California Solar Initiative

RD&D: Research, Development, Demonstration and Deployment Program

GO solar CALIFORNIA

Final Project Report:

Improved Manufacturing and Innovative Business Models to Accelerate Commercialization in California of Hybrid Concentrating Photovoltaic/Thermal Tri-generation (CPV/T-3G) Technology

Grantee:

Cogenra Solar

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http://www.calsolarresearch.ca.gov/Funded-Projects/

Preface

The goal of the California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment (RD&D) Program is to foster a sustainable and self-supporting customer-sited solar market. To achieve this, the California Legislature authorized the California Public Utilities Commission (CPUC) to allocate **$50 million** of the CSI budget to an RD&D program. Strategically, the RD&D program seeks to leverage cost-sharing funds from other state, federal and private research entities, and targets activities across these four stages:

- Grid integration, storage, and metering: 50-65%
- Production technologies: 10-25%
- Business development and deployment: 10-20%
- Integration of energy efficiency, demand response, and storage with photovoltaics (PV)

There are seven key principles that guide the CSI RD&D Program:

1. **Improve the economics of solar technologies** by reducing technology costs and increasing system performance;
2. **Focus on issues that directly benefit California**, and that may not be funded by others;
3. **Fill knowledge gaps** to enable successful, wide-scale deployment of solar distributed generation technologies;
4. **Overcome significant barriers** to technology adoption;
5. **Take advantage of California's wealth of data** from past, current, and future installations to fulfill the above;
6. **Provide bridge funding** to help promising solar technologies transition from a pre-commercial state to full commercial viability; and
7. **Support efforts to address the integration of distributed solar power into the grid** in order to maximize its value to California ratepayers.

For more information about the CSI RD&D Program, please visit the program web site at www.calsolarresearch.ca.gov.

ACKNOWLEDGEMENTS

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The CPUC - *California Public Utilities Commission*

The CPUC Program Manager - Amy Reardon

Itron Program Manager - Ann Peterson

Itron Grant Manger – Jonathan Wanjiru

Also Cogenra would like to thank:

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FINAL REPORT: PROJECT SUMMARY

With support from the California Public Utilities Commission's California Solar Initiative Research Development, Demonstration and Deployment Program (CSI RD&D), Cogenra successfully executed the four tasks and subtasks outlined in the scope of work. The commercialized Cogenra product is now installed at over 20 sites mainly in California. Customers enjoy low paybacks with efficient and cost-effective generation of electricity, heat and cooling in one product. The grant workscope includes the following four tasks:

Task 1: Project management and reporting

Task 2: Complete specification of second-generation production methodologies

Task 3: Measure field performance and refine economic and financial models

Task 4: Adapt system to enable advanced flexible energy delivery capabilities

Under Task 1, periodic status reports, invoices and deliverables were provided by Cogenra. Summary reports for each task were provided and detailed content is also available in this final report, the final deliverable for Task 1. A project summary presentation is available upon request and is available via webinar for interested parties.

Under Task 2, the materials, installation, and operational cost of the Cogenra product were each reduced for a sum reduction of 50% from the baseline product installed at Sonoma Wine Company. The new product utilizes shared components and modular subassemblies and is able to be installed without heavy machinery or custom jigs. Modifications to the core Cogenra receiver yielded increased thermal and electrical performance while minimizing weight and installation time. With the improved product and supply chain, custom packaging was designed to complete the requirements for a simple merge-at-site installation process. The end result is a product already installed at numerous California sites and posed for rapid commercial diffusion.

Under Task 3, the Cogenra energy models were validated and refined with a demonstrated 97% accuracy. The Return on Investment (ROI) tool was developed that uses the energy models to provide detailed and comprehensive project financials internally and to customers. Providing validated energy and financial modeling ensures accurate payback analysis and ultimately successful projects and repeat customers. The work completed under this task is essential for continued growth and adoption of the cogeneration product.

Under Task 4, the Cogenra PVT receiver was successfully modified to perform at high temperatures. The high temperature PVT product allows for tri-generation of solar heat, electricity and cooling. The high temperature water output can be delivered to a thermal chiller (absorption or adsorption) to produce cooling. The first installation of the Cogenra product with an absorption chiller was installed at the Southern California Gas Company in Downey, CA in May 2012.

INTRODUCTION

SOLAR COGENERATION

While clean energy is a key theme in the climate change debate, most of the attention focuses on electricity generation and in the solar industry that typically means photovoltaic (PV) electricity. Solar Hot Water (SHW) represents the prevalent use of solar energy worldwide, exceeding photovoltaic (PV) energy production by roughly 500%. The combination of photovoltaic and solar hot water technologies in one system makes solar cogeneration a cost-effective and environmentally beneficial solar energy solution for commercial and industrial-scale customers. The combination of PV and SHW in one system optimizes the value of both at low incremental cost due to shared component systems.

Solar cogeneration delivers approximately five times the energy of a PV system of the same area. Solar cogeneration captures and delivers the thermal energy that conventional PV dissipates as waste heat. Solar cogeneration produces as much electricity per square foot as PV technology allows (~15% module efficiency) and captures a majority of the remainder of the sun's energy in the form of thermal energy (~60% efficiency). This is a total system efficiency of 75%.

More importantly, the total economic value of the energy that a solar cogeneration system delivers is more than twice that of a PV system in California where the natural gas cost is about 20% of the electricity cost per unit energy. In areas with electric heating, the economic value can be as high as 5 times vs. PV alone.

Solar cogeneration also has significant environmental benefits. By creating both heat and electricity, solar cogeneration achieves at least 3 times reduction in greenhouse gas (GHG) emissions compared to PV and 1.2 times reduction vs. a SHW system of the equivalent size.

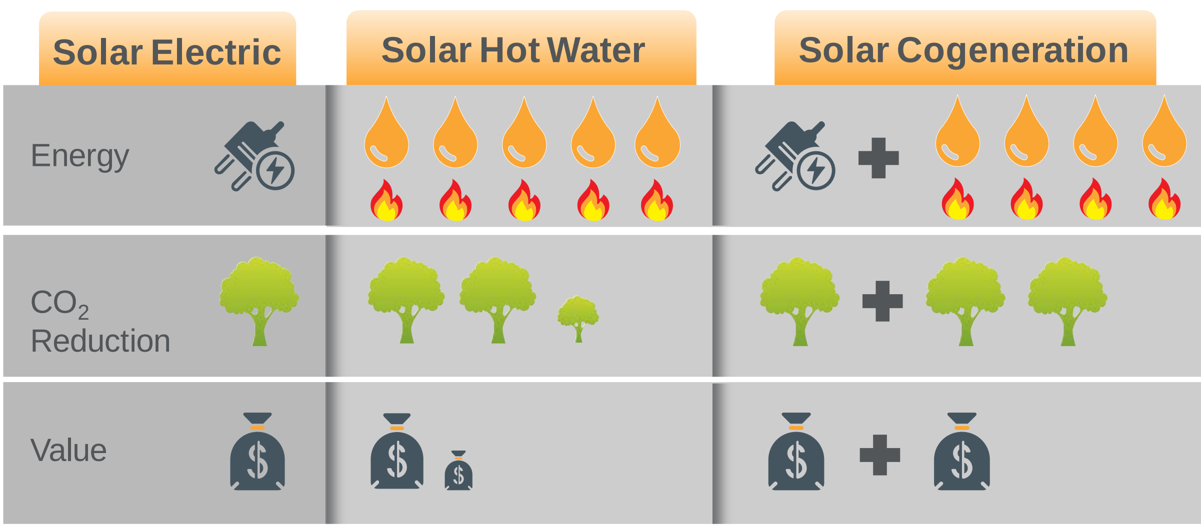


FIGURE 1: COMPARISON OF ENERGY, GHG REDUCTION AND VALUE

In addition to the economic and environmental benefits, solar cogeneration also has significant technical advantages over conventional SHW. Stagnation is a serious risk in conventional SHW. The tracking capability of solar cogeneration intrinsically mitigates this risk by moving off the sun when maximum temperature capacity is exceeded. Eliminating stagnation risk considerably simplifies engineering requirements, operating protocols, and maintenance.

COGENRA APPROACH

Cogenra's innovative technology, the SunPack system, uses solar cogeneration to deliver faster financial payback and greater reliability than conventional SHW systems. Cogenra's solution allows customers to enjoy the best of both worlds: the high efficiency of SHW and the high economic value of solar PV. However, since it is a relatively new technology, limited data on the performance and cost of such solar cogeneration systems exists. Cogenra built a demonstration system at Sonoma Wine Company in Graton, California. This first-generation system served as the baseline for performance modeling and evaluation, cost targets and reduction, and future integration with flexible distributed energy systems such as absorption chillers.

TASK 2: SUMMARY

Develop second-generation production methodologies that will reduce overall system cost by up to 20% compared with current production techniques.

This task has been successfully executed with cost reduction greater than the target of 20%. The baseline system was re-engineered to utilize shared drive mechanisms and controllers. Shared components allow for greater simplicity – reducing cost, weight and maintenance. Under this task, the Cogenra product transitioned from a large ground mount system to a system that can be mounted on a roof or ground with weight and structural requirements comparable to traditional photovoltaic panels. Installation costs and complexity were decreased for the mirror attachment and complete system. Yield and thermal performance of the receiver was optimized by production techniques and redesign of the junction box. With the improved product and supply chain, custom packaging was designed to complete the requirements for a simple merge-at-site installation process. Subtasks 2.1 – 2.4 provide detailed information on these improvements.

FIGURE 2: 1ST GENERATION - GROUND MOUNT

FIGURE 3: 2ND GENERATION- ROOF MOUNT OR GROUND MOUNTS INSTALLATION

A summary of cost-reduction by subsystem is provided in Table 1. Cost reduction for production and freight improvements are included. The table shows percent cost reduction by six month time periods which allows for progress tracking. For example, mirror improvements were concentrated in period 1 with additional refining in periods 2&3, while controls improvements were concentrated in period 2. The line by line improvements and contribution to overall reduction are available in Appendix C of this report.

TABLE 1: PERCENT COST REDUCTION BY SUBSYSTEM

	P1: Baseline - Dec 2010			**P2: Dec 2010 - June 2011**			**P3: June 2011 - Dec 2011**		
	Product	Freight	Total	Product	Freight	Total	Product	Freight	Total
STRUCTURAL	32%	15%	29%	24%	30%	25%	7%	5%	6%
MIRROR	50%	67%	54%	18%	-50%	8%	5%	20%	8%
CONTROLS	35%	37%	35%	65%	65%	65%	0%	0%	0%
RECEIVER	19%	66%	30%	17%	6%	-3%	-11%	1%	-5%
HYDRAULICS	73%	75%	74%	29%	-75%	26%	1%	0%	1%
PERCENTAGE REDUCTION FROM BASELINE			**21%**			**38%**			**50%**

REPORT ON CONSOLIDATING ARRAY DEPLOYMENT: SUBTASK 2.1

Cogenra will re-engineer the system and controller to enable adjacent arrays to share a mounting post, tracking unit, and controller unit and also to simplify the water interconnections. This modification will reduce the system bill of materials as well as field installation cost.

The first Cogenra installation at Sonoma Wine Company was a large, non-modular system of separate arrays. Large posts were ground mounted with poured concrete as shown in Figure 4. Heavy racking required the use of a crane and welded connections.

FIGURE 4: SONOMA WINE COMPANY MOUNTING POST INSTALLATION

FIGURE 5: 1ST GENERATION RACKING INSTALLATION AT SONOMA WINE COMPANY

The pumps and control electronics were separate components and each required individual engineering design and permitting. In addition to being costly and site specific, these components required a large amount of space and were located on a custom concrete pad.

FIGURE 6: 1ST GENERATION CONTROLLER UNITS AT SONOMA WINE COMPANY

The second-generation product was developed as a shared component system, the SunPack. A SunPack system consists of an array of SunDeck® modules, an iBOS™ (integrated Balance Of System) controller, and an inverter. SunPack systems are arranged as two rows of four, five, or six SunDeck modules, for a total of 8, 10, or 12 modules. Each SunPack is a complete, self-contained system. The pack configuration retains the benefits of a modular system while reducing bill of materials and cost.

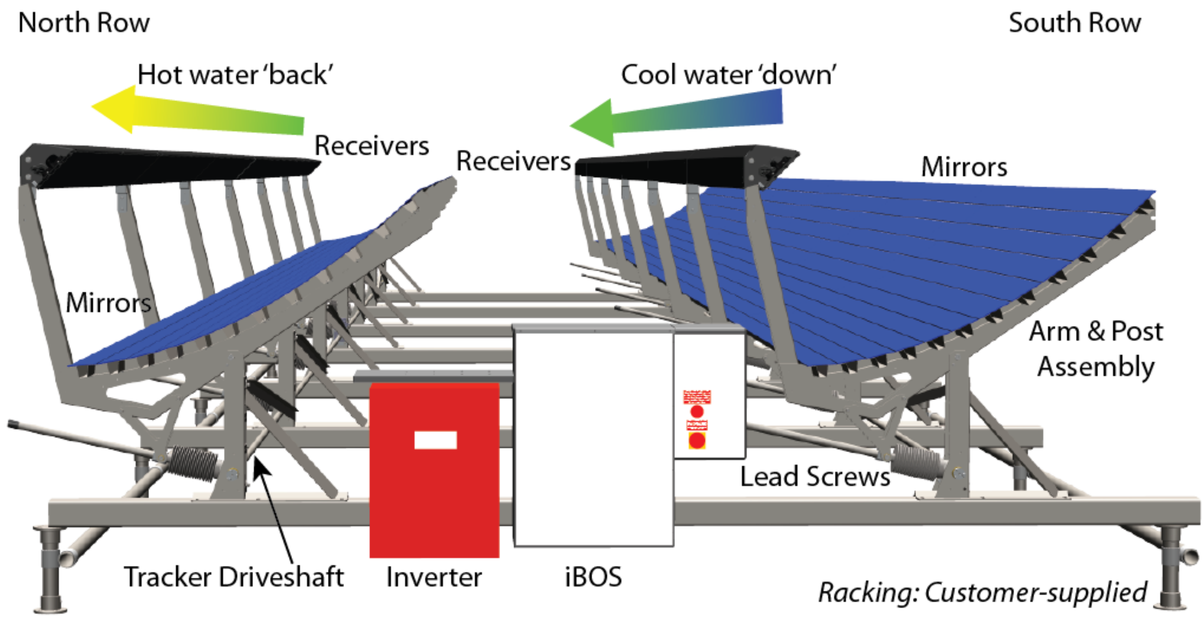


FIGURE 7: SUNPACK SYSTEM

The iBOS, integrated inverter and balance of the system, contains the coolant circulation pump for the array, as well as temperature sensors and safety components. It also includes the control electronics for the array. A pump in the iBOS unit draws cool heat-transfer fluid from the tank (not shown) and pumps it 'down' one row of SunDeck modules, typically the southern-most unit. The heat-transfer fluid returns via the second row of modules.

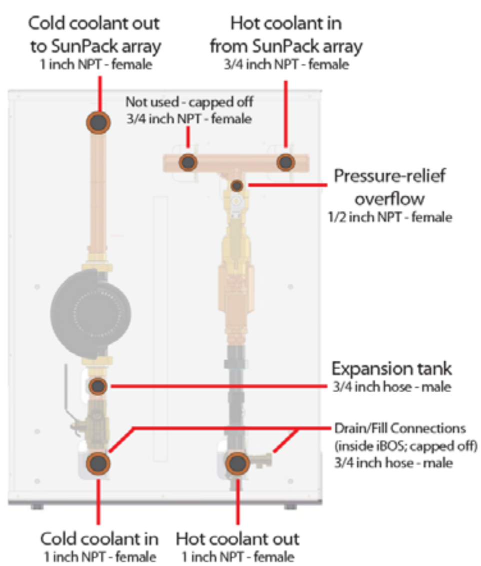


FIGURE 8: HYDRONICS CONNECTIONS

Installations of the re-engineered, shared component system demonstrate the success of the design in reducing bill of materials and installation cost. The ease and simplicity of a new roof mounted installation can be seen in the images below – a stark contrast to the heavy machinery and construction shown in the first installation.

FIGURE 9: ROOF INSTALLED MOUNTING POST

FIGURE 10: STANDARD RACKING

FIGURE 11: ARM AND POST SUBASSEMBLY ATTACHED

Standard installation time for the SunPack is less than half of what was required for the original product.

REPORT ON NOVEL FIELD INSTALLATION TECHNIQUES AND RIGS: SUBTASK 2.2

Cogenra will develop a clamping system that simplifies the procedure for attaching the mirrors to the support beds in the field, reducing installation cost. This subtask will also include the design and construction of custom rigs to expedite assembly, optimization of the assembly procedures to minimize complexity and time, development of training manuals and instructional aids for contractors, and development of water-efficient cleaning procedures.

Mirror assembly and installation were optimized for ease of production, installation and maintenance. Linear mirrors approximate a parabola to provide concentration. Solar mirrors glued to the supporting bed were stress-tested to ensure operation for 25 years in outdoor installations. Gluing the mirrors to the supporting bed lowers installation cost by shifting work from the field to an efficient manufacturing facility. A roll forming tool was developed to lower the attachment cost and a snap-in mirror bed attachment was designed for fast and easy mounting in the field. The linear mirrors are laminated at the factory and shipped to the job site where they are snapped into the assembled modules.

Similarly, the arm and post were integrated for shipping from the manufacturer as a sub-assembly instead of separate components requiring assembly on site. The sub-assembly was designed with the ability to mount on standard photovoltaic racking for either roof or ground installations. Receivers and brackets were redesigned to be easily lifted by an installer and set in place without special equipment. Two 3/8-16 x 2 inch bolts standard bolts are used to secure the receivers to the brackets.

A complete installation guide was developed for the product and can be found in Appendix A. Additional training materials were also created to support contractors and installers. Appendix B provides a training video as an example of one such product.

To minimize water use for mirror cleaning, controls for a new stow position were designed. The collectors stow overnight in an orientation where the mirror view field is primarily warm land, not cold sky. This minimizes dew collection and dramatically reduces the need for water intensive mirror cleaning. At Sonoma Wine Company, the six month mirror cleaning showed less than a 2% impact on performance. The chart in figure 12 on the following page demonstrates the performance before and after mirror cleaning at Sonoma Wine Company.

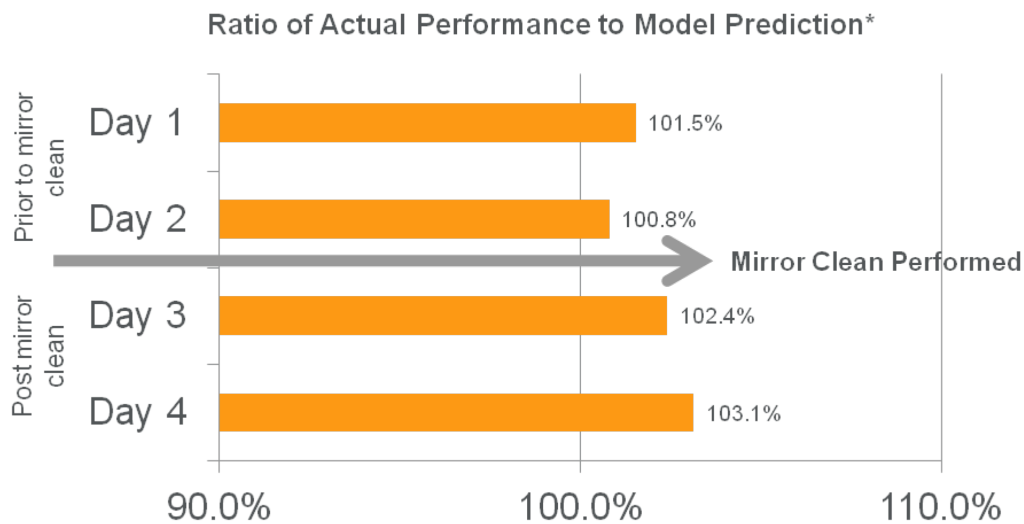


FIGURE 12: MINIMAL MIRROR CLEANING NEEDED

*NOTES: RATIO OF ACTUAL PERFORMANCE TO MODEL PREDICTION NORMALIZED TO A "CONTROL" MODULE-ROW THAT WAS LEFT UN-CLEANED. NORMALIZATION TO "CONTROL" PERFORMED TO ELIMINATE DAY-TO-DAY PERFORMANCE CHANGES DUE TO SOLAR IRRADIATION

TOOLS AND EQUIPMENT

The new product developed under this grant eliminates the need for heavy equipment, customized jigs, other specialty tools and welding. Jigs were designed to speed installation initially, but the increased simplification and refinement of the installation process made them obsolete. Note the standard, commonly available tools now used for product installation compared to the list of custom parts previously required.

TABLE 2: COMPARISON OF EQUIPMENT NEEDED FOR INSTALLATION

SunBase (v1)	SunDeck (v2)
• Crane or forklift (771 kg capacity) and lift straps (x2) • Column alignment jigs (per row): • Column bubble levels (x2) • North column alignment laser jig (x1) • South column target jig (x2) (PN# 500-5291) • Lift jigs (per system): • North column lift jig (x1) (PN# 500-5263) • South column lift jig (x1) (PN# 500-5290) • Pedestal jigs (per row of systems): • North pedestal laser and bubble level jig (x1) (PN# 500-5295) • South pedestal target and bubble level jigs (x2) (PN# 500-5285) • Main shaft alignment pins (x2 per system) (PN# 500-5269) • Manual rotation jig (x1) (PN# 500-5290) • Spacer plate (x1 per system) (PN# 300-5192) • Pillow bearing (x1 per system) • Tools: • 1/2" ratchet drive • 1-3/4" socket • Portable work platform and tool box support • Ruler • Tool box • Portable work platform and tool box support • Arm-to-Main Shaft push-pull jig (x2) (PN# 500-5248) • Arm-alignment laser jig (x2) (PN# 500-5227) and target jig (x2) • Golden jig (x1) • Bubble level (x1) • Free-standing work ladders (x2) • Receiver submodule alignment jig (PN# 500-5697) • Mirror Bed North/South positioning jig (PN# 500-5294) • Mirror Bed Crate lifting jig • Mirror Bed Crate transportation cart	• Short digital level or digital angle gauge with magnetic attachment. Must be accurate to 0.2 degrees. • Bar clamp, one-hand operation, 6-inch (150 mm) capacity • Cordless drill or driver • 1/4" socket driver for cordless drill • 9/16" and 3/4" combination wrenches • 9/16" socket, ¼ or 3/8 drive, with handle • Coarse file • #2 Phillips screw driver • Torque wrench • Tape measure • Spray lubricant, such as PAM cooking oil • 32 mm flare wrench or open-end wrench. McMaster-Carr and others carry large flare wrenches. • 1-5/8" (42 mm) and 1-7/8"(48 mm) open-end wrenches - used to tighten the hydronic connectors. Alternately, an 18-inch (450 mm) adjustable wrench can be used. • 12" and 6" long Tek screw driver • Special tracker drive tool; available from Cogenra. • Chalk line • DVM • Glycol freeze-point tester (Misco model 7084VP (°F) or 7064VP (°C) or equivalent) • Solar irradiance meter (Daystar or equivalent) Infrared thermometer (Ryobi, General Tools, Klein, or equivalent).

REPORT ON RECEIVER MANUFACTURING IMPROVEMENTS FOR COST REDUCTION: SUBTASK 2.3

This sub-task will include a subset or all of the following elements: improve and qualify the receiver lamination process; anodize the receiver units to improve thermal performance; customize the design of the junction box to better accommodate the unique receiver geometry (thus simplifying assembly); improve the yield of the stringing technique.

Major mechanical, electrical and material improvements to the receiver were made. The improvements increased thermal and photovoltaic performance as well as reducing manufacturing and assembly costs.

PLASTIC COVER AND HYDRONIC INTERCONNECTS

A monolithic cover for the back of the receiver replaced multiple sheet metal parts used previously. This lowered materials cost and simplified assembly. The new cover is black to increase thermal gain, and interfaces the receiver in such a way that the contact area is reduced minimizing thermal loss. The cover also offers UV protection and insulation to the hydronic and electrical interconnections.

A new, molded water hose interconnect between adjacent receivers removed the need for custom machining on the manifold. As a result of the design improvement, tolerances for the connecting receiver bracket were loosened, again making the field installation easier

FIGURE 13: REDESIGNED RECEIVER WITH BLACK COVER AND MOLDED HOSE

SOLAR CELLS

Thermal and electrical performance of the receiver is dependent on the conductivity of the materials between the cells and aluminum substrate. Higher conductivity results in lower cell temperature which improves electrical efficiency and better thermal coupling between the cell and substrate also improve heat transfer efficiency. Cogenra executed reliability and temperature testing of numerous materials both at Cogenra and with contractors. Many of these materials were successful and these choices were narrowed down based on cost and ease of sourcing. A new cell concept was tested, proven and selected for product incorporation. The new cell concept uses cut fractions of cells. This concept demonstrated reliable, increased power input and allowed for ease of integration with the receiver using standard PV manufacturing techniques.

COATING AND LAMINATE

In order to maximize thermal performance the receiver substrate should have a high absorptivity coating which will not degrade in sunlight or with time. Several coatings which improve absorptivity were thoroughly tested for performance and degradation. A low-cost, high solar absorptivity coating was selected from those tested. The selected coating has nearly negligible long-term degradation in UV and an optimal surface for lamination adhesion. New laminate materials were investigated including a black, 3M dielectric and black dielectric from a second supplier. Unfortunately, the second supplier's dielectric used a primer that increased the separation between the PV and receiver and negatively affected performance. The 3M dielectric cracked under operations testing for Cogenra conditions. A high quality dielectric for use with the black anodized aluminum was selected instead. Lamination process tuning for the back sheet was completed with determined optimal temperature, vacuum, and lamination time for elimination of bubbles and wrinkles.

JUNCTION BOX

The original junction box (J-box) was unwieldy and difficult to integrate with Cogenra's unique receiver geometry. Research and development under this grant led to a new low cost method for attaching the diode assembly to the J-box wires as well as a method for sealing the un-used cable port. Subcomponents of the J-box were broken into pre-manufactured assemblies that eliminated the need for redundant heat sinks. As a result of these improvements, J-box size was reduced more than 60%.

ASSEMBLY

The receiver substrate was redesigned for simpler mounting and reduced machining. The receiver assembly and brackets were also redesigned to reduce wind load and increase thermal performance. The lower profile of the assembly results in about 25% less wind loading to the rack, easing racking design and roof penetration requirements and lowering installation cost and time.

REPORT ON MERGE-AT-CUSTOMER PLANNING SYSTEM AND SITE INTEGRATION: SUBTASK 2.4

Cogenra will develop approaches to handling the logistics of coordinating delivery of modules, mirrors, collector mechanical components, trackers, water handling equipment and components from multiple independent suppliers directly to the installation site, taking into account capacity constraints, financial, purchasing and forecasting requirements. Also it will develop the procedures to accelerate field installation.

Cogenra has defined and implemented effective operations and supply chain management procedures. Inputs considered were human portability, ease of inventory and storage, weight, ability to be lifted by crane and loaded/off-loaded from flat bed trucks. Separate components were merged into modular subassemblies able to ship directly from the manufacturer and new packaging was designed to ease the merge-at-customer process.

The flat, modular mirror and shared component design completed under Subtasks 2.1 and 2.2 greatly reduced shipping cost and complexity. The original mirrors were 38 feet long and very difficult to ship and maneuver at site. The new mirrors reduced length by 76% with a maximum dimension of 9 feet. The mirrors attached at the manufacturer to the mirror bed allowed for the mirrors to be packed and shipped flat.

All new packaging was designed to be packed densely in standard containers for domestic and international shipping. Each package containing subassemblies can go directly from a shipping container, craned (if necessary for roof mounts) then broken down and carried easily around the site. Photos from a recent installation show the packaging and shipping practices designed and enabled by the other improvements under this task.

FIGURE 14: ROOF MOUNT INSTALLATION

FIGURE 15: RECEIVERS IN COGENRA PACKAGING

FIGURE 16: MIRRORS POST – PACKAGING

Note that the packaging shown is primarily corrugated cardboard. Corrugated cardboard is recyclable and naturally biodegradable. This is an additional environmental benefit of the successful completion of task 2.4. Previous shipping material was primarily wood crates. The wood crates were more than double the price of the cardboard containers and was difficult to dispose of. The cardboard packaging can be easily broken down and recycled in standard containers at the site. The packaging can also be reused as it is built with tabs rather than tape or glue.

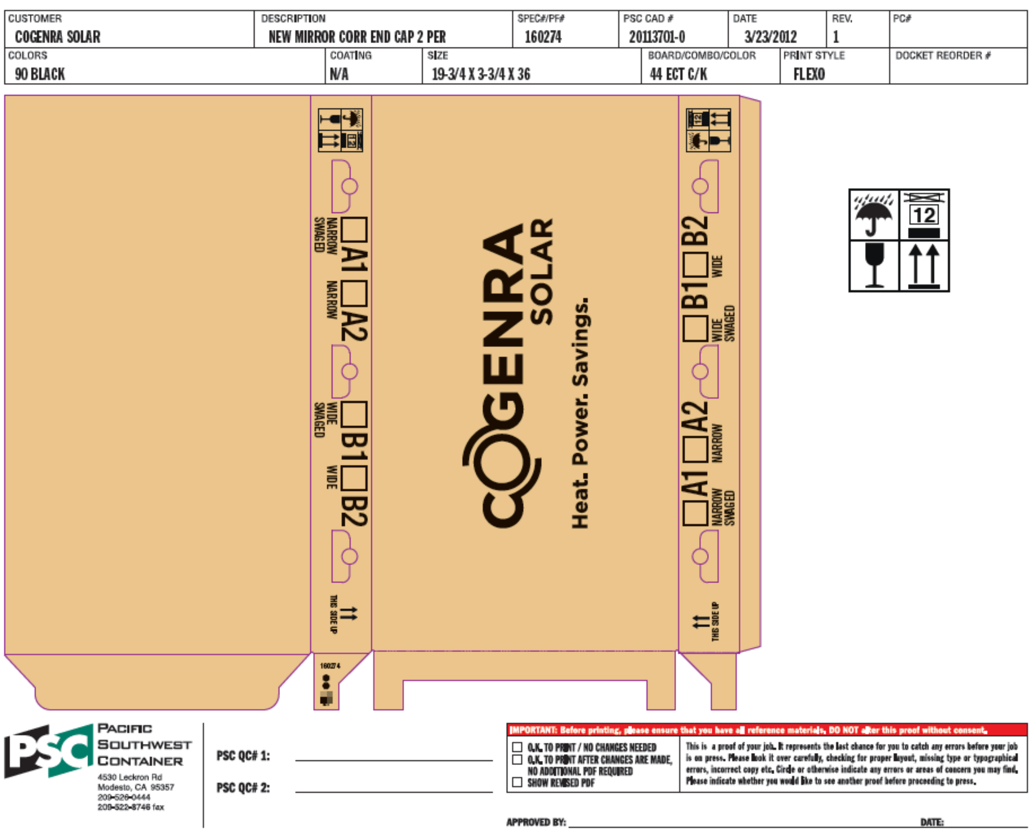


FIGURE 17: MIRROR END CAP

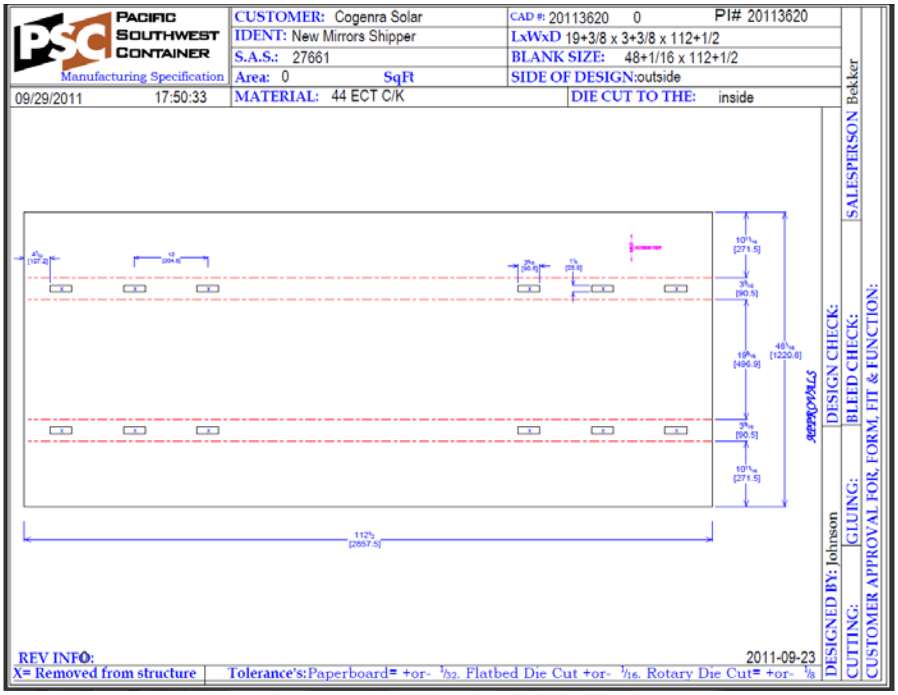


FIGURE 18: MIRROR BOX

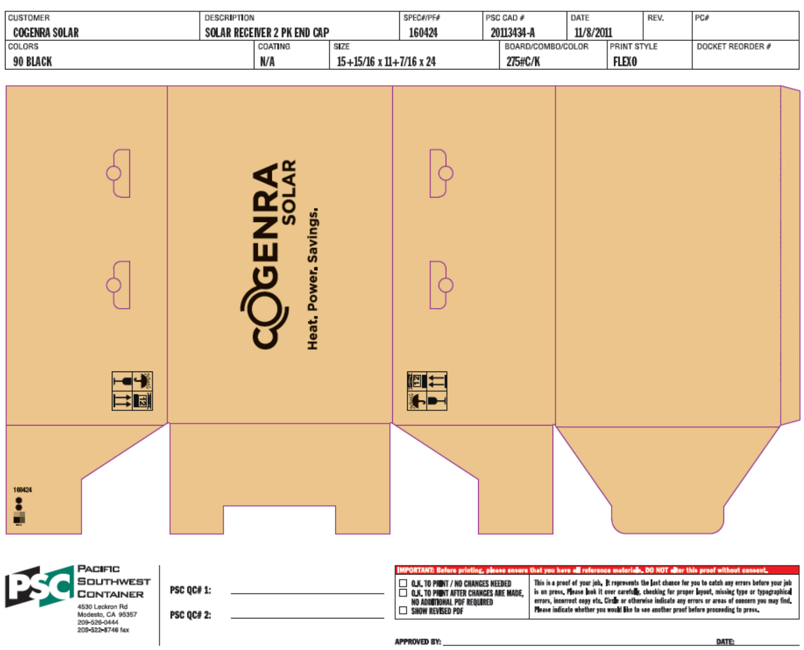


FIGURE 19: RECEIVER END CAP

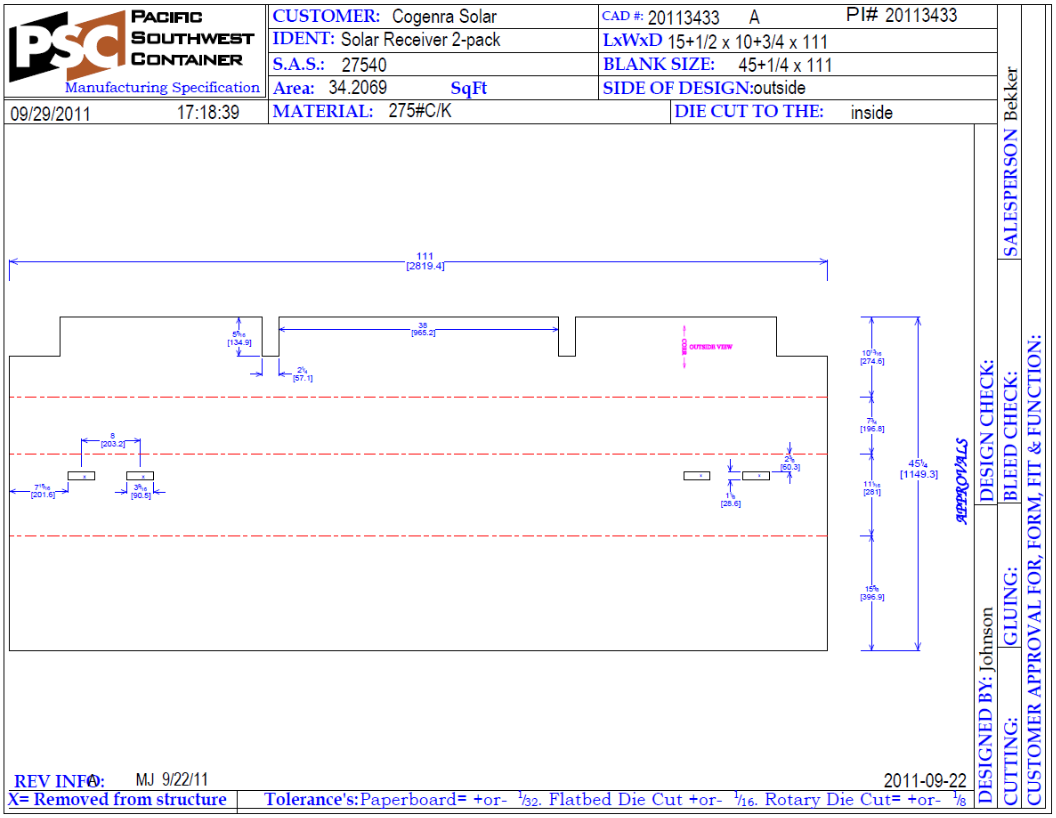


FIGURE 20: RECEIVER BOX

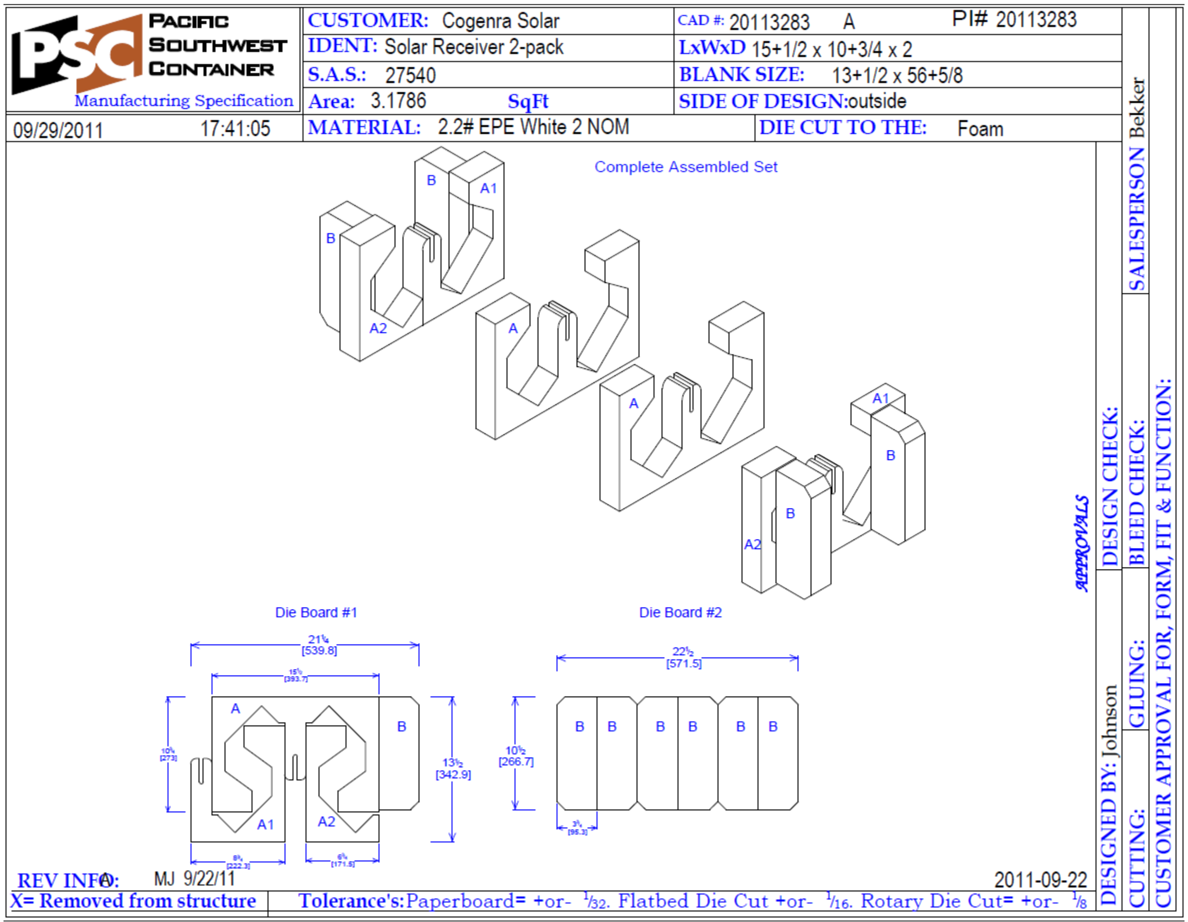
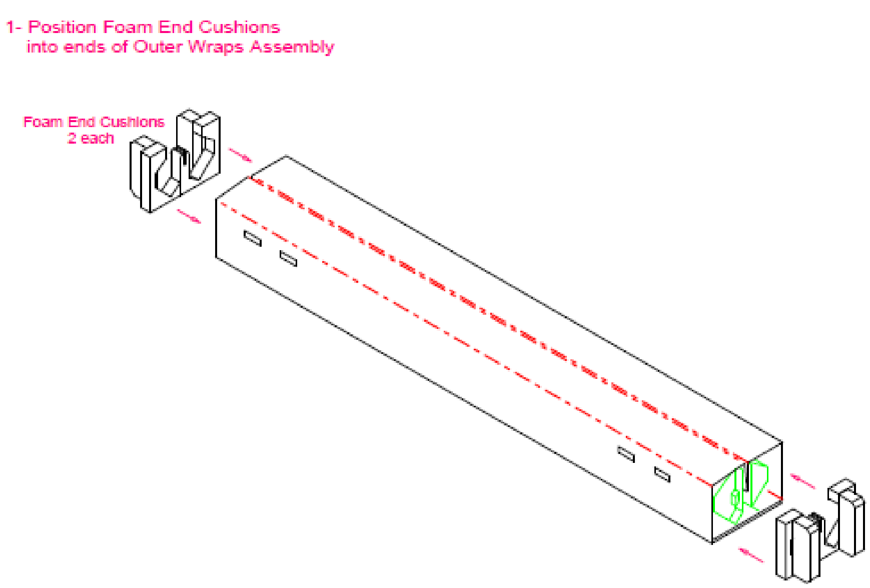


FIGURE 21: RECEIVER FOAM SUPPORT

The assembly of the box and foam support is as follows.



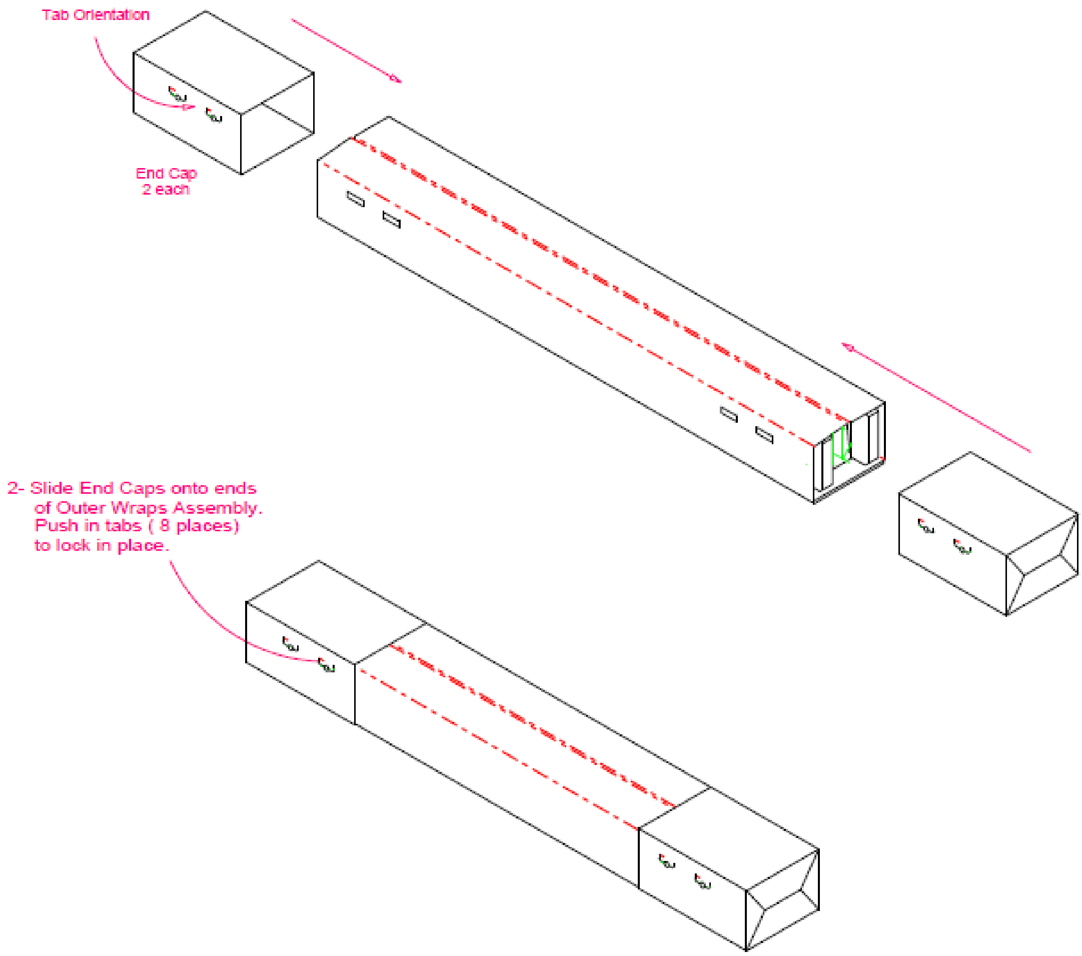


FIGURE 22: RECEIVER ASSEMBLY

TASK 3: SUMMARY

Collect detailed performance data from the Sonoma Wine Company (SWC) demonstration system and use the data to develop more detailed generalized models both to control and optimally run CPV/T-2G systems and to support marketing, sales, and financing of subsequent systems.

Cogenra built a commercial demonstration system at Sonoma Wine Company in Graton, California, USA to demonstrate the effective performance of one of the world's first solar cogeneration systems. Prior to installation, the photovoltaic and thermal energies were modeled using Cogenra modeling and third party software in order to predict system performance. Actual performance data was collected using remote monitoring technologies developed by Cogenra and the data was subsequently compared to the model. Data monitored includes weather data, flow, temperature, and electrical production. The results show that the modeled performance was highly correlated to the actual performance of the system and therefore validates the energy yield forecasting methodology.

Concurrent to data monitoring, financial and business models were developed and refined. The result was a complete economic modeling and proposal generation tool for sales, engineering, and marketing use. The tool, referred to as the ROI tool, takes site specific financial and energy inputs in order to evaluate the business opportunity for Cogenra and provide a detailed financial analysis to the customer.

REPORT ON THE COLLECTION AND ANALYSIS OF FIELD PERFORMANCE DATA FROM THE SONOMA WINE COMPANY (SWC) DEMONSTRATION: SUBTASKS 3.1 – 3.3

SYSTEM DESCRIPTION

Performance data from the SWC demonstration system was collected and analyzed. The SWC demonstration system consists of an array with 120 SunBase® Cogenra modules with 272kWp output, ($50kW_e$ + $222kW_{th}$). SWC uses the energy generated from the system for its tank and barrel wash system as well as for electricity.

DESIGNED AND DEPLOYED INSTRUMENTATION

Cogenra deployed weather station instrumentation to track meteorological conditions and insolation. The system also includes an electrical meter to measure electricity produced and a BTU meter to measure the heat captured and delivered by the system. Cogenra also deployed additional sensors to track thermal and electrical demand flows in the SWC facility. A web-based remote monitoring and diagnostics system was developed to take advantage of the wireless communication of the controllers that allows for two way communication enabling real time control of the systems. Various algorithms and communications protocols definitions were tested.

Cogenra collected the following data in 5 min intervals:

- DNI – Direct Normal Insolation
- Diffused Light
- Ambient temp
- Wind
- Water temperature into the solar system
- Water temperature out of the solar system
- Water flow rate
- Water temperature customer side In/Out
- Water Flow- customer side.
- Electricity generated
- Tracker angle.
- Water Storage tank temp.

TRACKED AND ANALYZED SYSTEM PERFORMANCE

All the data is fed into a model which calculates the expected output and then integrates the output for every hour, every day and every month. Simulation included predictions of changes in output due to storage tank temperature.

The Cogenra energy model and algorithms were compared to modeled outputs from Polysun which is a standard commercially available package used to predict output from thermal and cogeneration systems, such as Cogenra Solar. There was a very good correlation between the Cogenra model and the results obtained using the Polysun. Representative diagrams for both models are shown in Figures 23 & 24.

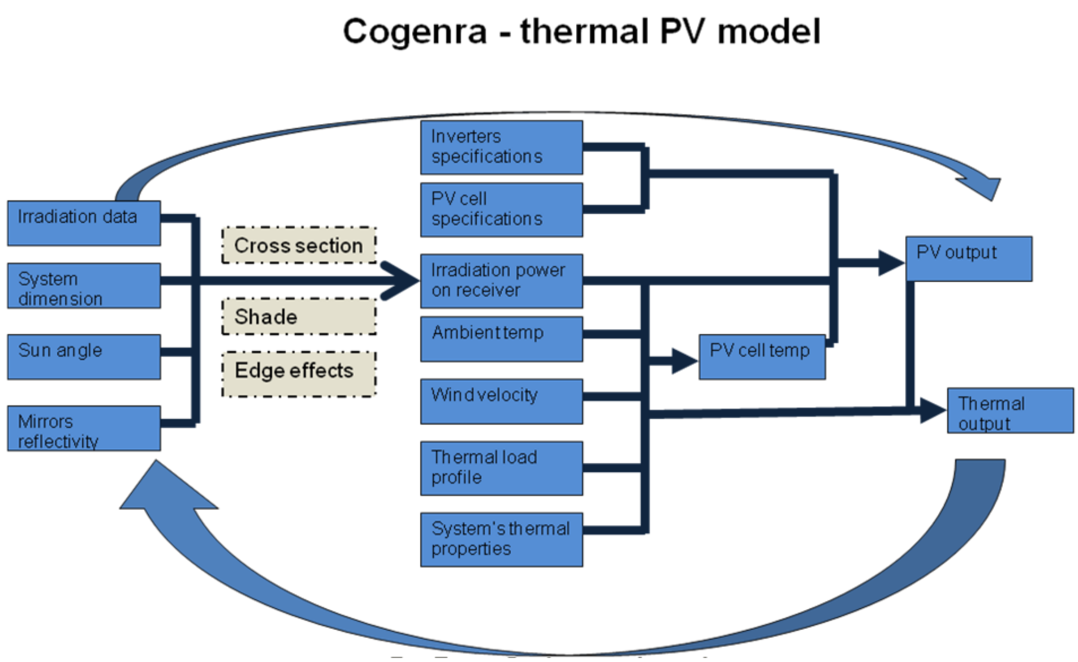


FIGURE 23: FLOW DIAGRAM OF PROPIETARY COGENRA ENERGY MODEL

Polysun- Solar-Thermal PV model

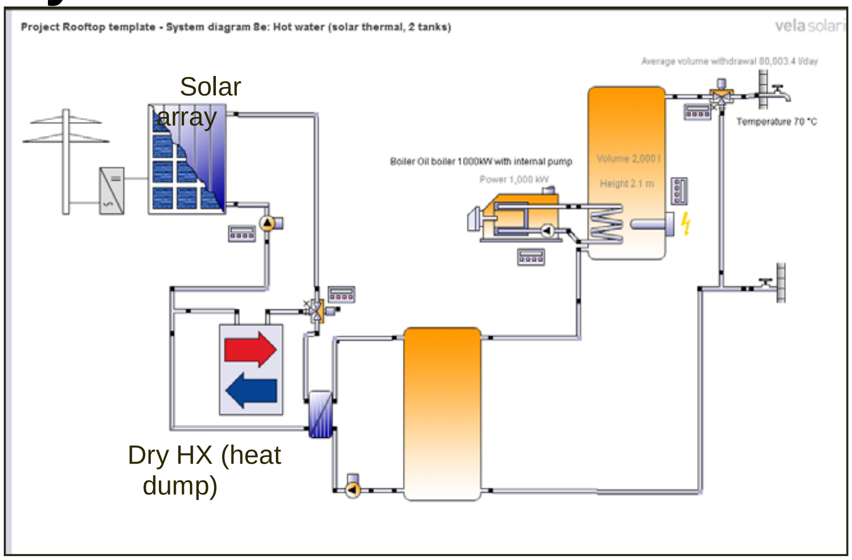


FIGURE 24: FLOW DIAGRAM OF POLYSUN ENERGY MODEL

Cogenra collected, correlated and analyzed the CPV/T-2G system performance data and assessed the impact of varying parameters such as the water flow rate, output temperature, and the way in which arrays are strung together with respect to water flow. Both electrical and thermal performance data were collected for the 2011 calendar year. The modeling algorithm's predicted performance was evaluated against the actual performance to determine accuracy of the Cogenra energy model. The financial model was refined based on actual performance data.

OPTIMIZED CONTROL LOGIC TO MAXIMIZE DELIVERED ENERGY VALUE.

Cogenra developed and implemented control algorithms to optimize system performance (in terms of delivered energy value) with respect to the models described above. The control electronics and necessary hardware to implement the algorithms are contained within the Cogenra engineered iBOS, integrated inverter and balance of the system. In addition to control electronics, the iBOS contains the coolant circulation pump for the array, temperature sensors and safety components. A variable speed pump in the iBOS unit draws cool heat-transfer fluid from the tank and pumps it 'down' one row of SunDeck modules, typically the southern-most unit. The heat-transfer fluid returns via the second row of modules. The pump speed is controlled to achieve optimal desired temperature as measured by the temperature sensors.

Proprietary sensing and tracking controls for the optical system were also developed and engineered. The Cogenra module follows the position of the sun in the sky and uses fine sensing to adjust for optimal concentration on the receiver. In the case of excess heat or emergency, the tracking controls automatically moves the module off sun, eliminating risk of stagnation or damage to the receiver. This control can also be implemented remotely for maintenance or monitoring.

PROJECT OUTCOMES: MODELED VS. PRODUCED

The results of predicted vs. produced energy for both PV and thermal demonstrate high model accuracy on a daily, monthly, and annual basis. Actual model results from day in June are shown in Figure 25. The measured data demonstrates more scatter than the model as expected but closely trends with the prediction.

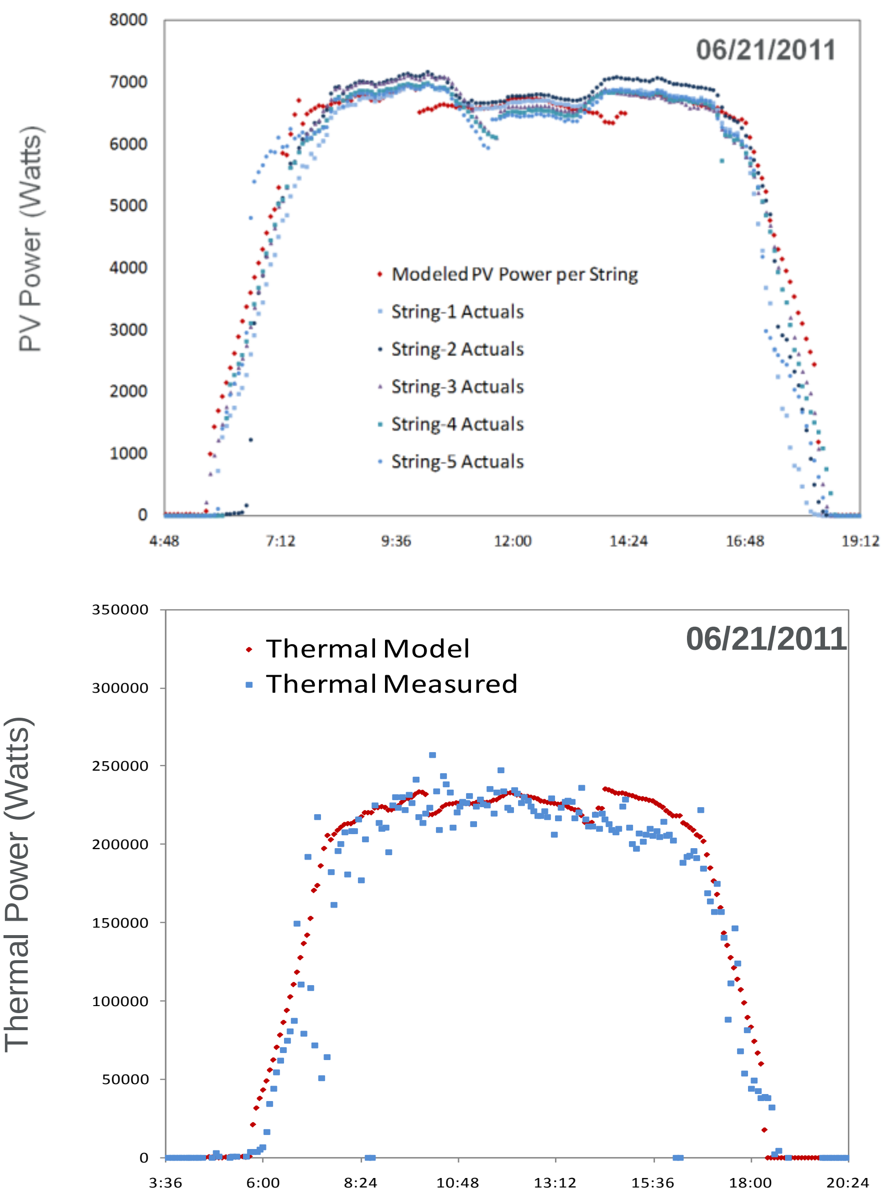


FIGURE 25: EXAMPLE OF DAILY PERFORMANCE MODELING, JUNE 21, 2011

A monthly comparison is also highly correlated.[1]

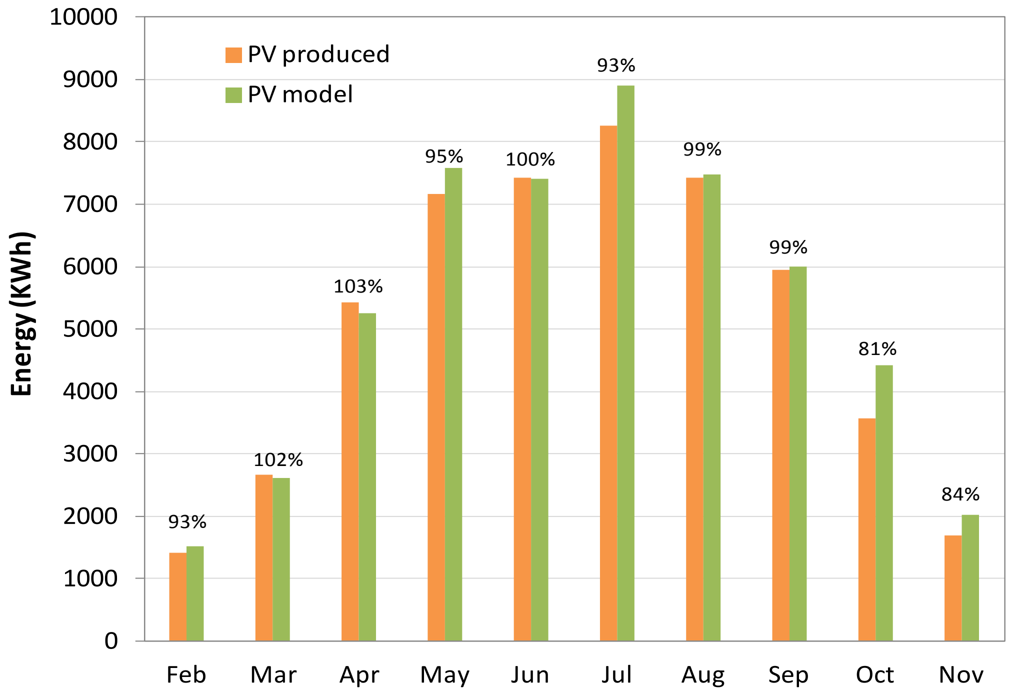


FIGURE 26: MONTHLY PV ELECTRICTY PRODUCED VS. MODELED AT SWC

For 2011, the total PV electrical energy produced by the SWC demonstration system was greater than 50 MWh. The PV production data was highly correlated to the model and was less than 4 % off from the model annually.

[1] The system was used for research and development activities at the beginning of 2011. The data from times of engineering work and research development and testing was filtered for precise comparison.

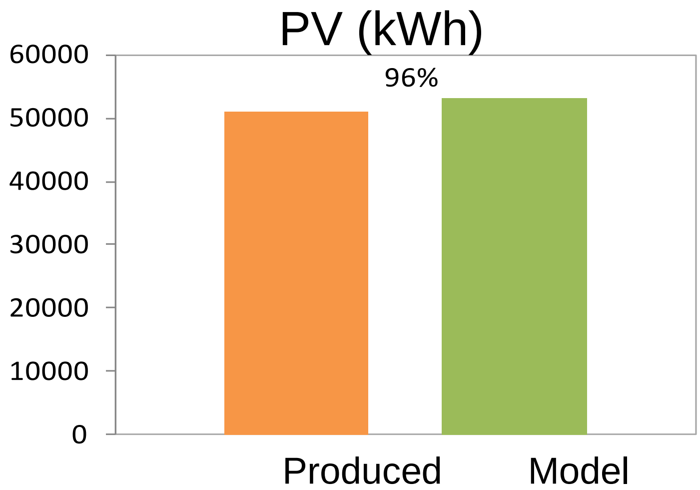


FIGURE 27: TOTAL PV ELECTRICITY PRODUCED VS. MODELED AT SWC

Results of thermal production vs. modeled were similar to those for PV production but a higher occurrence of production greater than modeled.

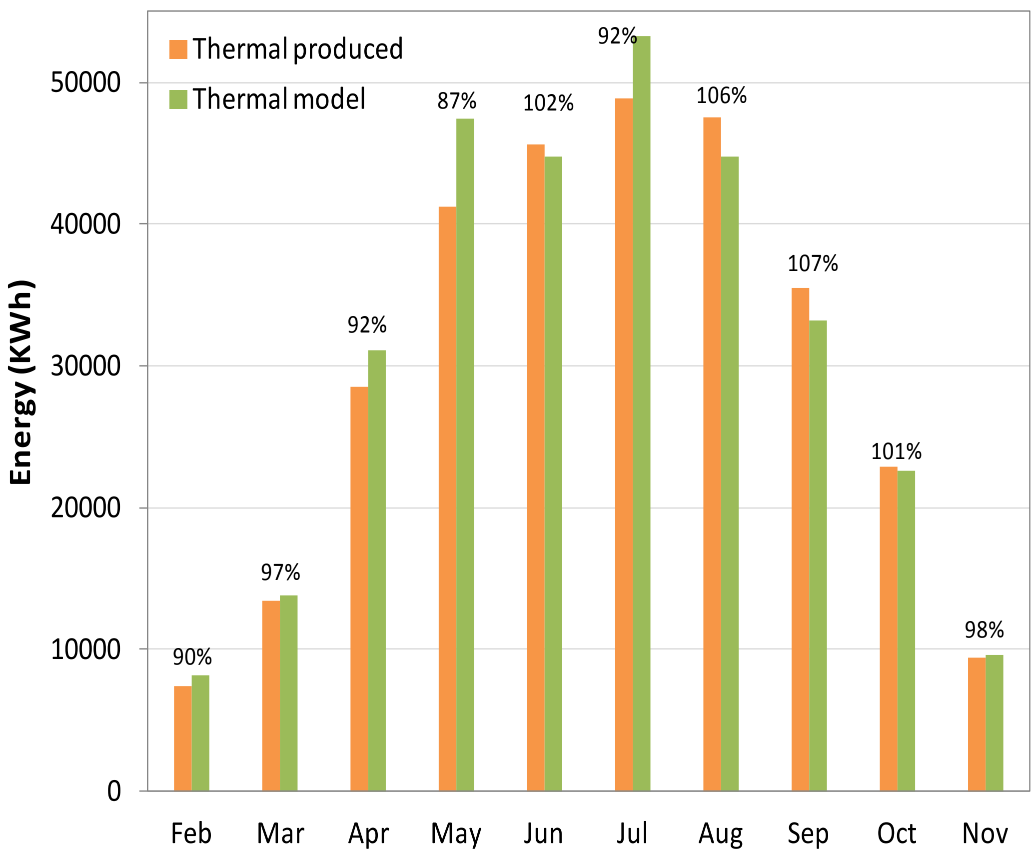


FIGURE 28: MONTHLY THERMAL PRODUCED VS. MODELED AT SONOMA WINE COMPANY

The thermal energy production in 2011 was approximately 300,000 kWh. The thermal performance data was also highly correlated to the model with a 3% annual discrepancy.

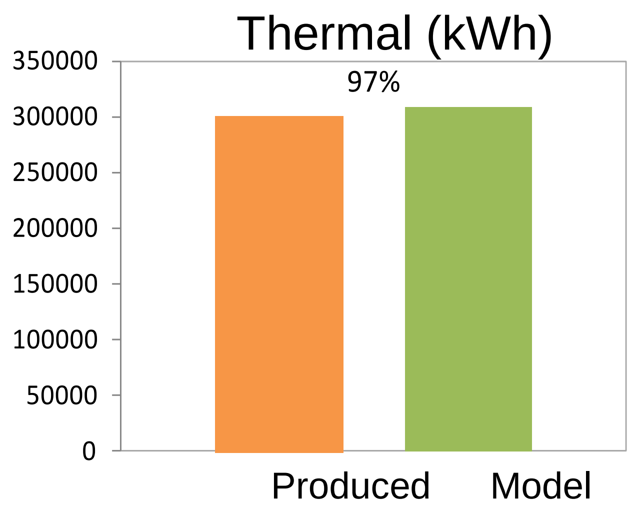


FIGURE 29: TOTAL THERMAL PRODUCED VS. MODEL AT SWC

Combining the comparisons of PV and thermal production, modeled results were on average within 97% of the prediction, with the system producing more than 350 MWh – 300 MWh thermal and 50 MWh electric.

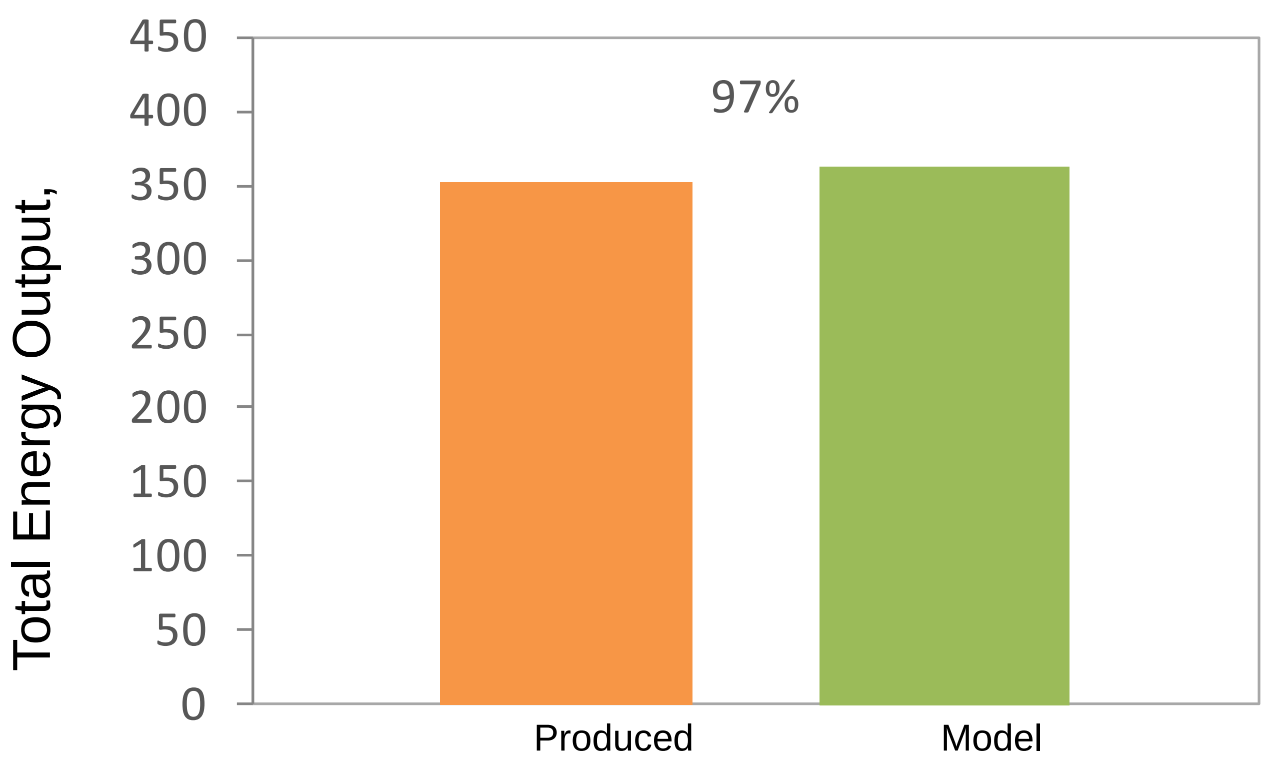


FIGURE 30: COMBINED ENERGY OUTPUT PRODUCED VS. MODELED.

The model results shown were produced by the proprietary Cogenra model and validated by comparison to the results of the Polysun model using thermal coefficients from testing of the Cogenra product. Since the Sonoma Wine Company installation, Cogenra became the first company to receive both SRCC thermal certification and IEC electrical certification. Subsequent modeling uses the coefficients as provided by these international certifying bodies.

REPORT ON FINANCIAL MODEL RESULTS: SUBTASKS 3.4 – 3.6

The interdisciplinary Cogenra team developed a complete economic modeling and proposal generation tool for sales, engineering, and marketing use. The tool, referred to as the ROI tool, takes site specific financial and energy inputs in order to provide a financial analysis for the customer including payback and internal rate of return (IRR). The tool automatically generates a complete customer proposal and cash flow summary. These automatically generated tools are essential to quick and efficient use by the sales team.

The extensive input capability ensures the ROI tool is robust and customer specific. Key energy inputs are the thermal and PV production per module. These values are calculated using the energy model described in the previous report. The model uses the customer weather data and site integration details as defined by the Cogenra engineering and operations team to ensure an accurate module energy production value for use by the sales team in the ROI tool. Engineering details obtained from the site walk such as customer boiler efficiency and year of installation can also be input for calculation of displaced energy. Default values are entered for preliminary proposals where this information is unavailable.

Customer energy prices for both electricity and hot water production are entered using customer or utility provided data. Tax effects including depreciation are included in the financial analysis. The model user can select a straight line or custom depreciation schedule and modify state and federal tax rates. The model uses monthly and annual cash flows for the complete product life-cycle to determine net present value. Federal and local incentives can also be entered and fully-modeled, including tax effects. The inputs cover a full range of potential incentives including:

- Federal incentives (Investment tax credit)
- Upfront incentives for PV and/or solar hot water production
- Local tax credits
- Electricity and thermal feed-in tariffs
- Electricity and thermal RECS
- Carbon incentive

Each incentive input can be adjusted for inflation, tax treatment, start and end years as applicable. A screenshots of a selection of the key inputs for the model is shown in Figure 31. This is a screenshot from the cash flow tab that is provided to the customer so that he or she can evaluate the effects of varying parameters on their payback and IRR. Additional detailed inputs are available to the sales team in the full model.

Inputs

Size, Performance & Evaluators	
Number of SunDeck® Modules	Site specific
Elec Prod / Mod (kWh)	Location dependent
Therms Prod / Mod (therms)	Location dependent
Space Required	Location dependent
Installation Price	Varies by array size
Weighted Average Cost of Capital	Varies

O&M, Insurance & Boiler Efficiency	
O&M ($/Module)	$50
O&M Escal. Rate	3.0%
O&M Warranty Period	5.00
Insurance Rate	0.2%
Insurance Escalation	-1.0%
Boiler Efficiency	Site specific
Rebate Boiler Efficiency	82% (CSI Thermal)

Thermal & Electric Rebates	
Thermal EPBB ($/Therm Offset)	$12.82 (CSI Thermal)
True Up/100% Upfront?	100.0%
Electric EPBB ($/W)	$0.00
Electric PBI ($/kWh)	$0.00
Electric PBI Duration (Yrs)	0
Thermal PBI ($/therm)	$0.00
Thermal PBI Duration (Yrs)	0

Depreciation, Taxes & Credits	
Federal Tax Rate	35.0%
State Tax Rate	5.8%
Fed Depreciation	50% Upfront
State Depreciation	Straight Line
Tax Credit Name	0
Tax Credit Cap	$0
Tax Credit Percent	0.0%
Tax Credit Carryover	1.0
Federal Grant or Credit?	Tax Credit

Utility Rates	
Electricity Price	$0.148
Electric Escalation Rate	2.0%
Natural Gas Price	$0.87
Nat Gas Escalation Rate	2.0%
Heating System Type	natural gas

Carbon, PBI & REC Value	
CO_2 Price ($ / ton)	$0.00
CO_2 Escalation Rate	0.0%
Electric REC ($/MWh)	$0.00
Thermal REC ($/MWh)	$0.00
REC Escalation Rate	0.0%

FIGURE 31: INPUTS FROM MODEL CASH FLOW SHEET, ILLUSTRATIVE

The proposals generated by the model are complete, 10+ page documents ready to be sent to the customer by the sales team. In addition to comprehensive financial analysis, the proposal includes an introduction to the Cogenra team and mission, technology description, case studies of installed projects, warranty and project timeline. An outline of a standard generated proposal is as follows:

- About Cogenra
- Leadership and mission
- Technology description
- Case studies
- Project overview
- Project output
- Site layout
- Environmental savings
- Project economics
- Financial analysis
- Lifetime cash flows
- Project timeline
- Warranty

FIGURE 32: ILLUSTRATIVE PAGES ROI MODEL GENERATED PROPOSAL

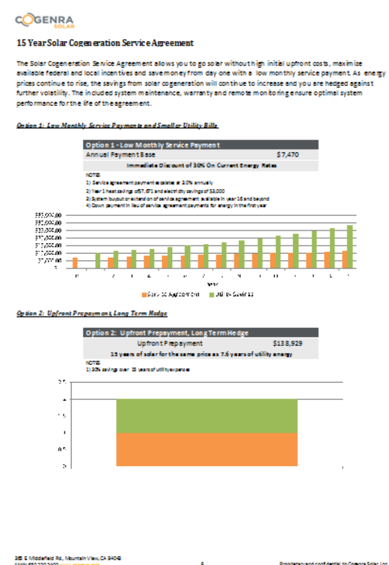
The proposals generated by the robust and highly detailed ROI model have been well received by customers. The ability to quickly and accurately present a specific, professional, detailed report has proven invaluable.

REPORT ON BUSINESS MODEL RESULTS: SUBTASKS 3.4 – 3.6

The ROI model also includes the ability to model and propose heat and power purchase agreements (HPPAs). The HPPA agreement for Sonoma Wine Company was defined for 15 years commencing with the commercial operations of the system. The system was installed at no up-front cost to SWC. SWC instead pays for the electricity and thermal energy produced by the system at a fraction of the avoided costs. Cogenra recoups the installed cost of the system and profits from the heat and power purchase agreement.

Evaluation of the business case for site specific heat and power purchase agreements is a sub of the ROI model described in the previous report. The Cogenra user may select direct purchase or heat and power purchase agreement in the ROI model. For the HPPA, the electricity and thermal (natural gas or propane) discount are input as well as the annual escalator for each energy flow. The term length of the HPPA is also entered. The model analyzes the Cogenra business case based on these inputs and those described in the previous section – e.g. site specific energy production, incentives and tax effects. Demand charges and time of use pricing can be selected to integrate within the model for California and Arizona utilities tariff structures at this time. Additional utilities and tariff structures are in progress.

A customer proposal similar to that described in the previous report is automatically generated by the model. This proposal contains the same general content as the direct purchase proposal but includes a page describing the two service agreements offered by Cogenra. Option 1 is the option selected by Sonoma Wine Company, a low monthly payment for the energy provided at a pre-defined discount from utility prices. Option 2 allows the customer to hedge against long-term increases in energy costs. Option 2 is an upfront payment for the 15 year energy use at a calculated discount. The model calculates the discount Cogenra is able to offer for this option based on the inputs selected.


COGENRA SOLAR

15 Year Solar Cogeneration Service Agreement

The Solar Cogeneration Service Agreement allows you to go solar without high initial upfront costs, maximize available federal and local incentives and save money from day one with a low monthly service payment. As energy prices continue to rise, the savings from solar cogeneration will continue to increase and you are hedged against further volatility. The included system maintenance, warranty and remote monitoring ensure optimal system performance for the life of the agreement.

Option 1: Low Monthly Service Payments and Smaller Utility Bills

Option 1 - Low Monthly Service Payment	
Annual Payment Base	$7,470
Immediate Discount of 30% On Current Energy Rates	

NOTES
1) Service agreement payment escalates at 3.0% annually
2) Year 1 heat savings of $7,671 and electricity savings of $3,000
3) System buyout or extension of service agreement available in year 16 and beyond
4) Down payment in lieu of service agreement payments for energy in the first year

Option 2: Upfront Prepayment, Long Term Hedge

Option 2: Upfront Prepayment, Long Term Hedge	
Upfront Prepayment	$138,929
15 years of solar for the same price as 7.6 years of utility energy	

NOTES
1) 30% savings over 15 years of utility expenses

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MAIN 650.230.2400 www.cogenra.com
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Proprietary and confidential to Cogenra Solar, Inc.

In the Option 1 HPPA, Sonoma Wine Company purchases all thermal and electrical energy from the system that can be used on-site. Sonoma pays for electricity and thermal energy at a fraction of Sonoma's "avoided costs." The discount after the first anniversary of the Commercial Operations date is 30%, i.e. SWC pays 30% less than they would to the utility.

The values of "avoided costs" for electricity and thermal energy are calculated individually. Detailed explanations of energy and demand charges are as follows.

ENERGY CHARGES – ELECTRIC

The AC electricity avoided costs will be reduced $/kWh electrical energy charges plus reduced demand charges. Reduced $/kWh electrical energy charges will be calculated as:

The value of the sum of AC Electricity (Less the value of AC electricity consumed by the solar array) produced and either

- Used by Sonoma
- Banked in the local utility's net metering program.

AC electricity produced by the array will be measured by a meter that will be installed next to the distribution panel. The meter will log the production by time. At the end of each billing cycle by PG&E, the kWhr produced each hour will be multiplied by the electricity rate for that hour and will be added up for all the hours of that billing cycle.

AC electricity consumed by the solar array will be measured by a dedicated meter which will feed the solar array and log its consumption by time. The value of this electricity will be calculated the same way as the AC electricity produced.

DEMAND CHARGES

The avoided cost of demand charges is the amount of each demand charge incurred, subtracted from the amount each such demand charge would have been if the facility had not been producing AC electricity at the time the demand charge was determined. For each billing cycle, the peak demand charge reductions at the time of peak demands billed by PG&E will be determined by measuring the amount of AC Electricity produced by the Facility at each such peak demand period and multiplying it by the amount of the applicable demand charge.

ENERGY CHARGES – THERMAL

The thermal energy avoided cost is the number of Therms delivered by the Facility to Sonoma multiplied by the delivered cost per Therm of natural gas charge to Sonoma by Sonoma's natural gas supplier during the billing period, divided by the boiler efficiency.

Therms delivered by the Facility to Sonoma will be measured by measuring the volume (gallons) and temperature (degrees F) of hot water delivered from the solar array to Sonoma and the temperature of the cold water in the cold water storage at the time of delivery. The amount of energy delivered will be taken to be the volume of the water delivered, multiplied by the difference in the temperature between the water delivered and the water in the cold storage tank, multiplied by the appropriate conversion factor to express the result in therms. The flow and temperature measurements will be done continuously and will be calculated for each hour.

The cost of natural gas will be taken from Sonoma's natural gas invoices applicable to the periods of hot water delivery. Sonoma's boiler efficiency shall be deemed to be 90%.

TASK 4: SUMMARY

The purpose of this task is to modify the system design so that it can support delivery of higher temperature water (enabling, for example, tri-generation of electricity, heat and cooling) and variable water flows enabling energy storage and "boost-on-demand" operation that allows the customer to capture additional value by generating more electricity when it commands the highest rates under variable TOU tariffs and by taking advantage of demand reduction incentives.

The first Cogenra installation at Sonoma Wine Company produces medium temperature hot water (approximately 115 – 130 °F) and electricity offsetting natural gas and electric use on-site. At hot water temperatures above 165 °F, thermal chillers can be integrated with the Cogenra array to produce cooling, heating, and electricity from the system. Cascading the use of energy in tri-generation is the most efficient use of the Cogenra array. Additionally, the cooling load profile of the typical building matches with peak electric rates and demand charges. Solar cooling adds to the customer value proposition of solar cogeneration.

WHY SOLAR COOLING MAKES SENSE

While the need for heat and solar resource availability correlate negatively, the demand for cooling matches solar resource availability perfectly: cooling demand is highest when temperatures are highest.

In the United States and worldwide, regions with high irradiance values are found to also have a large number of cooling degree days. A cooling degree day is an industry standard unit used to relate temperature to cooling energy demands.[2]

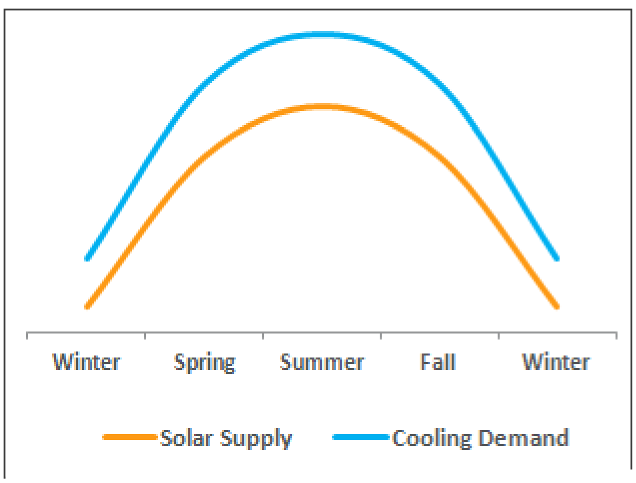


FIGURE 33: REPRESENTATIVE CORRELATION BETWEEN SOLAR RESOURCE AND COOLING DEMAND

[2] ASHRAE Handbook 2012 Fundamentals

Solar cogeneration produces heat (which can be used for heating or cooling) and electricity in one product. One product addresses customers’ need for heat in the winter, cooling in the summer, and electricity year-round. Thermal storage and controls that optimize for temperature, PV production, and demand charges ensure consistent chiller operation and maximize delivered energy value.

DESCRIPTION OF SYSTEM DESIGN, MODIFICATION AND COMPATABILITY ENABLING TRI-GENERATION: SUBTASKS 4.1 – 4.5

In order to achieve effective tri-generation, Cogenra was first tasked with developing a complete technical understanding of thermal cooling systems. The optimal set-point of these auxiliary cooling systems drove the temperature specification required for the new Cogenra design for tri-generation.

A solar cooling system consists of the solar collectors, buffer or storage tanks, thermally driven chiller or desiccant cooler and an optional backup heater, incorporated as a safe guard. Thermally-driven chillers are either absorption or adsorption chillers that produce chilled water in a closed loop process which is then used to condition the air to the desired temperature. Desiccant coolers are paired with evaporative coolers to directly condition air in an open loop process. Most solar cooling installations today use absorption chillers.

ABSORPTION CHILLERS

There are four primary components of a basic absorption chiller: a generator, a condenser, an evaporator and an absorber. Three heat exchangers facilitate heat flows into and out of the chiller.

Generator & Condenser

During the cooling process, heat is introduced into the generator – this is where solar heat is first used. In a direct-fired chiller, this may be heat produced by combustion of a fuel such as natural gas or propane. In a hot-water driven chiller (solar or other heat), the heated water flows through a heat exchanger in the generator.

The heat delivered to the generator vaporizes the Lithium Bromide (LiBr) and water solution, causing the LiBr to desorb into a concentrated solution. The concentrated solution is then passed to the absorber, while the water vapor travels to the condenser where the water returns to liquid (rejecting latent heat to cooling water), and is then throttled and sent to the evaporator.

Evaporator & Absorber

The purpose of the evaporator is to cool the water, similar to how moisture cools skin when it evaporates. The evaporator is maintained at a very low pressure by the chemical affinity of the water to the LiBr absorber, which allows boiling and evaporation at low temperatures. Evaporation of the water creates cooling by removing heat from the chilled water coil in the evaporator. The water vapor is then passed to the absorber where it is absorbed by the LiBr solution. This diluted solution of LiBr and water returns to the generator where the cycle begins again.

Heat Exchangers

An absorption chiller contains three loops of incoming and outgoing water that are used to exchange heat in the cooling process:

1. **Hot water loop (≈200 F in):** Transfers solar heat to drive thermal compression in the generator
2. **Cooling water loop (≈65 F in):** Rejects latent heat to maintain low temperatures in absorber and condenser. Chiller efficiency is more sensitive to absorber temperature than condenser temperature so cooling water passes first through absorber and then through condenser.
3. **Chilled water loop (≈44F out):** Cooled by vaporization of refrigerant in evaporator.

Absorption chillers are commonly available as single-effect or double-effect. A single-effect absorption chiller has one of each basic component described above. A double-effect absorption chiller is like a single-effect chiller with an additional generator and condenser to improve efficiency by cascading energy and pressure.

A standard efficiency metric for chillers is coefficient of performance, commonly referred to as COP. The COP is a measure of cooling energy out per unit of energy in.

Single-effect absorption chillers have a COP of approximately 0.7; double-effect chillers have a COP of approximately 1.2 but require pressurized vessels and much higher input temperatures. Research and development of triple-effect absorption chillers with a third generator and condenser set has been underway since the late 1990s. Triple-effect chillers achieve greater efficiency but with a high cost and added complexity. The simplicity, safety, and temperature requirements of single-effect chillers make them the ideal partner for solar cogeneration.

ADSORPTION CHILLERS

Adsorption chillers are less widely deployed and less commercially available than absorption chillers. Adsorption chillers have a growing presence in the European market. An advantage of the adsorption chillers are the low driving temperatures (beginning from 140 F), the absence of a solution pump and lower noise levels during operation.

Adsorption chillers use a solid sorbent material, typically silica-gel although other sorbents are being developed, to absorb and release refrigerant to create cooling. Adsorption chillers consist of two compartments, the evaporator and the condenser, both containing beds of the solid sorbent material. Solar heat input causes water in the evaporator to vaporize and desorb. The sorbent bed in the condenser adsorbs the water and rejects heat to start the process again. To efficiently manage heat, the beds will periodically switch from hot water to cooling water.

DESICCANT COOLERS

Thermally-driven open cooling cycles employ dehumidification with a desiccant cooler. The desiccant material can be either solid or liquid and uses lower solar heat input temperatures than absorption and adsorption chillers.

These types of coolers are most often found in developing regions, because while they are low-cost and simple to install, they are not a standalone cooling solution. However, the desiccant cooler dehumidification can be configured with evaporative cooling or chilled water to create a complete cooling solution.

SYSTEM MODIFICATION

The thermal coolers described above operate at minimum temperatures of 140 F (adsorption and desiccant coolers) and maximum temperatures of up to 210 F. The Cogenra receiver, hydronics and integration components were redesigned to achieve these temperatures and compatibility with thermal chillers.

Varying modifications to the high temperature receiver were analyzed and the highest probability results tested for performance, sensitive to UV exposure, durability at damp heat and freeze sensitivity. The highest performing laminate material and technique was selected for the final receiver design. Manufacturing processes for the new receiver were developed in parallel. A new back cover design was also researched and developed for increased thermal gain from diffuse radiation.

Variable flow circulators were tested early-on in the development process. Control signals and logic were designed for initially tested versions of the pump and modified for the final pump selection as determined by performance, reliability and cost. Receiver blocks were tested in various array configurations. By connecting the rows in parallel instead of in series (previous configuration), the total power required was reduced by approximately 20%. The flow needed was reduced by a factor of 2 and the pressure drop by a factor of 4. The variable flow circulator was incorporated into the design of the Cogenra iBOS, integrated inverter and balance of the system. The iBOS contains the temperature sensors, safety components and control electronics in addition to the circulation pump. Integrating the critical components for achieving desired temperature set point in a central location allows for high accuracy and ease of maintenance.

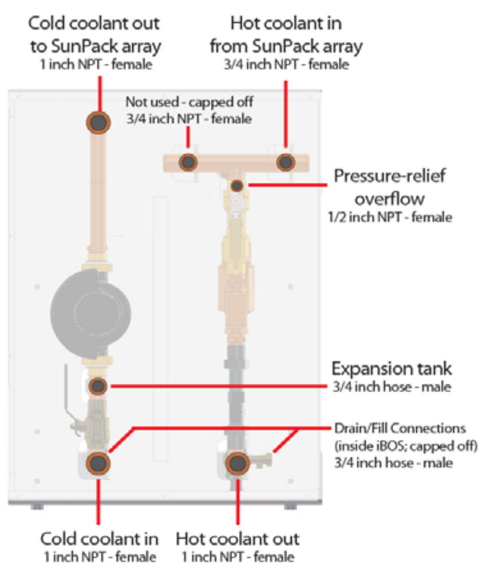


FIGURE 34: HYDRONICS CONNECTIONS, IBOS

As shown in *Table 3,* solar cogeneration uniquely offers over 100% cooling performance, maximizing customers' financial benefits. Traditional photovoltaics, at 15% efficiency, provide electricity for high-efficiency mechanical chillers with a COP of 5. Cooling performance is determined by multiplying energy captured by COP of the integration equipment. In Table 3, this is a vertical column multiplication. The resulting system cooling performance for PV is 75%.

*PV cooling performance: 15% PV * 5x COP = 75%.*

	PV	Solar Hot Water	Solar Cogeneration		
	AC Electricity	**400 F Hot Water**	**AC Electricity**	**200 F Hot Water**	**Total**
Energy	**15%**	**60%**	**15%**	**60%**	**75%**
Integration Equipment		*Double Effect Absorption Chiller*		*Single Effect Absorption Chiller*	
COP*	5X	1.3X	5X	0.7X	
Cooling Performance	75%	78%	75%	42%	117%

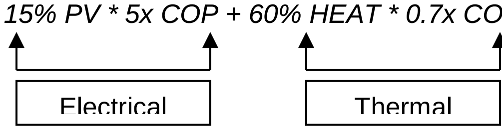
*COP: Coefficient of performance

** Cooling performance defined as cooling power delivered relative to solar power landing on aperture

TABLE 3: EFFICIENCY COMPARISON FOR SOLAR COOLING TECHNOLOGIES

Standalone solar hot water capable of reaching very high temperatures at 60% efficiency can be integrated with a double effect absorption chiller with a COP of 1.3. This yields a slightly higher system cooling performance at 78%. For solar cogeneration, temperatures are lower than standalone hot water to optimize photovoltaic efficiency and minimize system complexity. Solar cogeneration captures 15% energy with photovoltaics and 60% efficiency with solar hot water. Performance can again be determined by multiplying the energy captured by the coefficient of performance of the integration equipment for each energy stream (thermal and electric). Solar cogeneration yields the most total cooling to the customer with the combined production of cooling from PV and hot water produced by solar cogeneration yielding a 117% cooling performance.

*Solar cogeneration cooling performance: 15% PV * 5x COP + 60% HEAT * 0.7x COP = 117%*



DESCRIPTION OF SYSTEM CONFIGURATION TO OPTIMIZE ENERGY STORAGE AND ELECTRICITY PRODUCTION: SUBTASKS 4.5 – 4.6

Cogenra developed and implemented control algorithms to optimize system performance (in terms of delivered energy value). Proprietary sensing and tracking controls for the optical system were also developed and engineered. The Cogenra module follows the position of the sun in the sky and uses fine sensing to adjust for optimal concentration on the receiver. In the case of excess heat or emergency, the tracking controls automatically moves the module off sun, eliminating risk of stagnation or damage to the receiver. This control can also be implemented remotely for maintenance or monitoring.

In order to optimize for energy storage, additional control logic must be added to the Cogenra production controls. This additional logic requires communication between the Cogenra iBOS, the thermal chiller controls, and building management system if available. Input weather forecast data is also necessary. Cogenra developed the algorithm for translating weather forecast data to predicted output. This enables the control decision of how much energy to store or release from the tank based on output availability and customer demand input. The customer demand is passed to the iBOS from the chiller controls. Chiller controls are available as a standard offering for single-effect absorption and adsorption chillers. Protocol modification to ensure communication between iBOS and chiller control systems is underway in collaboration with industry.

With thermal energy storage, and coincident cooling and peak demands, the Cogenra system is able to engage in significant demand reduction using relatively simple algorithms and control logic with existing Cogenra iBOS and chiller controls.

DEMONSTRATION INSTALLATION AT SOUTHERN CALIFORNIA GAS COMPANY

Southern California Gas Company (SCG) is the first Cogenra customer to implement a cogeneration solar cooling system. The 20 SunDeck™ module demonstration system was installed atop the roof of SCG's Energy Resource Center (ERC) in May 2012. The 50.2kW installation will produce electricity to power the building and heat to drive a single-effect absorption chiller.

Instead of using electricity to run mechanical chillers, SCG's' demonstration project captures and stores the heat generated by solar cogeneration to power one of the Energy Resource Center's absorption chillers and support the building's air-conditioning system. The Resource Center includes office space, meeting rooms for workshops and seminars, and an exhibit hall – in all, capable of accommodating over 700 people.

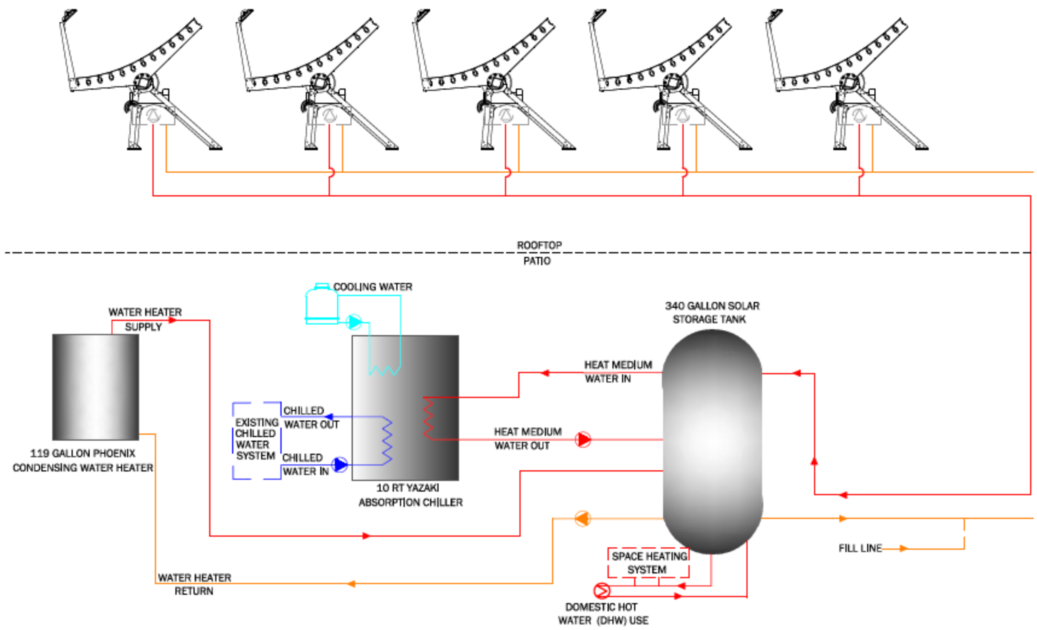


FIGURE 35: SCG SITE INTEGRATION

SCG INSTALLATION

SCG tracks the system performance including flow rate, pressure, temperatures, PV production and weather data. Data is collected in 1 min intervals. An example of results for thermal temperature and PV output from a late summer day are shown here. The Cogenra array is set to detrack so that temperatures above 200 F are not achieved. This ensures that the production is not above the chiller maximum operable temperature. The graph below shows the Cogenra array nearing maximum at 1 pm and maintaining maximum levels through the afternoon.

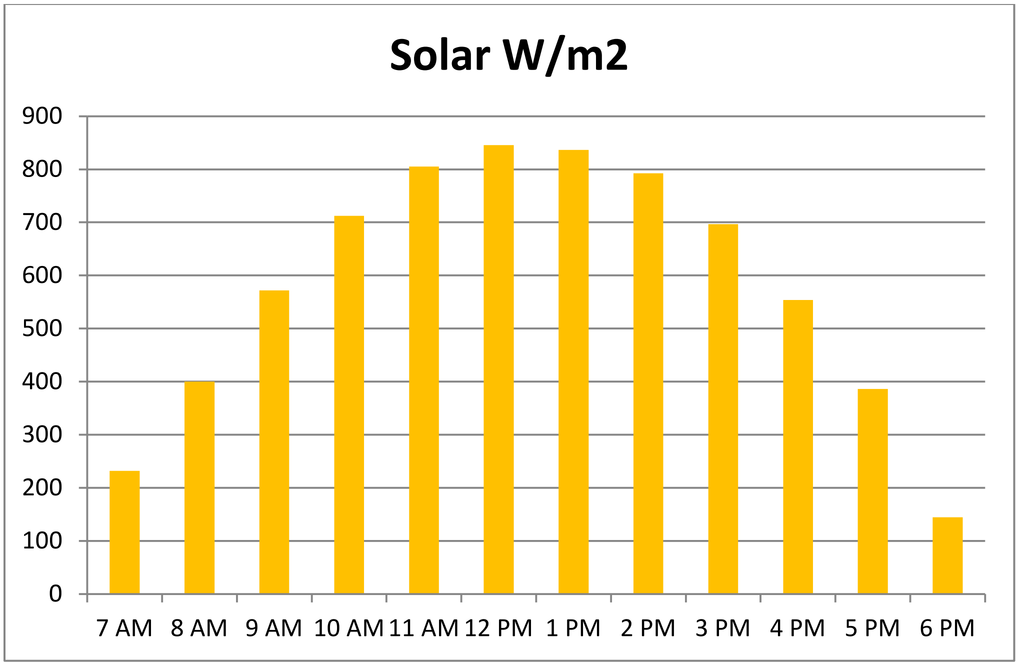


FIGURE 36: SOLAR AVAILABILITY

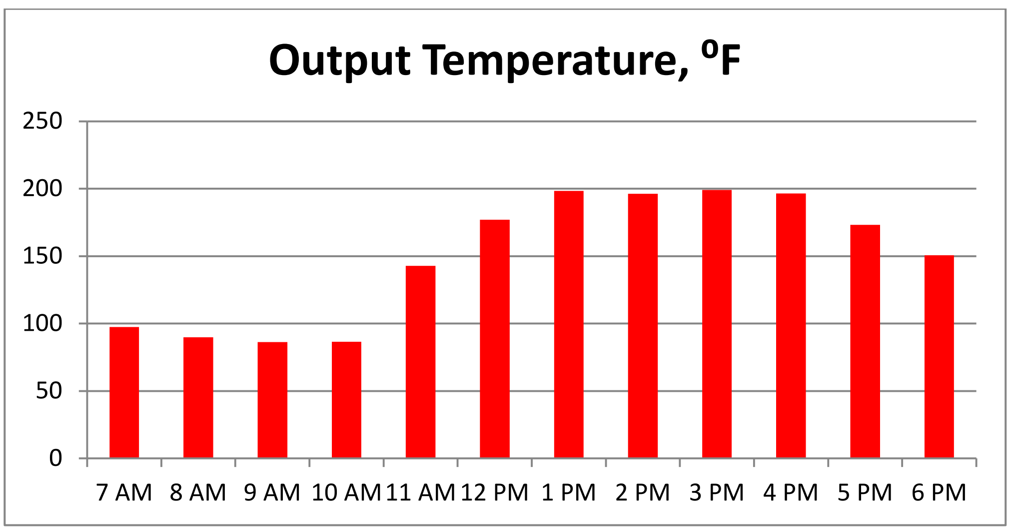


FIGURE 37: COGENRA ARRAY OUTPUT TEMPERATURE

PUBLIC BENEFITS OF PROJECT COMPLETION

The commercialized Cogenra product is installed at over 20 sites. California is home to more than half of these Cogenra installations. California customers enjoy renewable energy generation at low paybacks with economic value increased by the CSI-Thermal incentive program. Local component manufacturing and fully local installation provides revenue to California businesses. The end-of-wire energy generation reduces the stress on California electrical grid and natural gas transmission lines. The advances made possible by this grant created these opportunities and benefits to California citizens, businesses, and utilities.

- Demonstrated the integration of Distributed Solar Cogeneration at customers sites while lowering grid congestion and local GHG emissions
- Developed software tools that enables the calculations of the energy output from a cogeneration system and supporting the financials models including the California CSI Thermal Rebate Program
- Developed California suppliers for high technology solar panel especially in this difficult time in the solar industry
- Used and developed California wealth of human capabilities, mainly in engineering and Software
- Demonstrated financial viability for solar system with improved economics when doing cogeneration
- Demonstrated Tri-generation, which can lower electrical usage for air-conditioning, on hot days, on peak demand when the grid is congested

APPENDIX A – INSTALLATION GUIDE

Cogenra Solar Installation Guide (PDF)

APPENDIX B – INSTALLER TRAINING VIDEO

Cogenra Solar Installer Training Video (PDF)

APPENDIX C – COST REDUCTION

Cogenra Solar Installation Cost Reduction (PDF)

APPENDIX D – COGENRA COOLING PRODUCT OVERVIEW

Cogenra Cooling Product Overview (PDF)

APPENDIX E – GREENHOUSE GAS REDUCTION WITH SOLAR COGENERATION

Greenhouse Gas Reduction with Solar Cogeneration (PDF)

APPENDIX F – SONOMA WINE COMPANY CASE STUDY

Sonoma Wine Company Case Study (PDF)

APPENDIX G – COGENRA SOLAR WHITEPAPER AND WEBINAR

Cogenra published several case studies, whitepapers and presented a webinar. The links follow:

http://calsolarresearch.ca.gov/Funded-Projects/solicitation2-skywatch.html

- http://www.cogenra.com/support/cogenra-resources/
- Heat & Power Purchase Agreement Flyer
- LEED with Solar Cogeneration Flyer
- Cooling with Solar Cogen White Paper
- Solar Cogen in Context White Paper
- Mitigating Stagnation White Paper
- GHG Reduction with Solar Cogen White Paper
- Renewable Energy Use in Breweries and Wineries Webinar