, and annual loads that must be met with renewable energy generation and any back-up generation. Since no electrical loads currently exist at the site, SRA developed a load profile based on assumed electrical end-uses at the site as well as their frequency and duration.

For the development of the load profile at the Starr Ranch facility, a number of assumptions were required. One of the largest unknowns with respect to electrical usage profiles is the occupancy rate of the facility. Based on discussion with FWS personnel, it was determined that while the facility's occupancy patterns were likely to be intermittent, there would be periods of continuous occupancy. For example, visiting scientists or researchers may occupy the facility for extended periods of time while conducting research in the area. For off-grid renewable energy systems (which typically utilize battery back-up systems), it is important to design for the "worst-case" scenario in terms of maximum potential electricity usage. In this case, the worst-case scenario is that all end-uses are operating in a continuous manner for several or more days in a row. However, since the facility's occupancy patterns are expected to be intermittent, actual monthly and annual energy consumption will be less, providing some flexibility in the design load. In addition, actual daily energy consumption from the base load end-uses could be reduced if energy was used conservatively. For example, turning off the lights when not in use or minimizing / eliminating use of the microwave and hot plate would save moderate amounts of energy and maximize the use of the renewable energy generation.

Based on the constant occupancy assumption, SRA staff conducted research on applicable electrical end uses that would likely be installed by the FWS and/or utilized by inhabitants of the facility. These base load assumptions included lighting, appliances, groundwater pumping, and plug loads. In addition, SRA conducted research and interviews to determine what the likely usage patterns of these end-uses and appliances would be at a remote extended stay facility (i.e., vacation cabin). SRA conducted research to determine the lowest wattage end-uses for each of the measures identified for use in the facility.

As shown in Figure 3-1, the base load energy consumption of the Starr Ranch facility is estimated at 300 kWh per month, or 3,600 kWh per year. This level is commensurate with that of base load energy consumption of a small house occupied full-time.

The heating and cooling design loads were estimated in a slightly different manner than the design loads for the base load end-uses. SRA conducted research to determine the measures and duration of usage of heating and cooling equipment, by far the largest end-use at the facility comprising an estimated 60 percent of the total electrical load.

Since it is unknown whether the structure will be remodeled or razed/rebuilt, it is difficult to estimate the "tightness" of the building envelope as well as the level of insulation that will be used. While it is recommended that the exterior facing walls should be insulated to achieve a minimum of R-15, and attic insulation of between R-30 to R-60 to maintain interior temperatures and reduce the electrical requirements of the heating and cooling system, the final design of the Starr Ranch building structure is currently unknown with respect to R-values of insulation and windows, passive solar design features, and other weatherization measures. Therefore, it was determined that the best approach would be to provide a daily energy allowance for heating and cooling equipment.

Based on the square footage of the conditioned space within the structure, it was estimated that an energy budget of 15,000 watt-hours/day (15 kWh/day) would allow for sufficient heating and cooling of the building. This budget would allow for a 1500W window air-conditioning unit to run for 10 hours per day, or a low-wattage propane furnace blower fan continuously, if needed. Other heating configurations are also possible within this energy budget, including running a 1500W electric resistance heater for 10 hours a day supplemented with heat from the existing fireplace. The heating and cooling allowance of 15 kWh/day should be more than adequate to keep the space comfortable and within temperature parameters. The electrical load for heating could be reduced if the fireplace was maintained in the structure and used as a primary or secondary heat source.

To ensure that this energy budget is adequate, it is recommended that a programmable thermostat be installed with minimum temperature set-points for cooling, and maximum temperature set-points for heating to prohibit the space from being over-conditioned. Also, since there is no need to condition the space when it is not occupied, except in extreme cold weather conditions where pipe freezing is possible, the thermostat should be turned off when occupants leave the building.

The 15 kWh per day heating/cooling allowance comprises 60 percent of the total electrical load of the facility, and also provides for some flexibility in the monthly energy budget. If the building is not occupied, or if the ambient temperature is comfortable, then the heating/cooling allowance will not be consumed that day, and instead could used to charge the battery back-up system if needed.

END USE	Location	Quantity	Watts	Hrs/Day	Days/Week	Watt-hrs/day
Lighting						
25 Watt CFL	Kitchen Area	2	25	4	7	200
25 Watt CFL	Screened Front Porch	2	25	2	7	100
25 Watt CFL	Main Bedroom	2	25	4	7	200
25 Watt CFL	Bedroom #2 / Screened	1	25	2	7	50
25 Watt CFL	Living Room	4	25	6	7	600
25 Watt CFL	Bathroom	1	25	2	7	50
25 Watt CFL	Outdoor Area / BBQ	4	25	4	3	171
Appliances						
Sunfrost RF19 Refrigerator/Freezer	Kitchen Area	1	48	24	7	1152
Washing Machine	Main Bedroom	1	600	1	3	257
Groundwater Pumping						
1/2 HP Surface Jet or Submersible Well Pump	TBD	1	900	2	7	1800
Plug Loads						
Laptop Computers (intermittent use)	Living Room	3	180	4	7	2160
Printer	Living Room	0.5	50	1	7	25
Entertainment System	Living Room	1	120	4	7	480
Coffee Maker	Kitchen Area	1	900	1	7	900
Microwave	Kitchen Area	0.5	900	1	7	450
Hot Plate	Kitchen Area	1	1400	1	7	1400
SUBTOTAL OF BASELOAD END-USES						
TOTAL WATT-HOURS PER DAY						9996
TOTAL KWH PER MONTH						300
Heating & Cooling						
Heating/Cooling Electrical Allowance	Main Structure	1	1500	10	7	15000
TOTAL OF BASELOAD AND HEATING & COOLING END-USES						
TOTAL WATT-HOURS PER DAY						24996
TOTAL KWH PER MONTH						750

Figure 3-1. “Power Needs” Checklist and Electrical System Load Sheet

The energy usage profiles calculated above are for daily and monthly electricity supply requirements. It is also helpful for the generation sizing calculations detailed later in the report to estimate annual electricity requirements for both base load and total (with heating and cooling loads) end-uses, as follows:

- Annual base load electricity requirements: 300 kWh/month X 12 months/year = 3,600 kWh/year
- Annual total electricity requirements: 750 kWh/month X 12 months/year = 9,000 kWh/year

It is important to point out that the electrical load profile illustrated above is based on full-time occupancy and normal usage of all the end-uses in the structure. This is due to the "worst-case scenario" design strategy to ensure that the facility has power at all times, and that no damage is done to the electrical generation or battery storage equipment should power demands exceed power supply capabilities. As such, the load profile illustrated above could be significantly reduced if occupants utilize electrical appliances conservatively, as well as not overheating or overcooling the space. Further, since 60 percent of the load is estimated to result from heating and cooling requirements, occupants should be instructed to turn off the thermostat when they leave so that the building is not heated or cooled between periods of occupancy.

4 IDENTIFICATION OF RENEWABLE ENERGY TECHNOLOGIES, APPLICABLE REGULATIONS AND APPLICABLE FINANCIAL INCENTIVES (TASK3)

4.1 Identification of Renewable Energy Technologies

One of the initial tasks of the Starr Ranch energy supply feasibility assessment was to conduct a screening analysis of applicable renewable energy technologies. Based on the interviews with FWS and EPA project staff during the site visit, it was determined that an initial set of renewable energy technologies had potential at the Starr Ranch site, including:

- solar photovoltaics,
- small wind turbines,
- solar domestic hot water heating,
- solar radiant floor heating w/ solar absorption chiller space cooling, and
- a water-source heat pump for space conditioning.

The following sub-sections of this report describe the reasons why each of the above technologies were included or excluded from the final recommended renewable energy technology package.

4.1.1 Solar Photovoltaics

The Starr Ranch facility is located in a very good solar resource area, and is well suited to PV energy production. The site itself has several areas that provide year-round unobstructed solar access and are ideal for siting a PV array. The decision-point in the screening analysis was not whether to include PV in the recommended technology package, but rather what type of PV technology should be employed. There are two main types of PV technologies, crystalline and thin film, and each has a unique set of advantages and disadvantages. The advantages of crystalline silicon (single and multi-crystalline) PV technologies are:

- higher energy conversion efficiencies (~14-20+ percent),
- long history of proven performance,
- less performance degradation over time, and
- higher power density / less area required.

The advantages of thin film (amorphous silicon, CdTe, CIGS) PV technologies are:

- slightly lower costs,
- lower efficiency losses at higher temperatures,

- some thin film modules weigh significantly less than crystalline modules, and
- better performance in diffuse sunlight conditions.

In reviewing the pros and cons of these two technologies, several factors led to the selection of crystalline silicon technology over thin film. The primary reasons were its long track record of proven in-field performance, and the lower rate of module performance degradation over time. Crystalline PV panel's output performance degrades at a rate of about 0.5 percent per year, while thin film output performance degrades at a rate of about 1.0 percent per year. Over the expected 30-year life of the system, this means that output of crystalline system may decline by as much as 15 percent at end of life, while the thin film system's output may decline by as much as 30 percent over the same period. Furthermore, thin film is still a relatively new technology without the proven long-term performance exhibited by crystalline products. Since the PV system is anticipated to be the primary source of power generation site, and the site's electrical loads are expected to remain relatively constant over the next 30 years, it is important to minimize annual performance losses due to module degradation. For example, if the energy output of the PV system falls below the electrical loads it is designed to serve due to module degradation, then auxiliary power generation sources will be needed to supplement the PV system. Auxiliary power generation for off-grid applications typically includes a fuel-based electrical generator, which is extremely expensive to run. Therefore, the crystalline silicon PV technology was selected for inclusion in the conceptual design package based its ability to better serve anticipated electrical loads at the site over time.

4.1.2 Small Wind Turbines

Based on a review of the National Renewable Energy Laboratory's wind resource maps for the State of Texas, it does not appear that the Caddo Lake area meets the minimum screening criteria for small wind turbine power production. While the Starr Ranch site may have some potential for wind generation based on micro-climate conditions, further investigation and data collection would be required to verify its applicability to the site. However, based on discussions with FWS personnel, it was determined that a small wind turbine would not be appropriate for the site due to threat of potential bird kills. While the bird kill issue has largely been alleviated with large wind power turbine technology using slow rotating blades, small wind turbine blades rotate at high RPMs and may pose a hazard to birds. Since Starr Ranch is located within the Caddo Lake National Wildlife Refuge, home to a large population of both migratory and permanent residence birds, the small wind option was not selected for inclusion in the conceptual design technology package.

4.1.3 Solar Domestic Water Heating

Solar water heating (SWH) systems provide a simple and efficient solution for providing hot water for such domestic uses as showers, hand washing, food washing, and dish washing. SWH systems have been employed around the world—even in cold climates with technologies that provide freeze protection. Since the Starr Ranch facility is anticipated to include a shower and two or more faucets as part of the building refurbishment project, hot water will be required at the site. Hot water requirements could be adequately served by a solar hot water heating system coupled with a storage tank and a small back-up fuel-based (e.g., propane) hot water heater. The primary concern associated with specifying a solar water heating system at Starr Ranch is whether the hot water needs at the site will be high enough to make the use of a SWH system economical. The use of a SWH system at Starr Ranch was included in the conceptual design technology package for further analysis.

4.1.4 Solar Space Heating and Cooling

One of the biggest concerns associated with the development of the design day load profile for Starr Ranch was determining how to heat and cool the building in the most energy and cost efficient manner. One of the options explored was the use of a large solar water heating system that would provide hot water to a radiant floor heating system in the winter and a small absorption chiller in the summer to provide space cooling. While the solar heating and cooling option was intriguing, it was not included in the conceptual design technology package for several reasons. First, solar radiant floor heating technology has a very high initial cost, particularly in remodel/retrofit applications, and would still require a fuel-based back-up boiler (e.g., propane). Secondly, while solar absorption chillers are emerging in the marketplace, they are only available in commercial-scale sizes. The smallest unit available on the market today is a 30-ton system, which would be grossly oversized for Starr Ranch application. Smaller, residential-sized units are expected to come on the market within the next 2-3 years, but are currently not commercially available. Due to the fact that small solar absorption chillers are not commercially available, neither it nor solar the radiant floor heating system were included in the conceptual design technology package. Without the solar absorption chiller, the solar water heating system would have no load to serve during the summer months, which would make the system less economical and require that the solar panels be covered during the summer or excessively hot water purged from the system to avoid overheating and possibly damaging or ruining the system.

4.1.5 Water-Source Heat Pump

Another option investigated for meeting the heating and cooling requirements of the Starr Ranch structure was a water-source heat pump. FWS personnel were very interested in this option during the site visit and suggested possible locations in Caddo Lake adjacent to the building where the water loop could be safely placed away from potential hazards such as a dragging anchor from a recreational boater. However, for water source heat pumps to be most efficient for space cooling requirements, the water loop should be at least 30 feet deep in the Lake. Based on a review of the lake temperature data provided by FWS personnel, it was determined that the use of a water-source heat pump was technically feasible for the location. However, while water-source heat pumps are very efficient technologies for providing space heating and cooling, they do have large electricity consumption requirements and high duty cycles as a result of the need to pump through the loop and to operate the heat pump unit itself. As a result of the high electrical energy requirements associated with a water-source heat pump, it was determined that the PV system size would have to be significantly increased and as such would be cost-prohibitive. Therefore, the water source heat pump option was not included in the conceptual design technology package.

4.1.6 Renewable Energy Technology Screening Summary

Based on the screening analysis of renewable energy technologies described above, only the PV system and the solar hot water system were included in the conceptual design technology package. While other technology options were analyzed, they were either deemed not appropriate for the location due to FWS policy concerns (e.g., wind turbines presenting hazards to birds), their operating characteristics, lack of commercially available residential-scale technology, or high cost.

These results are to be expected, as the most common renewable energy technology mix for off-grid applications is PV and SWH. However, both of these technologies require back-up systems to ensure an uninterrupted supply of electricity and hot water when required. Therefore, while both technologies passed the screening analysis and are included in the conceptual design technology package, the package was expanded to include 1) a battery bank to store PV generated energy for use at night or when facility loads exceed PV system output, 2) a back-up propane generator to provide electricity when the battery bank has been drawn down to maximum allowable levels, and 3) a back-up propane water heater to meet hot water requirements not met by the solar water heating system.

4.2 Summary of Federal and State Incentives for Off-Grid Renewable Energy Systems

There are no federal renewable energy incentives that apply to the proposed PV installation at Starr Ranch. The only direct incentives from the federal government are in the form of individual and corporate tax credits, which are not applicable to federal government entities such as the FWS. However, Caddo Lake NWR may be eligible for funding through the following two programs:

- **Federal Renewable Energy Requirement (EPACT)**
  - The U.S. Government Green Power Purchasing Goal expanded goals and standards to promote renewable energy use in existing and new federal buildings. According to the guidance provided by the DOE Federal Energy Management Project, a bonus equivalent to doubling the amount of renewable energy used or purchased is available if the renewable energy is produced and used on-site at a federal facility.
    - http://www1.eere.energy.gov/femp/renewable_energy/renewable_fedrequire.html
- **Department of the Interior Recovery Act Investments**
  - The U.S. Fish and Wildlife Service is investing $8.4 million in American Recovery and Reinvestment Act funding in energy efficiency retrofitting projects at National Wildlife Refuges. Many of these FWS Recovery Act projects will install renewable energy sources and improve current building standards (including LEED certification) at FWS facilities.
    - More information is available at http://recovery.doi.gov/press/bureaus/us-fish-and-wildlife-service/us-fish-and-wildlife-service-energy-efficiency-retrofitting-projects-under-the-american-recovery-and-reinvestment-act/.
    - Contact: recoveryact@fws.gov.

At the state level, the Texas Renewable Energy Mandate establishes a Renewable Portfolio Standard that includes a target of 500 MW of non-wind renewable energy. However, A PV installation at Starr Ranch is not affected by this legislation, because the mandate applies only to grid-connected renewable energy purchased by electricity retailers.

At the utility level, the Starr Ranch facility is located in the service area of Southwestern Electric Power Company (SWEPCO). SWEPCO does not currently offer financial incentives for solar power development, and does not purchase Renewable Energy Credits from off-grid projects.

5 RENEWABLE ENERGY SYSTEM RECOMMENDATIONS AND CONCEPTUAL DESIGN (TASKS 4 AND 5)

A key component of the Starr Ranch renewable energy feasibility study is the development of a conceptual design. The conceptual design describes how the renewable energy and back-up generation and storage systems work together to meet the facility's load requirements. It also provides technical specifications and cost estimates for individual system components, as well as preferred locations for those components. As a package, the conceptual design provides:

- Detailed guidance for the final engineering design,
- Documentation of system specifications that can be inserted in bid documents, and
- An estimate of the total system cost that supports the economic analysis portion of the feasibility study.

In planning the renewable energy system for the Starr Ranch facility the system sizes, components and design choices were optimized to meet the projected electrical loads of the facility in the most cost-effective, efficient, and environmentally sound manner. As an off-grid system, it must also be designed to meet full load conditions with renewable energy generation and battery storage for days on end, while minimizing the use of a back-up generator. As discussed in Section 3, the energy infrastructure design should assume near-constant occupancy. In this manner, the facility is less likely to run out of power for lighting, space conditioning, water pumping, etc. It is important to note that the full time occupancy assumption is for system design purposes only and represents the most demanding type of design scenario.

Combining the base load consumption estimates with the heating/cooling energy allowance results in design loads of:

- 25 kWh/day,
- 750 kWh/month, and
- 9,000 kWh/year.

These design loads determine the size of the energy system components (i.e., PV, batteries, gen-set) with the goal of maximizing the use of PV generation with batteries and minimizing the use of the propane generator. For example, in order to provide for the total daily load of the facility, a minimum 9 kW DCp (DC peak output) photovoltaic array would be required for a "photovoltaic only" power source. This is defined by the lowest solar radiation months of December and January, wherein a 9 kW PV system would be required to generate the necessary 750 kWh for those months. As the actual occupancy is more likely to be intermittent, and the resulting energy load would be lower than the design load, the addition of a 14 kW propane back-up generator allows for the down-sizing of the PV system to ~6 kW. In this configuration, the back-up generator picks up the difference of any loads in excess of the PV system power supply.

5.2 System Specifications and Estimated Costs

This section of the conceptual design provides descriptions, specifications, and costs for the technology components of the off-grid energy generation and storage system. As a supplement to the technology summaries below, a sample single line electrical schematic of the conceptual design is provided in Appendix D. In addition, sample product data sheets for the energy system components are provided in Appendix E to provide examples of product specifications used to develop the conceptual design. The product data sheets are for illustrative purposes only, and define technology specifications that can be used in soliciting bids for equivalent products available in the market.

The solar photovoltaic panels specified for the conceptual design are industry standard 175W to 235W single or polycrystalline modules with minimum 25-year warranties. The choice of modules is largely dependent upon current market pricing and availability, as well as compatibility with the selected mounting system. As the panels chosen may range between the 175-235 wattage ratings, and the mounting systems specified for this design have defined module configurations (i.e., 3 rows of 12 modules), the photovoltaic system size may range from 6300WDCp with 175W modules up to 8460WDCp with 235W modules. For the purposes of the conceptual design analysis the 175W module was selected, resulting in a total system size of 6300WDCp.

The photovoltaic panels are anticipated to account for $3.00/Watt of the total system cost.

Mounting System for Photovoltaic Panels

During the site visit to the Starr Ranch facility, the project team assessed several options for the siting of a potential PV array. A roof mounted system is not possible due to potential load bearing issues, as well as limited space on the south facing roof pitch. Therefore, a ground- or pole-mounted support structure would be warranted.

The mounting system / canopy structure options that were selected for the photovoltaic array were conceived with economy of installation and ease of maintenance in mind (cleaning of panels, hosing down and/or wiping with dust retardant/cleanser). Either a multi-pole mounting system or canopy-roof structure may be utilized as an awning structure over or adjacent to the BBQ area. The choice between the two mounting structures depends as much on aesthetics as on ease of installation. The multi-pole system is likely to be the more economical of the two, since the main support system is accomplished by a series of single poles in a straight-line configuration, supporting a horizontal pole upon which the array superstructure may be mounted. The installation of the multi-pole system would be accomplished by setting the poles in concrete at depth (amount of concrete and depth to be determined by soil engineering requirements). The system as configured is set at three rows of 12 modules, totaling 36 photovoltaic modules for the complete system—all on a single or double line of poles. Layout of the system may depend on coverage area and shape of awning structure desired. This multi-pole system will cover an area of ~600sf with the specified 175W panels. The panels should be installed at a 30-degree angle facing True South to maximize for annual energy production, as well as to slightly boost production during the summer months when air conditioning loads are highest.

Mounting System Option 1: Multi-pole Mounting System

The multi-pole mounting system is likely to result in the most efficient cooling and operation of the photovoltaic array, given that the modules specified in the system will be of single or poly-crystalline type. This is due to the fact that crystalline modules experience conversion efficiency losses as the module temperature rises, so it important to design the PV array to allow for adequate air flow to the back of the module to cool it. While the multi-pole mounting system will provide shade, it will not necessarily provide rain cover due to the spacing between the modules and lack of a roof beneath the solar array. Photo 5.1 below illustrates an example installation of a multi-pole mount shade structure. Note that pitch angle of the PV array will not be as steep for the Starr Ranch installation as the one depicted in the photo below. A representative product data sheet for multi-pole mounting structures is provided in Appendix E.

Mounting System Option 2: Canopy-roof Structure

Alternatively, a roof structure may be constructed over the BBQ/common area that will allow for a standard rail mounting system to be attached once the canopy structure is completed, thus providing a rain cover to the area and a solid roof structure to mount the rails and panels. If this alternative is chosen, the mounting system cost will be reduced by approximately 50 percent, although it will be additional to the cost of building the canopy support structure. As such, this may be an economic equal to the multi-pole system, or cost more depending on engineering design considerations. If this mounting system is chosen, the rails should be mounted a minimum of 4” to 6” off of the roof surface itself to allow for adequate cooling and efficient operation of the photovoltaic modules.

The multi-pole mounting system, with concrete and pole base structure, is anticipated to account for $1.20/Watt of the total system cost.

5.2.3 Inverter / Charge Controller System

Solar energy is generated in direct current (DC) and needs to be converted to alternating current (AC) to provide useful power for common end-uses. An inverter is an electrical device that inverts DC power into AC power. In off-grid applications, a battery back-up system is typically utilized to meet energy requirements when the loads are higher than PV system output or during nighttime hours. In order to charge the batteries, the inverter must have a charge controller to regulate the power going from the solar panels to the batteries. Overcharging batteries will at the least significantly reduce battery life and at worst damage the batteries to the point that they are unusable.

The inverter(s) specified for the conceptual design should be rated at ~4,000 watts of continuous power 120/240 VAC @ 60hz single phase operation. The inverter should also contain a maximum power point tracking (MPPT) solar charge controller compatible with 24V batteries. The 4,000 watt inverter size was selected as it is the optimal match of size and cost. Increasing the inverter wattage rating would increase the cost of the inverter itself, and most of the larger inverters with charge controllers are configured for 48V batteries which would result in nearly doubling the cost of the battery bank. Product data sheets for a representative inverter and supporting components are included in Appendix E.

The inverter(s) may also be tied to the generator with an auto-start configuration that is based on the inverter's capability to monitor the battery bank voltage level. This configuration will enable a user programmable maintenance level of battery state of charge at no less than 70 or 75 percent. The generator auto-start module is available for 4000W inverter systems and provides the most economical system sizing configuration for both the solar photovoltaic system and the generator operations cycle. The system is programmable to enable a generator maintenance run/stop sequencing of one hour of run time every thirty days, regardless of the battery bank charge level. This takes care of both the unknown potential duty cycle of the generator side of the system, as well as a maintenance level running of the generator to provide consistent operating performance and lubrication. The monthly maintenance sequence also keeps the generator start battery in proper condition to respond to variable battery bank voltage level operation.

The inverter specified for the conceptual design of the Starr Ranch PV System should also employ the following accessories:

- photovoltaic input breaker combiner boxes,
- Maximum Power Point Tracking (MPPT) photovoltaic charge controllers, and
- a power distribution panel for PV controller inputs and outputs, inverter AC power inputs and outputs, as well as generator and additional auxiliary power source and load circuitry.

The power distribution panel simplifies the safety and routing issues, per NEC requirements, to a main AC load distribution panel for the facility. A second inverter may also be considered to double the AC output or provide the second 120VAC leg of the system to the facility (if the inverter chosen is not capable of 240VAC output). Representative product data sheets for the inverter accessories are provided in Appendix E. There are a number of manufacturers that produce comparable or equivalent components that meet the specs for this system.

The inverter with accessories (generator start module, MPPT solar charge controllers, combiner boxes and photovoltaic panel series circuit breakers) is anticipated to account for $0.80/Watt of the total system cost.

5.2.4 Battery Bank Equipment

The battery bank is sized according to the daily design load in order to provide two to three days of autonomy (cloudy weather storage) without dropping below a 75 percent battery charge level using 16 maintenance-free 6Vdc nominal L-16 AGM (or equivalent) batteries wired in a 4 in-series, 4 in parallel configuration. With a load profile of 10,000 Watt-hrs/day for the base load (excluding the space conditioning load allowance of 15,000 Watt-hrs/day), the total daily amp-hour load at the system designed 24Vdc nominal system voltage is 416 Amp-hrs/day. The battery bank capacity is approximately four times that at 1620 Amp-hrs, thus a daily amp-hour usage and replenishment of 416 amp-hrs will create a ~25 percent draw on the solar power array. While the 6.3 kW PV system will provide approximately 20-30 kWh daily (varying according to time of year and weather conditions) this will allow ample power to operate the space conditioning equipment with minimal generator run time (or none), thus extending generator life, reducing generator maintenance, and lowering propane fuel costs. Battery banks have an expected life of ~7 years, and should be budgeted and scheduled for replacement accordingly.

The battery bank should be mounted in a sealed vented enclosure as required by the National Electric Code, and placed in an area accessible only to trained maintenance personnel. Final system design will depend on placement of this utility area with respect to the other electrical panels and sub-panels served by the system.

The battery bank is anticipated to account for $1.50/Watt of the total system cost.

5.2.5 Propane Backup Generator

A back-up generator is typically a standard component of an off-grid PV system with battery storage back-up. Even though the PV system with battery back-up is sized to meet the projected energy requirements of the Starr Ranch facility, there may be periods when the back-up generator will be required to run to meet hourly loads. For example, the back-up generator will need to run in situations where there are several cloudy days in a row that reduce the PV system's output and the battery bank is drawn down to the 75% charge level; conversely, the generator may also need to run on hot summer days when the air conditioning load exceeds the PV output and battery drawn down levels reach 75%.

Based on discussions with FWS personnel early in the project, they stated a preference for a low RPM propane generator. While the goal of the conceptual design process is to minimize back-up generator run times, it is also to minimize the noise to the surroundings when the generator is running. A low RPM generator is much quieter than a higher RPM model, although low RPM models should still be enclosed in noise-attenuated structures to minimize noise pollution. The back-up generator should be used only as an emergency energy supply, and not a supplemental energy supply to the PV system as that is the role of the battery bank. Propane generators are expensive to run, and cost in the $7-$8/kWh range at current propane price levels. Occupants and visitors to the Starr Ranch facility should be informed that if the back-up generator turns on, they should begin turning off all non-essential electrical items to minimize the generator run time and save energy and dollars. While the back-up generator is expensive to run, it is an essential component to the overall energy package in terms of providing emergency power and protecting the battery bank from being overdrawn and potentially damaged.

The back-up generator specified for the conceptual design is an 1,800 RPM, 14 kW propane generator capable of producing 120/240 VAC @ 60 Hz frequency, single phase. Not only is the 1,800 RPM model quieter than the more standard 3,600 RPM model, it also has a longer in-service life. The 14 kW size was selected for a number of reasons. First, there is not a wide selection of generator sizes in the 1,800 RPM models. Second, the generator must be sized to meet instantaneous design loads at the facility. In the event, however unlikely, that all the end-uses at the Starr Ranch facility were operating simultaneously, the load would be approximately 7 kW. If the generator were to turn on to meet this load, by default this would mean that the batteries were in a maximum draw-down state, and the generator would also have to provide 4 KW of power to begin charging the batteries back up. As a result, the design load for the back-up generator is 11 KW. However, the next available size up for 1,800 RPM is 14 kW, and the next size down is 8.5 kW. Fortunately, the cost difference between the 14 kW model and 8.5 kW model is minimal. Product data sheets are provided in Appendix E of this report. Note that the data sheet is for the 12 kW model, which has been discontinued and replaced with the 14 kW model; there is no product data sheet available yet for the 14 kW model, but the specifications are nearly identical.

The generator is anticipated to account for $0.80/watt of the total system capital cost, not the system operational cost (this does not include the cost of a propane tank).

5.2.6 Soft Costs

In addition to the capital costs for the system equipment (i.e., PV system, batteries, and gen-set), soft costs such as installation and balance of system costs need were considered in this analysis. Installation labor costs for the system were estimated to be $1.50/watt and balancing of system costs were estimated at $0.50/watt. Therefore, the total estimated soft costs for the system are $2.00/watt.

5.2.7 Total Installed Energy System Cost

The turn-key cost of the complete PV system, including batteries and soft costs, but excluding the back-up generator, is estimated at $8.50/watt. This cost estimate is based on research of solar module and component costs in the market today and includes system design, equipment mark-up, profit, labor and shipping. The cost estimates do not include tax as the Starr Ranch facility is part of the FWS' Caddo Lake National Wildlife Refuge, which is tax-exempt as a federal agency. As such, the solar energy system specified for the site does not qualify for any federal tax incentives.

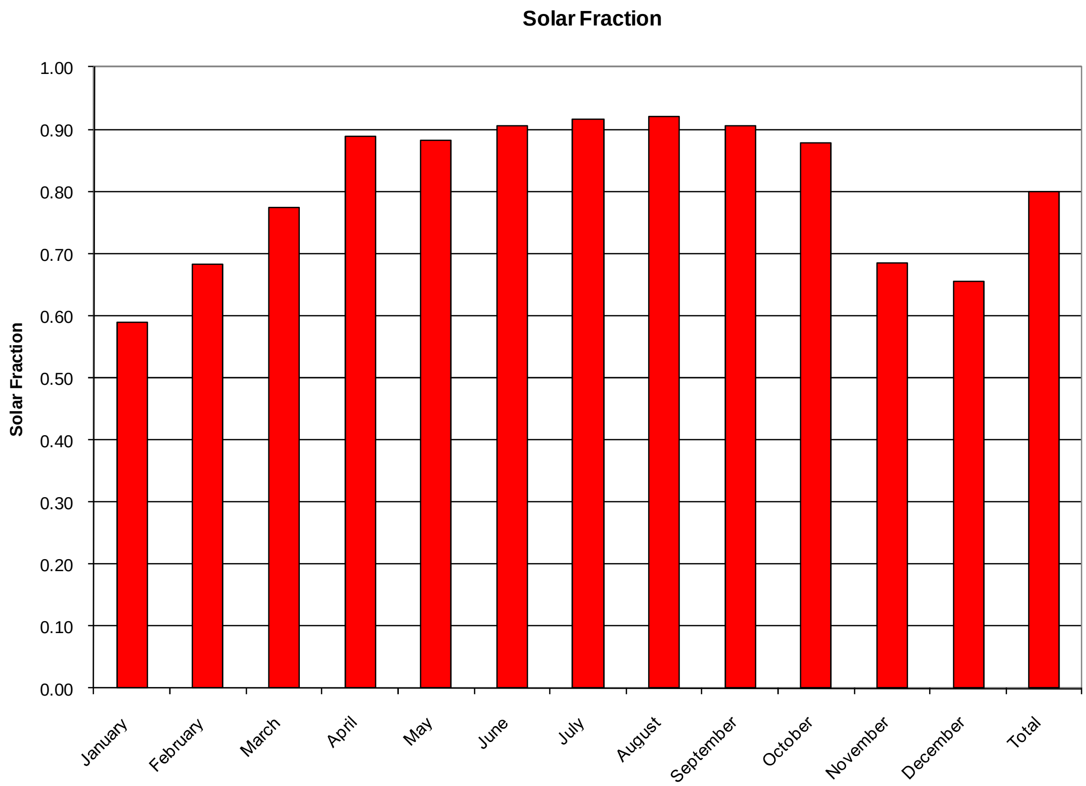
As mentioned in the previous section, the cost of the back-up generator is estimated at $.80/Watt, resulting in an "all-in" cost estimate of $9.30/Watt. In total, the PV system package is estimated to cost approximately $56,000, and the complete energy package including the back-up generator is estimated to cost approximately $67,000. It is important to note, however, that these cost estimates are based on current market conditions and could change. Further, the cost estimates could be impacted by the selection of specific modules, availability of local integrators/installers, and engineering requirements and design modifications as a result of soil conditions at the site. Figure 5-1 below provides a break-down of estimated costs by energy package component.

Component	$/Watt	Total
Solar Panels	$3.00	$18,900
Mounting Structure	$1.20	$7,560
Inverter w/ Charge Controller	$0.80	$5,040
Batteries	$1.50	$9,450
Balance of System Costs	$0.50	$3,150
Installation Labor	$1.50	$9,450
Materials Shipping		$2,500
PV System Sub-Total	**$8.50**	**$56,050**
14-kW Propane Generator	$0.80	$11,200
PV System w/ Gen-Set Total	**$9.30**	**$67,250**

Key Costs of PV/Battery/Gen-Set Energy Package

5.2.8 Solar Hot Water System

The final element of the conceptual design development was to analyze the potential for solar hot water heating at the Starr Ranch facility. SRA conducted an analysis of the benefits of a solar hot water system utilizing the National Renewable Energy Laboratory's (NREL) TRNSED simulation tool to determine energy savings attributable to offsetting fuel consumption from a propane water heater. Based on this analysis, it was determined that 80 percent of the hot water needs of the facility could be served by a solar hot water heating system. The percentage of hot water demand that can be met with a solar water heating system is known as the "solar fraction." Figure 5-2 below illustrates the monthly and annual solar fraction of a solar water heater at Starr Ranch.



While the solar fraction is high for this location, that is only part of the equation. The analysis assumed a two-panel glycol heat exchange solar hot water system with a daily hot water demand of 40 gallons. Since the facility should be fitted with a water efficient showerhead and low-flow faucets, 40 gallons per day is a reasonable assumption for this application. The analysis also assumed a 40 gallon hot water storage tank with propane backup. Based on these assumptions, the NREL simulation model estimated annual propane savings of ~98 gallons per year. With current propane prices at ~$2.75 gallon, the total dollar savings is ~$270 per year. Installed costs of a two-panel glycol solar hot water system are currently in the $8,000 range, resulting in a simple payback period of ~30 years, which is longer than the expected life of the solar hot water system. The analysis also assumed full-time occupancy of the structure with a constant daily hot water demand of 40 gallons per day, so with intermittent occupancy the savings values are further reduced. As a result, the economic value of a solar hot water system is limited at best. However, a solar hot water system at the site could still be employed as part of the renewable energy package supplying energy to the site and incorporated into the environmental theme of the location. While it is not included as part of the final conceptual design, it can still remain an option at the discretion of the FWS and other stakeholders.

5.3 Renewable Energy System Conceptual Design Summary

The Starr Ranch renewable energy conceptual design utilizes a PV/Battery/Gen-Set hybrid system with the PV and battery back-up sized to meet the majority, if not all, of the predicted loads at the facility.

- Supplemental power is supplied, when necessary, by an auto-start propane back-up generator.
- The back-up generator is triggered by programmable battery bank voltage parameters designed to maximize battery life and performance, while minimizing generator run time and propane consumption.

- Operations and maintenance requirements of the entire system should be minimal based on the limited maintenance of the PV system (periodic module washing), the specification of maintenance-free sealed batteries, and a back-up generator with limited maintenance (periodic oil and spark plug changes).
- State-of-the-art inverter technology provides high quality power that accommodates the use of delicate electronics such as computers, printers, and satellite communications equipment without the surge characteristics that might be found in conventional utility power supplies at the end of radial distribution lines.

Hybrid PV/Battery/Gen-Set systems, when properly designed and installed, provide reliable and high quality power to off-grid end-users.

6 FEASIBILITY STUDY OF CONCEPTUAL DESIGN TECHNOLOGY PACKAGE (TASK 6)

The feasibility assessment of the Starr Ranch off-grid energy system is focused on determining: 1) the technical feasibility of the PV/Battery/Gen-Set energy supply package in meeting projected daily, monthly, and annual electrical loads of the facility, and 2) the economic feasibility of the project when compared to utility supplied power which requires an expensive distribution line extension.

6.1 Technical Feasibility

The conceptual design of the off-grid renewable energy system at Starr Ranch detailed in Section 5 is based on selecting and sizing the PV and battery storage components to meet estimated design day loads for several days in a row without the use of the back-up propane generator. These moderate-to high level energy design day requirements were then extrapolated to estimate the maximum monthly and annual energy requirements under year-round occupancy conditions. Under the daily design load and constant occupancy conditions, it was determined that a 6.3 kW DCp PV array with battery storage would be able to meet the vast majority of the monthly and annual energy requirements at the site. Figure 6-1 below illustrates the facility's monthly energy requirements of 750 kWh under continuous occupancy and moderate energy usage conditions compared to the monthly output of the specified 6.3 kW PV array.

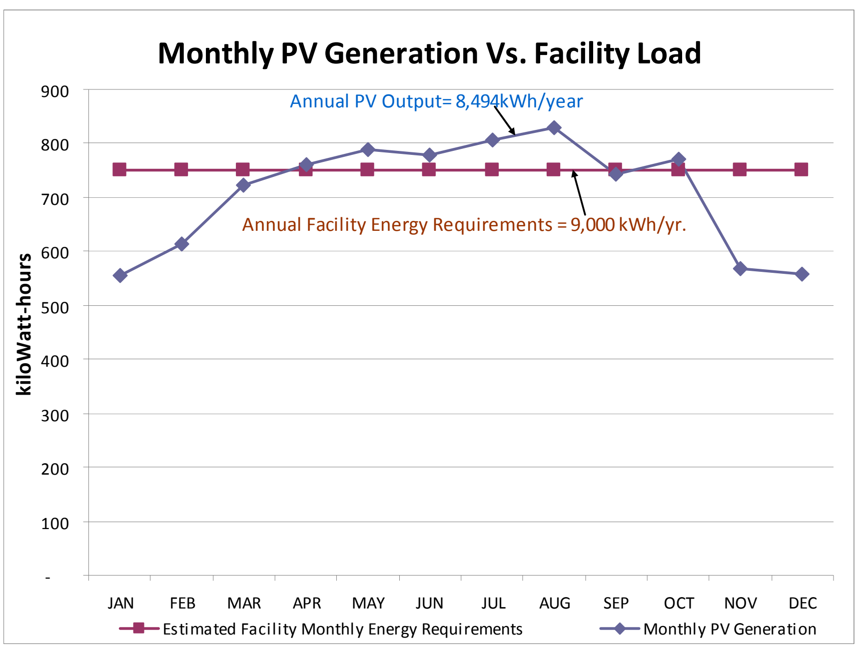


Figure 6-1. Monthly PV Energy Generation Vs. Design Day Facility Energy Requirements

As seen in Figure 6-1, the energy generated by the PV system and stored in the battery bank would meet the design-day based monthly energy requirements for the majority of the months in the year without the use of the back-up generator. The PV/Battery system would fall short of meeting energy requirements in the winter months due to lower PV production. However, the energy requirements in the winter months include a 15 kWh/day heating energy allowance which is likely high, assuming that an electric resistance heater is not used. Installation of a propane furnace with a low wattage fan blower would reduce the energy allowance for space heating and bring the monthly energy requirements in line with PV production without the need for back-up propane generation.

Furthermore, the projected monthly and annual energy requirements of the facility are based on continuous occupancy. If, for example, the facility's occupancy rate was lowered to 50 percent, then the projected energy requirements would correspondingly be reduced by 50 percent and possibly more if occupants used energy efficiently and in a conservative manner. If facility occupants operated electrical end-uses in line with the design day guidelines, even a slight reduction in the assumed occupancy rate would bring monthly PV energy production in line with facility energy requirements and eliminate the need for back-up generation except on rare occasions. With these more "real-world" operating characteristics in mind, it can be seen that the PV/Battery system should be able to easily meet the monthly and annual energy requirements at the site. While it would appear that under a reduced occupancy and energy conservation-minded operating scenario that the PV system may be oversized, it is important to note that the design day load requirements drive the PV system size requirements. Due to the fact that there is no control over individual occupant's energy consumption, and some of them may not be aware of the limitations of an off-grid energy system, it is imperative to size the PV and battery storage system for the worst-case scenario. As such, the specified PV/Battery/Gen-Set energy package provides the optimal mix of generation supply and cost efficiency to meet a wide range of potential loads at the facility.

6.2 Economic Feasibility

The economic feasibility of the off-grid energy supply package detailed in the conceptual design is determined by comparing the annual cash flow of utility provided power with a line extension to the cash flow associated with the PV/Battery/Gen-Set package. Based on the cash flow analysis for each energy supply option, economic metrics are calculated to determine the levelized cost of energy of each option, as well as the real dollars savings (2010 dollars), net present value, benefit cost ratio, and payback period of the conceptual design technology package.

Economic Analysis of Utility Provided Power

The Starr Ranch facility is located in the service area of Southwestern Electric Power Company (SWEPCO), but there is currently no power distribution line to the site. In order for the facility to receive utility provided power, a line extension of approximately 2.75 miles would be required. The cost of the line extension would be borne by FWS, and is estimated to cost in the $300,000 to $500,000 range. For the purposes of this analysis, the lower end ($300,000) cost estimate was assumed.

In developing the cash flow analysis for utility provided power, it was assumed that the $300,000 line extension cost would be paid in Year 1 of the analysis period. The cash flow analysis period was assumed to be 30 years to match the expected service life of the conceptual design energy package. The analysis also assumed that starting in Year 1, that the FWS would purchase energy from SWEPCO under its residential service rate tariff. The SWEPCO residential rate tariff is as follows:

- $75/month fixed customer charge, and
- Energy charges of $0.048/kWh in the May through October billing cycles, and a declining block energy structure of $0.038/kWh for the first 600 kWh/month and $0.0257 for each additional kWh in the months of November through April.

The cash flow analysis assumed that all of the annual the energy requirements at the Starr Ranch facility would be purchased under this rate tariff. Based on this set of assumptions, it was determined that the Year 1 blended utility energy cost for the site (i.e. fixed customer charge, and seasonal energy structures) is $0.051 per KWh. This blended utility cost does not include the cost of the line extension and is for the energy charges only in Year 1, and this rate is then escalated by 3.5 percent per year (to account for general inflation and commodity cost increases) for the remaining analysis period.

When factoring in the estimated line extension cost of $300,000 and adding the expected annual energy purchases from SWEPCO, the total cost of this option (2010 dollars) is estimated at $320,950 over the 30-year analysis period. The average cost of energy under this option (2010 dollars) is $1.33/kWh. However, the average cost of energy in current dollars does not take into account the time value of money. Therefore, a levelized cost of energy (LCOE) calculation was performed to account for the value of money over time. The LCOE is calculated through a discounted cash flow analysis, which applies a discount rate to the year's cash flow value. For this analysis, a 4 percent discount rate factor was assumed. The formula for the LCOE calculation is as follows:

- Net Present Value (NPV) of Annual Cash Flows / Net Present Value of Annual kWh Consumption.

Utilizing the NPV analysis approach accounts for the time value of money by assuming that the value of money in Year 1 is worth more than its value in each of the successive years in the analysis period. The total NPV of the utility provided power option was calculated to be approximately -$300,000. Based on this analysis, the LCOE of utility provided power from SWEPCO was calculated to be $2.14/kWh. The reason the LCOE value is higher than the average cost of energy value is that over 93 percent of the total lifecycle costs of utility provided power occurs in Year 1, and thus these costs are not discounted in the cash flow model. As such the LCOE value of $2.14/kWh represents the benchmark value that the off-grid conceptual design technology package must be lower than in order to be cost-effective. It should also be noted that the utility provided power option has no payback period, since the cost of the line extension is never recovered, and utility bills must be paid in perpetuity.

6.2.2 Economic Analysis of Off-Grid Power System

The economic analysis of the off-grid renewable-based energy supply package employs the same discounted cash flow methodology as the utility power supply option. The annual cash flows, calculated over a 30-year period to correspond to the expected life of the off-grid power system, utilized the following assumptions:

- Year 1 turn-key energy supply package costs of $67,250;
- Annual equipment O&M costs of $500/year in Year 1, escalated at an annual rate of 3.5 percent per year for the remaining analysis period to account for annual labor rate increases and inflation;
- Propane costs of $2.75/gallon in Year 1, escalated at an annual rate of 3.5 percent for the remaining years in the analysis period;
- Minimal generator run-time of 12 hours per year;
- Annual facility energy requirements equal to the output of the 6.3 kW PV system and 12 hours per year of generator run-time;
- Replacement costs of the battery storage bank in Years 8, 16 and 24 of the analysis period. Replacement costs were discounted by 20 percent of current market prices to account for anticipated price reductions of battery storage equipment in the future;
- Replacement costs of the PV inverter and charge controller equipment in Year 20. Replacement costs were discounted by 20 percent of current market prices to account for anticipated price reductions of inverter equipment in the future; and
- A four percent discount rate factor.

Based on these assumptions, it was determined that the total cost (2010 dollars) of the off-grid energy supply option is approximately $153,000 over the 30-year analysis period. The average cost of energy (2010 dollars) provided by the off-grid power system is calculated to be $0.70/kWh over the system's expected life. Factoring in the time value of money via an NPV-based cash flow analysis, the LCOE of the off-grid power supply option was calculated to be $0.78/kWh. Similar to the utility provided power supply option, the LCOE of the off-grid power supply option is higher than the average cost of energy (2010 dollars) since nearly 45 percent of the lifecycle costs occur in Year 1 of the analysis period and are not discounted.

A key assumption in the economic analysis of the off-grid energy package is the minimal the run-time of the back-up propane generator. Running the propane generator is extremely expensive, and would cost in the $6-$8 per kWh range at current propane prices, depending upon whether the generator runs at part load or full load. Even moderate usage of the back-up propane generator would significantly reduce the economic value of the off-grid energy supply package. However, if the PV/Battery/Gen-Set package is operated within the design parameters and within the design day load budgets, keeping generator run times to a minimum should not be an issue.

6.2.3 Comparative Analysis of Utility Vs. Off-grid Supply Options

Based on the economic analyses conducted for the power supply options at Starr Ranch, it is apparent that the off-grid energy supply package provides significant economic value over the utility power supply option. This increased economic value of the off-grid supply option is in addition to the other benefits of sustainability, environmentally-conscious energy production, and avoided disturbance of land that would be required for a utility line extension.

The LCOE is a useful metric for comparing the energy supply options at Starr Ranch. As described earlier in the previous sections, the LCOE of the utility power supply option is $2.14/kWh while the LCOE of the off-grid supply option is $0.78/kWh. This represents a LCOE cost savings of $1.36/kWh from the off-grid supply option under the analysis methodology and assumptions employed for the feasibility study.

In terms of real dollars (2010 dollars), the off-grid supply options would save an estimated $168,000 over its 30-year expected life compared to the utility supply option. Perhaps even more important is the comparison of the payback periods of the two options. Under the utility supply option, the $300,000 investment in the line extension is never recovered, and requires the purchase of energy from the local utility in perpetuity. As a result, there is no payback period associated with the utility supply option. Conversely, the payback period for the off-grid energy supply system is immediate since it avoids the estimated $300,000 line extension payment to the local utility. In fact, the Year 1 savings attributable to the off-grid energy supply package amounts to over $230,000, primarily due to avoidance of the line extension payment and off-grid energy package turn-key costs estimated at ~$67,000.

The final metric calculated for the comparative analysis of the off-grid supply option at Starr Ranch is the Benefit-Cost Ratio. The Benefit-Cost Ratio is a simple calculation that compares the total benefits of the project (avoided line extension costs, avoided utility energy purchases) to the total costs of the project (turn-key installation costs, annual O&M costs, and annual propane costs) in real dollars (2010 dollars). The Benefit-Cost Ratio calculation performed for the off-grid energy supply option yielded a value of 2.3 to 1. This means that the benefits provided by the off-grid energy supply option are 2.3 times greater than its costs. As a general rule, a Benefit-Cost Ratio of greater than 1 indicates a positive economic value and that a project should be considered for implementation.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

As can be seen from the analyses presented in this report, the development of an off-grid renewable-based power supply system at Star Ranch is both technically and economically feasible. The recommended technology package—comprised of a 6.3 kW DCp PV system with battery storage and a 14 kW back-up propane generator—will meet the daily, monthly and annual energy requirements of the facility if operated within system design parameters and anticipated load conditions. With the PV system as the primary source of energy generation, nearly all of the electrical energy requirements at the site will be met in an environmentally sound manner. The facility's energy requirements will be met in a cost-effective manner as well, particularly when compared to a utility power supply option requiring an expensive line extension to the site.

A number of conclusions were drawn from the report and are summarized as follows:

- The off-grid power supply package detailed in the conceptual design is sized to meet projected loads of moderate usage under full-time occupancy, with minimal back-up generator run times. Since it is highly likely that the facility's occupancy rates will be much lower than full-time, the energy supply package as designed should be able to meet the projected energy requirements with little or no generator run-time.
- While the 14 kW generator is a necessary component of the off-grid power supply package, it is extremely expensive to run and its use should be minimized. Even moderate use of the back-up generator will severely impact overall project economics due to the resulting increase in propane costs. In fact, generator run times of eight hours per month over the course of the year would like reduce the project economics to "break-even" if continued over the 30-year analysis period.
- The conceptual design of the off-grid power supply package provides detailed equipment specifications, as well as their estimated costs based on current market conditions. The conceptual design can be used for both planning and engineering purposes to assist in the proposed refurbishment of the Starr Ranch building, and should also be included in any RFP documents if the energy technology package is put out to bid. In addition, the equipment cost estimates may prove useful for budgetary planning purposes.
- The power quality of the system will be better than utility supplied power from the aging local distribution system within the Caddo Lake National Wildlife Refuge.
- The specified off-grid technology package is a highly cost-effective option for the Starr Ranch facility, and may provide more than $150,000 in savings over its expected 30-year life when compared to the utility power supply option.
- The payback period of the off-grid power supply package is immediate if compared to the utility power supply option. Conversely, there is no payback period associated with the utility power supply option.
- Additional economic value can be provided by the PV system at Starr Ranch by counting its annual generation towards FWS's renewable energy goals set forth in the 2005 Energy Policy Act. Under this guidance, federal agencies must meet 7.5 percent of their annual energy requirements with renewable energy resources by 2013. The 2005 EPACT also states that on-site renewable energy generation shall count double towards meeting Agency goals.

7.2 Recommendations

A number of recommendations are provided for the FWS's consideration in moving forward with the proposed off-grid power supply package:

- The conceptual design developed in this report should be disseminated to the architects and engineers who will be working on the refurbishment of the Starr Ranch building, to assist in their design and planning efforts.
- A major key to the success of the off-grid power supply package is to reduce the electrical end-use loads at Starr Ranch to the highest extent practicable. Since the levelized cost of energy from the off-grid power supply package is estimated at $0.78/kWh, it is critical to ensure that facility energy requirements are as low as possible and remain low over time. It is not economically prudent to serve inefficient loads with expensive energy. Therefore, it is recommended that all end-use appliances, lights, and plug loads purchased for permanent placement in the facility be as energy efficient as possible. In addition, since the heating and cooling loads account for ~60 percent of all energy consumption at the site, the building envelope should be designed to be as "tight" as possible and incorporate recommended R-values for insulation and windows, incorporate passive solar design features (e.g., thermal mass rock walls and roof overhangs), and utilize weather stripping where appropriate. Building and maintaining an energy efficient building envelope will go a long way towards reducing heating and cooling energy requirements and maximizing the economic value of the PV/Battery/Gen-Set technology package.
- Once the off-grid power supply package has been installed, it is highly recommended that FWS personnel monitor usage of the back-up propane generator. If the generator runs too frequently, it is recommended

that FWS personnel consider implementing measures to reduce the facility energy requirements and/or increase the size of the solar array and battery back-up system.

- It is highly recommended that the PV system be sub-metered and records kept on its monthly generation output. Sub-metering the PV system and monitoring its performance will enable FWS staff to determine if the system is operating to specifications, or if it is underperforming and troubleshooting is required. In addition, sub-metering of the PV system and accounting for its production will allow FWS to count the annual PV energy production towards its 2005 EPACT renewable energy goals.

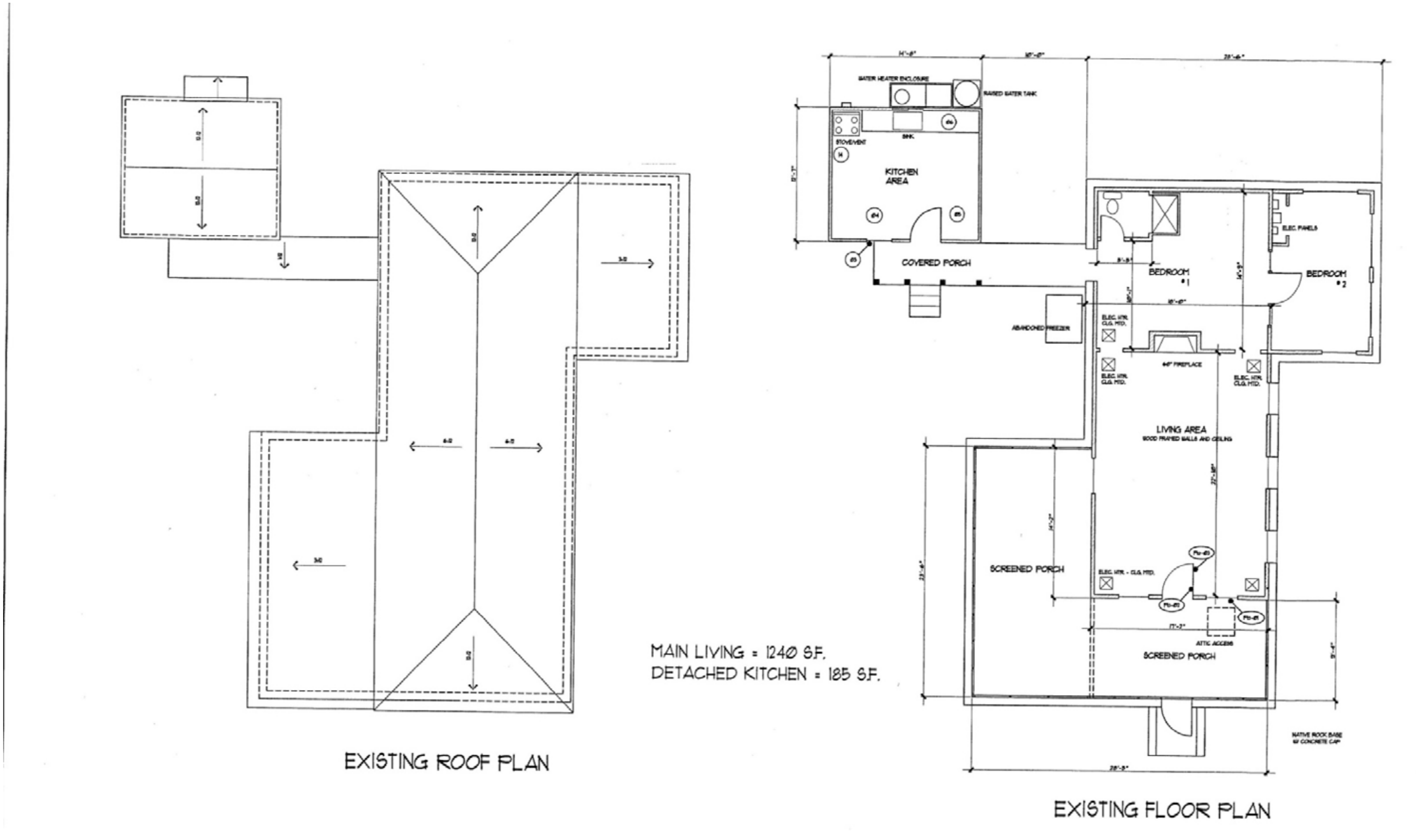
APPENDIX A: SAMPLE LOAD ANALYSIS CHECKLIST TEMPLATE

Alternative Energy System Load Sheet

END USE	Electric	Propane	Quantity	Watts (Volts X Amps)	Hrs/Day	Watt-hrs/day
Lighting						
25 watt CFL	X		5	25	8	1000
Heating						
Cooling						
Appliances						
Refrigerator		X				
Water Heater	? - or solar thermal					
Plug Loads						
Computer						
TV / video displays						
Coffee Pot	X		1	200	4	800
TOTAL WATT-HOURS PER DAY						1800
TOTAL KWH PER MONTH						54

Battery Bank Sizing		
Watt-Hours per Day	1800	
Days of Back-up Power	2	
Lowest Temperature of Battery Bank		^oF
Battery Bank Voltage	24	V

APPENDIX B: BUILDING FOOTPRINT FOR STARR RANCH FACILITY

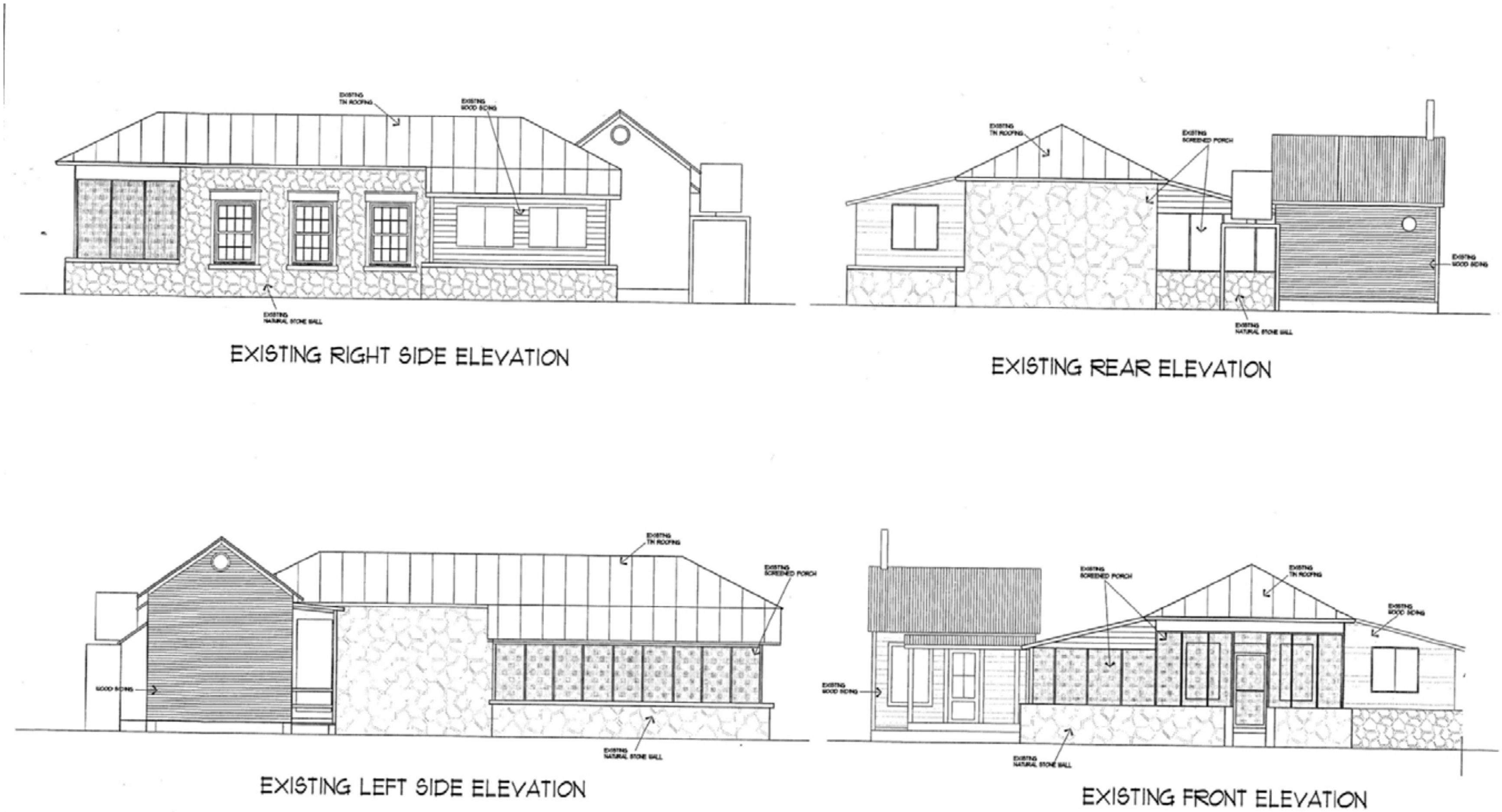


DAVID K. CHANDLER HOMES, INC.
RESIDENTIAL DESIGN SERVICES
1111 EMERSON LN. DENTON, TEXAS 76209 PHONE (940) 387-1329

PROPOSED PLANS FOR:
STAR RANCH - CADDO LAKE, TEXAS

A1

APPENDIX C: STARR RANCH FACILITY ELEVATION PERSPECTIVES

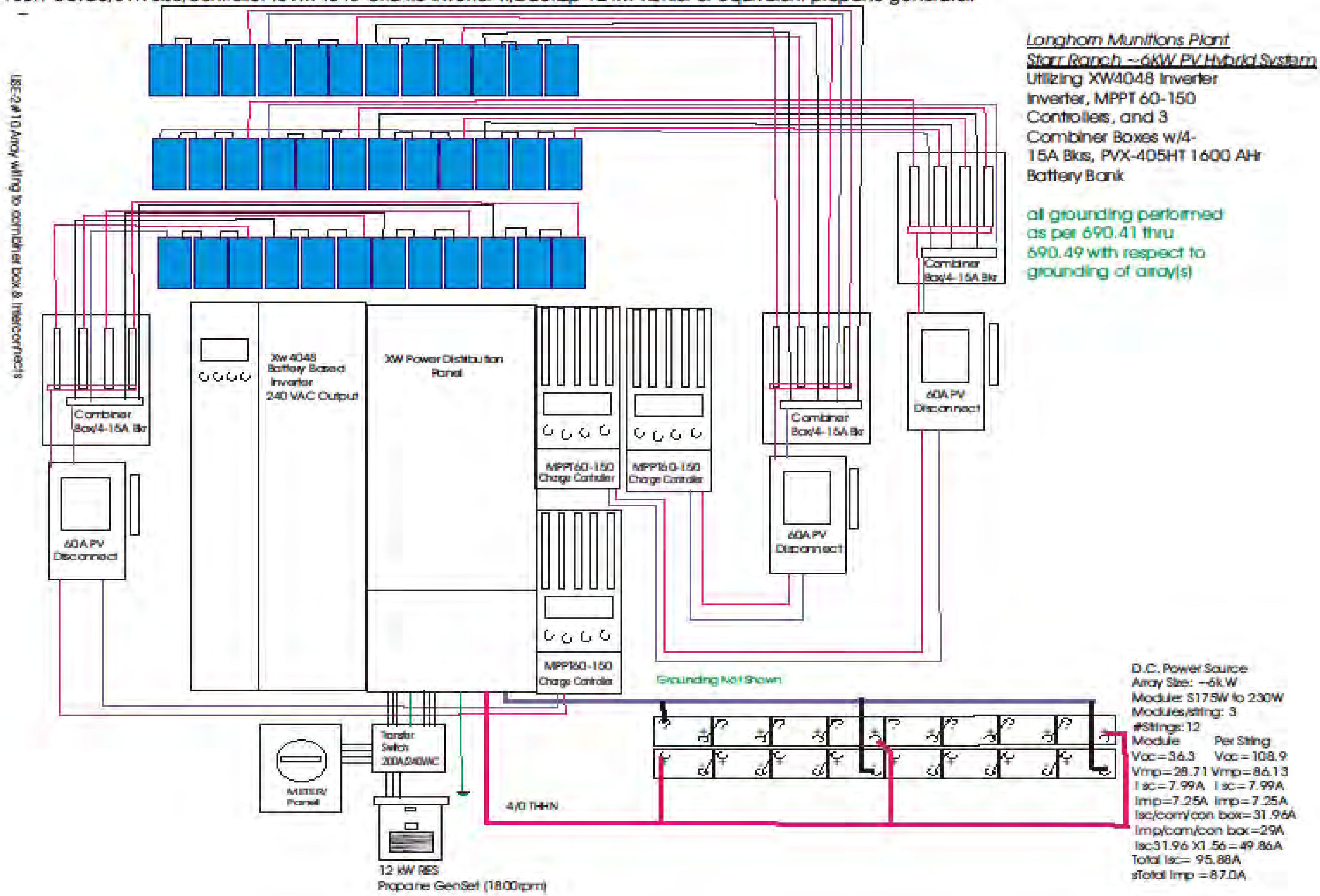


DAVID K. CHANDLER HOMES, INC.
RESIDENTIAL DESIGN SERVICES
1711 EMERSON LN. DENTON, TEXAS 76209 PHONE (940) 387-1329

PROPOSED PLANS FOR:
STAR RANCH - CADDO LAKE, TEXAS

A2

S 175-230Watt solar modules, 4 strings/3 in Series per combiner box (3) to 3 XW60-150 MPPT controllers,
108.9 ocvdc, 31.96Isc/controller to XW4048 Grid-Tie Inverter w/backup 12 kW Kohler or equivalent propane generator.




Underside of multi-pole mount


Sleeve attachment


Rail-To-Pipe brackets

Photos courtesy of:
Mississippi Solar and LightWave Solar Electric

MULTI-POLE MOUNTS

Features

- Designed to mount on 3", 4" or 6" Schedule 40 galvanized steel pipe (installer supplied)
- Supports 2 to 4 modules high in landscape orientation
- Limitless horizontal expansion
- Full range of seasonal elevation adjustability
- Fewer ground penetrations than traditional ground mounts
- Ideal for shade and carport structures
- Capable of significant ground clearance
- Utilizes under-flange module clamp for installation ease

For help with foundation recommendations and pipe sizing, please call us or e-mail info@power-fab.com. Please be ready to provide the following site-specific details: Maximum design wind speed, exposure category, soil type, steepest expected tilt angle, and above ground clearance.

MULTI-POLE MOUNT RAIL SETS (INCLUDES MODULE RAILS AND CLAMPS, RAIL-TO-PIPE BRACKETS, AND ASSOCIATED HARDWARE):

MODULE	# OF MODULE	PART #	PRICE	MODULE	# OF MODULE	PART #	PRICE
BP 3160 / SX 170B	2	MPM2-BP170	$410	REC SCM210/ 215/220/ 225/230	2	MPM2-REC210	$430
	3	MPM3-BP170	$525		3	MPM3-REC210	$565
	4	MPM4-BP170	$625		4	MPM4-REC210	$690
BP SX195/ 200	2	MPM2-BP200	$415	Sanyo HIT Power 205/210/215N	2	MPM2-SY205	$410
	3	MPM3-BP200	$530		3	MPM3-SY205	$525
	4	MPM4-BP200	$630		4	MPM4-SY205	$625
Canadian Solar CS6P-170/180/ 190/200/210	2	MPM2-CS1200	$430	Sharp NE-165/170U1 or NT-175/180U1	2	MPM2-SHP170	$415
	3	MPM3-CS1200	$565		3	MPM3-SHP170	$530
	4	MPM4-CS1200	$690		4	MPM4-SHP170	$630
Evergreen ES-170/180/ 190/195	2	MPM2-EG180	$425	Sharp ND-208/216/ 224U1F	2	MPM2-SHP224	$430
	3	MPM3-EG180	$560		3	MPM3-SHP224	$565
	4	MPM4-EG180	$685		4	MPM4-SHP224	$690
Evergreen ES-A-190/195/ 200/205/210	2	MPM2-EG200	$425	SolarWorld SW220/230	2	MPM2-SWD230	$430
	3	MPM3-EG200	$560		3	MPM3-SWD230	$565
	4	MPM4-EG200	$685		4	MPM4-SWD230	$690
GE PV-200-M	2	MPM2-GE200	$430	Sunpower SPR210/215/ 220/225/230	2	MPM2-SPR220	$410
	3	MPM3-GE200	$565		3	MPM3-SPR220	$525
	4	MPM4-GE200	$690		4	MPM4-SPR220	$625
Kyocera KD180GX-LP	2	MPM2-KD180	$430	Suntech STP170/175/ 180S-24/Ab-1	2	MPM2-STP175	$410
	3	MPM3-KD180	$565		3	MPM3-STP175	$525
	4	MPM4-KD180	$690		4	MPM4-STP175	$625
Kyocera KD205/210 GX-LP	2	MPM2-KD205	$430	Suntech STP190/200/ 210S-18/Ub	2	MPM2-STP200	$430
	3	MPM3-KD205	$565		3	MPM3-STP200	$565
	4	MPM4-KD205	$690		4	MPM4-STP200	$690
Mitsubishi PV-UD175/180/ 185/190MF5	2	MPM2-MT180	$415	SunWize SW170/175/180	2	MPM2-SWZ175	$415
	3	MPM3-MT180	$530		3	MPM3-SWZ175	$530
	4	MPM4-MT180	$630		4	MPM4-SWZ175	$630

MULTI-POLE MOUNT PIPE CAPS (INCLUDES U-BOLTS):

DESCRIPTION	PART #	PRICE
For connecting 3" vertical to 3" horizontal steel pipe	PC-3V3H	$210
For connecting 4" vertical to 3" horizontal steel pipe	PC-4V3H	$230
For connecting 4" vertical to 4" horizontal steel pipe	PC-4V4H	$240
For connecting 6" vertical to 3" horizontal steel pipe	PC-6V3H	$275
For connecting 6" vertical to 4" horizontal steel pipe	PC-6V4H	$285

DPW SOLAR

PREFORMED LINE PRODUCTS

Direct Power & Water Corporation
4000-B Vassar Drive NE
Albuquerque, New Mexico 87107
USA

Telephone: 800.260.3792
Fax: 505.889.3548
Web Site: www.DPWSolar.com
E-mail: info@power-fab.com

SL-SS-1048-2P
09.10 2M

Product data sheet
Characteristics

865-1010
Xantrex XW - hybrid inverter / charger XW4024-120/240-60 - input: 178A DC

Main

Range of product	Xantrex XW
Device short name	XW4024-120/240-60
Product or component type	Hybrid inverter / charger
Network number of phases	Single phase
Type of signal	True sine wave
Continuous power	4000 W AC - 120 V) 4000 W AC - 240 V)

Complementary

Peak output current	70 A - phase to neutral (L-N) - 20 s 70 A - phase to neutral (L-N) - 20 s 35 A - phase to phase (L-L) - 20 s 35 A - phase to phase (L-L) - 20 s
Network frequency	60 Hz +/- 0.1 Hz (output)
Cos phi	0.98 0.98
Harmonic distortion	< 5 %
Input voltage	120 V AC (L-N) - bypass/charge mode 120 V AC (L-N) - bypass/charge mode 240 V AC (L-L) - bypass/charge mode 240 V AC (L-L) - bypass/charge mode 25.2 V DC 25.2 V DC
Input voltage limits	80...150 V AC (L-N) - bypass/charge mode 80...150 V AC (L-N) - bypass/charge mode 160...270 V AC (L-L) - bypass/charge mode 160...270 V AC (L-L) - bypass/charge mode 108...130 V +/- 1.5 V AC (L-N) - sell mode 108...130 V +/- 1.5 V AC (L-N) - sell mode 214...260 V +/- 3.0 V AC (L-L) - sell mode 214...260 V +/- 3.0 V AC (L-L) - sell mode 22 - 32 V DC 22 - 32 V DC
Input current	178 A DC at rated power
Input frequency	55...65 Hz - bypass/charge mode (default) 44...70 Hz - bypass/charge mode (allowable)
Charging current	150 A
Efficiency	94 % - low-load 94 % - low-load 91 % CEC weighted 91 % CEC weighted 85.8 % - maximum charge rate 85.8 % - maximum charge rate
Power consumption in W	< 8 W - search mode < 8 W - search mode
Communication network type	Xanbus
Device mounting	Wall mounted
Provided equipment	Battery temperature sensor included for temperature compensation
Height	580 mm
Width	410 mm
Depth	230 mm
Product weight	52.5 kg

Product data sheet
Characteristics

865-1020
Xantrex XW - connection kit for second inverter XW CK INV2

Main

Range of product	Xantrex XW
Device short name	XW CK INV2
Product or component type	Connection kit for second inverter

Complementary

Provided equipment	3 AC breakers 60 A 120/240 V AC, 2P 1 DC breaker 250 A 160 V DC, 3/8" stud 1 pair AWG 4 battery cables AWG 6 AC wiring 1 XW conduit box 1 custom designed bypass interlock plate 4 power distribution bus bars 1 bus bar for DC positive AC Sync and Xanbus cables
Product compatibility	XW inverter/charger
Height	229 mm
Width	406 mm
Depth	210 mm
Product weight	10.5 kg

Product data sheet
Characteristics

865-1015
Xantrex XW - power distribution panel XW PDP

Main

Range of product	Xantrex XW
Device short name	XW PDP
Product or component type	Power distribution panel

Complementary

Provided equipment	3 AC breakers 60 A 120/240 V AC, 2P 1 DC breaker 250 A 160 V DC, 3/8" stud 1 ground terminal bus bar 1 neutral terminal bus bar 1 battery negative terminal bus bar 1 pair AWG 4 battery cables AWG 6 AC wiring Mounting plate 1 XW conduit box
Product compatibility	XW connection kit XW inverter/charger XW solar charge controllers C series charge controllers
Height	761 mm
Width	406 mm
Depth	210 mm
Product weight	30.5 kg

Product data sheet
Characteristics

865-1030-1
Xantrex XW - solar charge controller XW-MPPT60-150 - 12...60V DC - 2.5W

Main

Range of product	Xantrex XW
Device short name	XW-MPPT60-150
Product or component type	Solar charge controller
Battery voltage	12 V DC 24 V DC 36 V DC 48 V DC 60 V DC

Complementary

Input voltage	140 V DC <= 150 V DC - open circuit
Short-circuit current	60 A DC
Power consumption in W	2.5 W while operating
Enclosure type	Ventilated
Enclosure material	Sheet metal chassis
Device mounting	Wall mounted vertical
Cable entry	7/8" and 1" knock-outs
Height	368 mm
Width	146 mm
Depth	138 mm
Product weight	4.8 kg

Environment

AWG gauge	AWG 10
Ambient air temperature for operation	-20...45 °C
Ambient air temp for storage	-40...85 °C
Operating altitude	4572 m
Standards	CSA 107.1 UL 1741
Product certifications	FCC Class B
Marking	CE

Product data sheet
Characteristics

865-1050
Xantrex XW - system control panel XW SCP - non-volatile memory

Main

Range of product	Xantrex XW
Device short name	XW SCP
Product or component type	System control panel
Product specific application	System configuration and diagnostic information
Control type	4 tactile keypad buttons

Complementary

Product compatibility	XW system devices
Display type	Backlit LCD screen
Display resolution	128 x 64 pixels
Feature available	Internal clock keeps time for the entire system Audible alarm when a fault condition arises Low power consumption
Local signalling	1 LED red fault 1 LED green online
Data backed up	Non-volatile memory
Communication port protocol	Xanbus
Provided equipment	Mounting hardware
Device mounting	Flush surface
Height	152 mm
Width	103 mm
Depth	40 mm
Product weight	0.207 kg

Environment

Ambient air temperature for operation	-20...50 °C
Ambient air temp for storage	-40...85 °C
Standards	CSA 107.1-01 UL 458
Product certifications	CSA FCC Class B Industry Canada
Marking	CE

Sun Xtender PVX-4050HT

Solar Battery Manufactured by: Concorde Battery Corporation

Enlarge Solar Battery

Battery Outline Drawings (PDF)

Click For Battery Spec Page

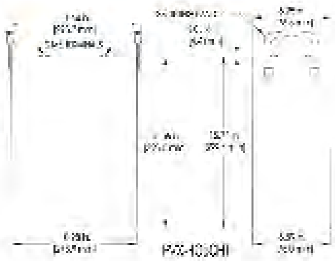
Description of Solar Battery:

VRLA-AGM Deep Cycle Battery for Off Grid and Grid Tied Systems.

This newest member of the SunXtender® solar battery product line is the L-16 battery size, a well known 6-volt option used in both grid tied and off grid renewable energy storage systems.

PVX-4050HT boasts the highest capacity in the 6-volt solar battery series, with a newly designed handle providing a comfortable hand grip for safe lifting.

VRLA-AGM: Valve Regulated Lead Acid battery with Absorbent Glass Mat. The sealed, maintenance free design means no spilling or spewing, no watering, and the option to operate upright, on its side, or on its end.



See the Sun Xtender solar battery Technical Manual for details.

PVX-4050HT

Voltage	6v
Battery Series	6 Volt Sun Xtender Series
Nominal Capacity Ampere Hours @ 25° C (77° F) to 1.75 Volts per cell - 24 Hour Rate	405 Ah
Weight	120 lb / 54.4 kg

Sun Xtender® Solar Battery Part Number	Length		Width		Height	
	in	mm	in	mm	in	mm
PVX-4050HT	11.64	296	6.95	177	15.73	399

Nominal Capacity Ampere Hours @ 25° C (77° F) to 1.75 volts per cell							
1 Hr Rate	2 Hr Rate	4 Hr Rate	8 Hr Rate	24 Hr Rate	48 Hr Rate	72 Hr Rate	120 Hr Rate
266 Ah	345 Ah	360 Ah	376 Ah	405 Ah	424 Ah	434 Ah	448 Ah

Specifications subject to change without notice.

Models: 12RESL/12RESM1

KOHLER. POWER SYSTEMS

Multi-Fuel
LP Vapor/Natural Gas

ISO 9001 KOHLER POWER SYSTEMS NATIONALLY REGISTERED

The Kohler® Advantage

- **The Smart Choice**
  Known for its reliability, the Kohler® 12 kW generator was named a "Best Buy" as well as the highest-rated generator in a leading consumer magazine in October, 2006
- **Powerful**
  Exclusive PowerBoost™ technology allows the Kohler® 12 kW generator to start and run a typical 4 ton (48,000 BTU) central air conditioner, while still running other home appliances and electronics *
- **Cleaner Power for Sensitive Electronics**
  Protects sophisticated electronics with clean, stable power that exceeds strict utility requirements and IEEE standards for total harmonic distortion (THD)
- **Faster Response**
  Kohler® generators restore power in as little as 10 seconds
- **Quiet**
  Quiet operation: 65 dB(A) at 7 m maintains neighborhood solitude
- **Premium Five-Year Limited Warranty**

Standard Features

- **Digital Control (DC-RET)**
  - Digital voltage regulation
  - LED display shows system status
- **Engine Features**
  - Kohler Command PRO® OHV engine with hydraulic valve lifters for reliable performance without routine valve adjustment or lengthy break-in requirements
  - Digital Spark Advance Ignition (DSAI) optimizes engine performance for natural gas and LP vapor fuels
  - Simple field conversion between natural gas and LP vapor fuels while maintaining emission certification
- **Designed for Easy Installation**
  - Polymer base eliminates the need for a concrete mounting pad, reducing installation time and cost
  - Fuel and electrical connections through the enclosure wall eliminate the need for stub-ups through the bottom
  - Field-connection terminal block simplifies electrical connections
  - Designed for outdoor installation only
- **Certifications**
  - California Air Resources Board (CARB)-certified for both LP vapor and natural gas
  - Meets Environmental Protection Agency (EPA) nonstationary unit requirements
  - UL 2200 listed
  - UL listed to Canadian safety standards
  - Approved for stationary standby applications in locations served by a reliable utility source
- **Power System Packages**
  - Model 12RESL/12RESM1 generator set with sound enclosure and all standard features
  - 100 amp Model RDT automatic transfer switch with 12-circuit load center for connection of essential loads
  - With or without optional carburetor heater for improved cold-weather starting

Generator Ratings

Alternator Model	Voltage	Phase	Hz	Standby Amps Natural Gas	Standby Amps LP Gas	Standby Ratings, kW/kVA Natural Gas	Standby Ratings, kW/kVA LP Gas
2F4	120/240	1	60	43	50	10.4/10.4	12.0/12.0

RATINGS: Standby ratings apply to installations served by a reliable utility source. All single-phase units are rated at 1.0 power factor. The standby rating is applicable to variable loads with an average load factor of 80% for the duration of the power outage. No overload capacity is specified at this rating. Ratings are in accordance with ISO-3046/1, BS5514, AS2789, and DIN 6271. GENERAL GUIDELINES FOR DERATING: *ALTITUDE*: Derate 4% per 305 m (1000 ft.) elevation above 153 m (500 ft.). *TEMPERATURE*: Derate 1.5% per 5.5°C (10°F) temperature increase above 16°C (60°F). Availability is subject to change without notice. Kohler Co. reserves the right to change the design or specifications without notice and without any obligation or liability whatsoever. Contact your local Kohler Co. generator distributor for availability.

* Due to the cycling operation of many electrical appliances, the generator set may not run all appliances simultaneously. Check the appliance manufacturer's specifications for actual power requirements. Consult a Kohler® Power Systems professional for your exact residential power system requirements.

G4-110 (12RESL/12RESM1) 2/10d

Application Data

Engine

Engine Specifications	60 Hz
Manufacturer	Kohler
Engine: model, type	CH740 4-Cycle
Cylinder arrangement	V-2
Displacement, L (cu. in.)	0.725 (44)
Bore and stroke, mm (in.)	83 x 67 (3.27 x 2.64)
Compression ratio	9.0:1
Main bearings: quantity, type	2, Parent Material
Rated rpm	3600
Max. engine power at rated rpm, kW (HP)	
CH740, LP vapor	17.6 (23.6)
CH740, natural gas	15.3 (20.5)
Cylinder head material	Aluminum
Valve material	Steel/Stellite®
Piston type and material	Aluminum Alloy
Crankshaft material	Heat Treated, Ductile Iron
Governor: type	Mechanical
Frequency regulation, steady state	±1.25%
Air cleaner type	Dry

Engine Electrical

Engine Electrical System	
Ignition system	Electronic, DSAM
Starter motor rated voltage (DC)	12
Battery (purchased separately):	
Ground	Negative
Volts (DC)	12
Battery quantity	1
Recommended cold cranking amps (CCA) rating for -18°C (0°F)	525
Maximum dimensions, L x W x H, mm (in.)	210 x 178 x 197 (8.25 x 7.00 x 7.75)

Exhaust

Exhaust System	
Exhaust flow at rated kW, m^3/min. (cfm)	3.8 (135)
Exhaust temperature at rated kW, dry exhaust, °C (°F)	760 (1400)
Exhaust temperature exiting the enclosure, °C (°F)	216 (420)

Operation Requirements

Cooling Air	
Total inlet air, m^3/min. (cfm)	28.0 (990)
Cooling air, m^3/min. (cfm)	26.9 (950)
Combustion air, m^3/min. (cfm)	1.1 (39.2)

Lubrication

Lubricating System	
Type	Full Pressure
Oil capacity (with filter), L (qt.)	1.9 (2.0)
Oil filter: quantity, type	1, Cartridge
Oil cooler	Integral

Fuel Requirements

Fuel System	
Fuel types	Natural Gas or LP Vapor
Fuel supply inlet	1/2 NPT
Fuel supply pressure, kPa (in. H_2O):	
Natural gas	1.2-2.7 (5-11)
LP	1.7-2.7 (7-11)

Minimum Gas Pipe Size Recommendation, in. NPT

Pipe Length, m (ft.)	Natural Gas (193,000 Btu/hr.)	LP Vapor (203,000 Btu/hr.)
8 (25)	3/4	3/4
15 (50)	1	3/4
30 (100)	1	1
46 (150)	1 1/4	1
61 (200)	1 1/4	1

Fuel Consumption at % rated load	
% Load	
Natural Gas, m^3/hr. (cfh)	
100%	5.4 (193)
75%	4.7 (163)
50%	3.5 (124)
25%	2.6 (93)
LP Vapor, m^3/hr. (cfh)	
100%	2.3 (81)
75%	2.1 (75)
50%	1.8 (60)
25%	1.2 (45)
LP Vapor, kg/hr. (lb./hr.)	
100%	4.3 (9.4)
75%	3.9 (8.7)
50%	3.4 (7.0)
25%	2.2 (5.2)

LP vapor conversion factors:
8.58 $ft.^3$ = 1 lb.
0.535 m^3 = 1 kg
36.39 $ft.^3$ = 1 gal.

Nominal fuel rating:
Natural gas: 37 MJ/m^3 (1000 Btu/$ft.^3$)
LP vapor: 93 MJ/m^3 (2500 Btu/$ft.^3$)

G4-110 (12RESL/12RESM1) 2/10d

Alternator

Alternator Features

- Compliance with NEMA, IEEE, and ANSI standards for temperature rise
- Self-ventilated and dripproof construction
- Vacuum-impregnated windings with fungus-resistant epoxy varnish for dependability and long life
- Superior voltage waveform and minimum harmonic distortion from skewed alternator construction
- Digital voltage regulator with ±1.5% no-load to full-load RMS regulation
- Rotating-field alternator with static exciter for excellent load response
- Skewed generator construction produces a smooth AC waveform

Alternator Specifications

Specifications	PowerBoost™ Generator 1-Phase
Manufacturer	Kohler
Output reconnectable	120/240
Type	2-Pole, Rotating Field
Leads, quantity	4
Voltage regulator	Digital
Insulation:	NEMA MG1-1.66
Material	Class H
Temperature rise	Class H
Bearing: quantity, type	1, Sealed Ball
Coupling	Direct
Amortisseur windings	Full
Voltage regulation, no-load to full-load RMS	±1.5%
One-step load acceptance	100% of Rating
Peak motor starting kVA	32

Controller

DC-RET Digital Control Features

- Compact controller
- Integrally mounted to the generator set
- LED display:
  - Runtime hours
  - Crank cycle status
  - Diagnostics
- LED display communicates faults:
  - High engine temperature
  - Low battery voltage
  - Low oil pressure
  - Overcrank safety
  - Overspeed
  - Underfrequency
- Master switch: Run/Off-Reset/Auto (on junction box)
- Remote two-wire start/stop capability
- Digital voltage regulation: ±1.5% RMS no-load to full-load
- Automatic start with programmed cranking cycle

KOHLER.
POWER SYSTEMS

KOHLER CO., Kohler, Wisconsin 53044 USA
Phone 920-565-3381, Fax 920-459-1646
For the nearest sales and service outlet in the US and Canada, phone 1-800-544-2444
KohlerPower.com

Standard Features

- 6-amp battery charger
- Battery cables
- CARB- and EPA-certified fuel system
- Critical silencer
- DC-RET Digital Control
- Field-connection terminal block
- Five-year limited warranty
- Flexible fuel line
- Fuel solenoid valve and secondary regulator
- Line circuit breaker
- Model RDT automatic transfer switch
- Multi-fuel system, LP vapor/natural gas, field-convertible
- Oil drain extension with shutoff valve
- Polymer base
- Rodent-resistant construction
- Sound-deadening, flame-retardant foam per UL 94, class HF-1
- Sound enclosure for quiet 65 dB(A) operation
- Designed for outdoor installation only

Available Accessories

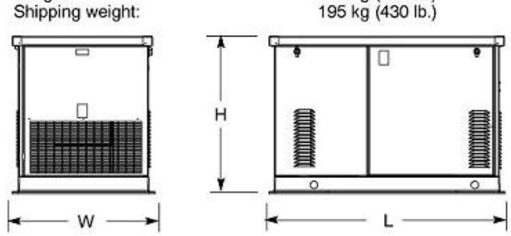
- ☐ Carburetor heater GM39564-KA1, 120 VAC (recommended for reliable starting at temperatures below 0°C [32°F])

Model RDT Automatic Transfer Switch

- 100 Amps, 240 VAC, 60 Hz
- 2 pole, single phase
- Withstand short circuit rating 22,000 amps
- NEMA Type 1 enclosure
- 12-circuit load center
- UL 67 listed
- Equipped with microprocessor-based controls for source sensing and required time delays
- Automatic engine start
- Engine cooldown
- Weekly exercise function, loaded or unloaded
- Load control contact allows delayed connection of selected loads to the generator set
- LED indicator shows:
  - Exercise running
  - Faults
- Dimensions, H x W x D:
  610 x 330 x 154 mm (24 x 13 x 6 in.)
- Weight: 12.3 kg (27 lb.)

Dimensions and Weights

Overall Size, L x W x H:	1123 x 726 x 804 mm (44.3 x 28.6 x 31.6 in.)
Weight:	182 kg (400 lb.)
Shipping weight:	195 kg (430 lb.)



NOTE: This drawing is provided for reference only and should not be used for planning installation. Contact your local distributor for more detailed information.

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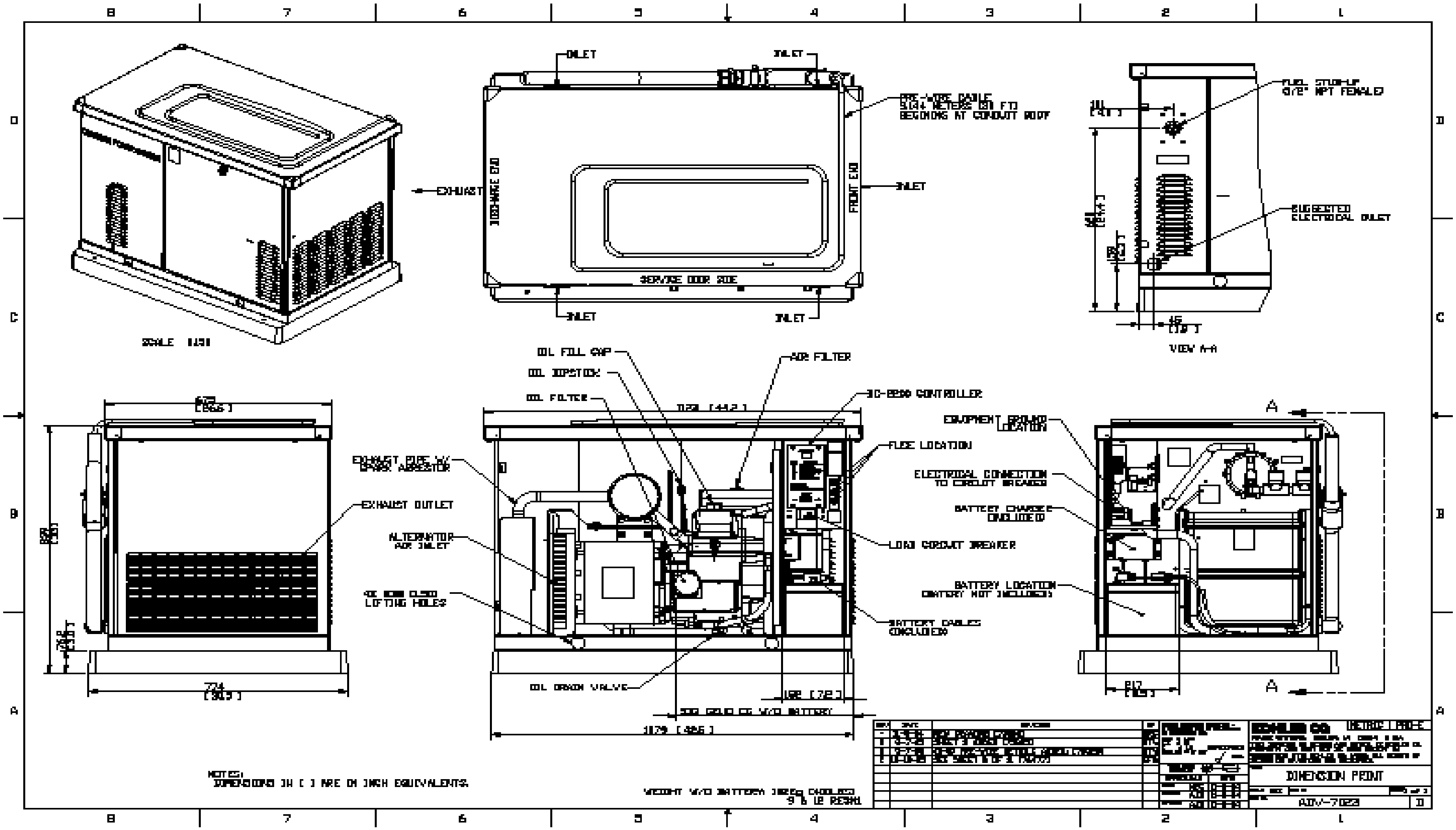
G4-110 (12RESL/12RESM1) 2/10d



INLET
EXHAUST
SERVICE DOOR SIDE
FRONT END
SCALE
VIEW A-A
OIL FILL CAP
OIL DIPSTICK
OIL FILTER
AIR FILTER
FUSE LOCATION
EXHAUST OUTLET
ALTERNATOR AIR INLET
LOAD CIRCUIT BREAKER
EQUIPMENT GROUND LOCATION
ELECTRICAL CONNECTION TO CIRCUIT BREAKER
BATTERY LOCATION
OIL DRAIN VALVE
774
NOTES:
DIMENSIONS IN [ ] ARE IN INCH EQUIVALENTS.
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