Redding Regional Airport

Redding, California

ASHRAE Level II Energy Audit Report

Provided by

Quest energy group

October 2024

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Executive Summary

As part of the Master Plan update for Redding Regional Airport, Quest Energy Group performed a comprehensive energy audit of selected buildings at the airport to assist in identifying and prioritizing potential energy conservation measures (ECMs) and considerations to be implemented for new construction buildings. This audit meets or exceeds the Level II requirements established by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), which requires a historical analysis of all building utility consumption, efficiency improvement recommendations, and a detailed financial analysis recommendation.

Key Audit Findings

In 2023, The Redding Regional Airport spent **$89,035 per year** on airport electricity consumption with a net annual electricity usage of **188,873 kWh per year.** The results of the audit yielded the following findings listed below. Additionally, individual energy conservation opportunities, solar PV evaluations, and new construction design considerations are detailed within each individual building/area report following this Executive Summary.

- The Terminal Building achieved Net Zero Energy status in 2023 even though a portion of its solar PV system was offline from January to February of 2023.
- While the Terminal Building is Net Zero Energy, the building still pays annual demand costs of about $38,000 per year. Additionally, the renumeration rate for excess solar PV has been reduced from $0.1044 to $0.609 per kWh.
- Investigating opportunities to reduce demand through demand control ventilation, chilled water storage, and/or battery storage should be considered to maximize energy and PV cost savings.
- As the airport considers expanding the Terminal, a detailed design process and analysis of envelope, lighting, and HVAC systems should be performed to achieve an optimal, energy efficient design. See ‘New Construction Design Guidelines for the Terminal’ section of this report.
- When operating for a full year, the 150-kW solar PV system serving the runway lighting can potentially offset 71% of runway lighting energy consumption. Based on initial estimates, an additional 25-kW PV capacity would be needed to offset 100% of runway lighting electricity usage.
- There is opportunity to improve lighting efficiency and controls for the T-Hangars and Box Hangars through simple installation measures.
- The T-Hangars and Box Hangars should consider meter consolidation to minimize meter costs and provide the optimal situation to install solar PV to offset hangar electricity consumption.
- For tenant operated buildings, consider the utilization of ‘Tenant High Performance Sustainability Guidelines’ to ensure tenants support sustainability efforts and goals.

Methodology

The primary focus of the site audit performed was to survey the existing envelope, lighting, domestic hot water (DHW) and HVAC equipment in the buildings and provide a summary of condition, age and life of the units, and overall performance level. This audit is composed of a site visit conducted by Michael Ising in April of 2023 with subsequent conversations with the project team.

Based on the information collected from the site audit, a detailed energy analysis for each building/group of buildings was conducted utilizing engineering grade spreadsheets. Inputs to the analysis included the following:

- Historical utility data and solar PV generation collected before and during the site visit.
- Building operational schedules were gathered on site.
- Equipment operation schedules were based on operational, occupancy, and usage data and supplemented through interviews with the operations and maintenance staff and field observations.
- Lighting fixtures and schedules based on field data and observations.
- HVAC and DHW equipment are based on field observations. Equipment efficiencies were based on nameplate data and/or standard values based on age of equipment.

Project Information

Project Name & Location

Redding Regional Airport
Redding, California 96002

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Site Map

The following map identifies the buildings and areas that were visited during the on-site investigation.

1. Terminal Building
2. Runway Lighting Vault
3. Redding Air Service
4. Redding Jet Center
5. ARFF
6. Air Chasta
7. Rental Car Service
8. FedEx
9. Maintenance Bldg.
10. Tullis Hangar
11. Baker-Barr Hangar
12. Twin Hangar
13. Peri Hangar
14. Wong Hangar
15. Stringer Hangar
16. Sierra Pacific Hangar
17. T-Hangars
18. Terminal Parking
19. Transient Ramp
20. Phi Air Medical (not shown)
21. REACH Air Ambulance (not shown)
22. Maintenance City Shop

Baseline Utility Summary

Electricity bills for the 2023 calendar year were collected and analyzed for all utility meters collected by the City of Redding. A summary of each meter and buildings/locations is shown in the table below both highlighting annual electricity usage and cost for each meter that including and excluding the solar PV system generation (See 'Solar PV Analysis' section of the report).

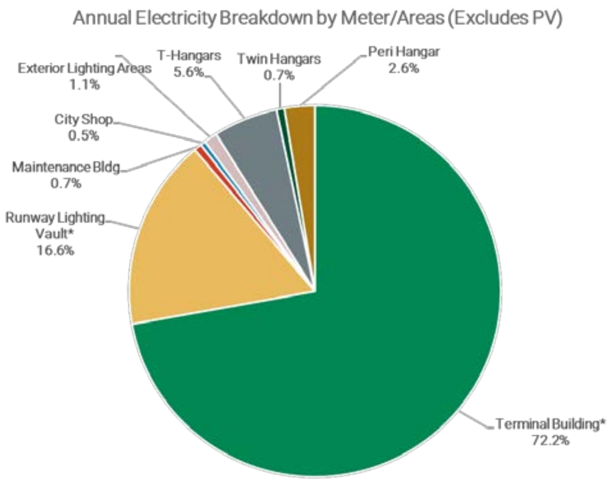
Based on the table below, the City of Redding spent **$89,035 per year** on airport electricity consumption with a net annual electricity usage of **188,873 kWh per year.** Without the installation of the Solar PV system, the annual electricity usage would have been **1,307,105 kWh per year** with an annual electricity cost of **$255,585 per year,** resulting Solar PV cost savings of **$166,560 per year in 2023**.

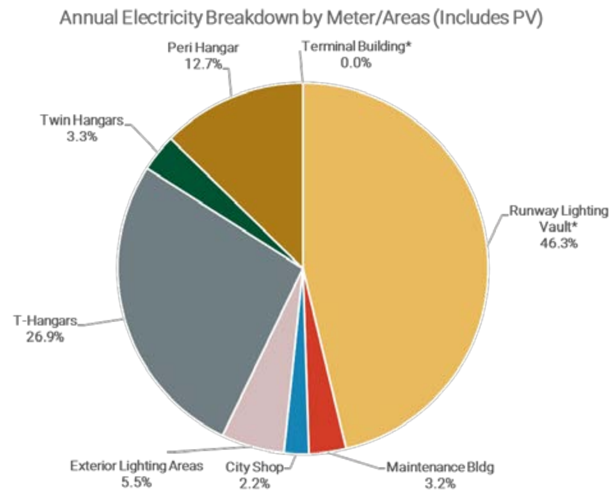
Annual Electric Utility Summary by Meter						
#	Building/Location	Meter Account #	Square Footage (SF)	Electricity Usage (kWh/year)	Total Cost ($/year)	Unit Cost ($/kWh)
1	Terminal Building*	37666-5	32,000	943,412	$183,249	$0.19
2	Runway Lighting Vault*	37665-7	N/A	217,360	$38,943	$0.18
3	Maintenance Bldg	102302-7	5,000	8,798	$1,940	$0.22
4	City Shop	196116-8	2,500	5,885	$1,454	$0.25
5	Eastside Sec Ltg	37998-2	N/A	6,887	$1,621	$0.24
6	Terminal Parking	148080-5	N/A	1,832	$777	$0.42
7	Transient Ramp	37680-6	N/A	3,570	$1,067	$0.30
8	Gate 25/OldTermPrkg	37662-4	N/A	2,721	$925	$0.34
9	Hangar A	37678	119,250	5,367	$1,367	$0.25
10	Hangar B	260607-7		3,586	$1,069	$0.30
11	Hangar C	260608-5		11,929	$2,466	$0.21
12	Hangar D	260609-3		4,603	$1,239	$0.27
13	Hangar E	260610-1		5,558	$1,399	$0.25
14	Hangar H	260611-9		13,656	$2,753	$0.20
15	Hangar I	260612-7		3,389	$1,036	$0.31
16	Hangar J	260613-5		4,663	$1,249	$0.27
17	Hangar K	260614-3		6,245	$1,514	$0.24
18	Hangar L	262288-4		2,993	$970	$0.32
19	Hangar M	192721-9		11,308	$2,361	$0.21
20	Twin Hangars	37837-2	11,600	8,894	$1,957	$0.22
21	Peri Hangar	199734-5	12,000	34,449	$6,230	$0.18
Total Building Consumption without Solar PV			182,350	1,307,105	$255,585	$0.20
Total Solar PV Energy Savings*			-	1,118,232	$166,550	$0.15
Net Energy and Cost to City of Redding			**182,350**	**188,873**	**$89,035**	**-**
***See Solar PV Analysis section of the Report**						

Figure 1: Electricity Usage and Cost by Utility Meter

The following pie charts break down the percent annual electricity usage by meter. The first pie chart on the left shows electricity usage without taking credit for the solar PV generation. As noticed, the Terminal Building accounts for over 70% of the total electricity usage at the airport with the Runway Lighting accounting for another 16.6%.

On an annual basis, the solar PV generation completely offsets Terminal Building electricity usage, thus, the Terminal Building can be considered a net zero energy building. The pie chart on the right shows the electricity breakdown when including solar PV generation. As noticed, Terminal Building electricity is reduced to 0%. Runway lighting now accounts for 46.3% of the total electricity usage with the T-Hangars accounting for 26%. The Peri Hangar by itself accounts for 12.7% of the total electricity.



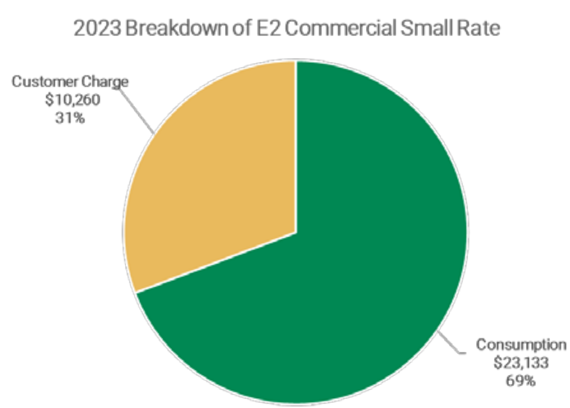


Utility Rate Breakdown

Based on the Redding Electric Utility billing, all meters fall under the E2 Small Commercial Rate except for the Terminal Building and Runway Lighting Vault meters. This rate structure includes a **$55/month per meter** and a **$0.1645 /kWh** consumption charge.

E2 Small Commercial Rate			
Category	**2023**	**2024**	**Unit**
Customer	$ 40.00	$ 55.00	month
Consumption	$ 0.1645	$ 0.1645	/kWh

The following pie chart breaks down the annual cost by of all meters under the E2 Small Commercial Rate by rate category. As noticed, the 'Customer Charge' comprises 31% of the annual electricity cost for this Rate Structure. This is mainly because there are 19 separate meters each with a monthly customer charge of $45-$55 per month. **It is recommended that the City of Redding investigate with Redding Electric Utilities (REU) the possibility of meter aggregation. If so, the City of Redding could potentially reduce the customer charge from $10,260 per year to $540 per year, a cost savings of $9,720 per year.**

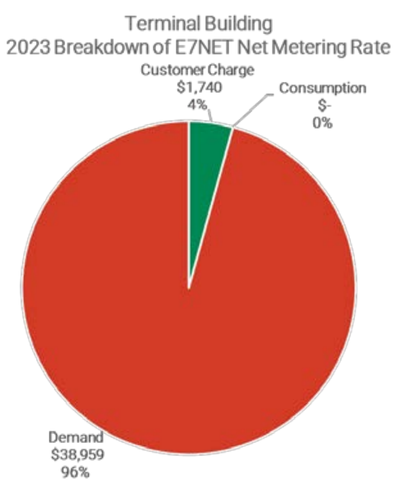


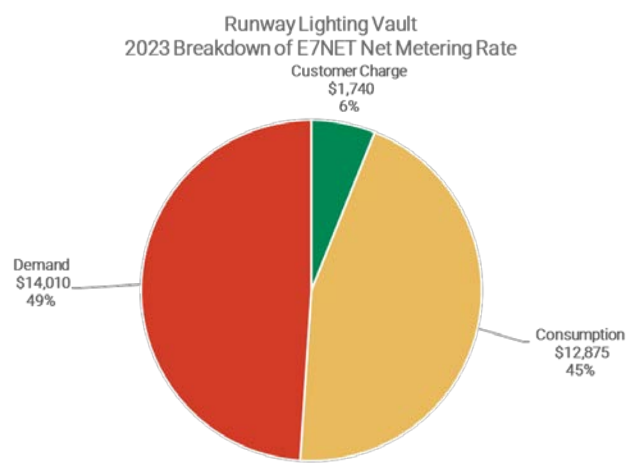
The Terminal Building and Runway Lighting Vault meters include solar PV generation; thus, these meters fall under the E7NET Renewable Resource Net Metering Rate shown in the table below.

E7NET Renewable Resource Net Metering Rate			
Category	**2023**	**2024**	**Unit**
Customer	$ 145.00	$ 95.00	month
Consumption	$ 0.1044	$ 0.1065	/kWh
	$ 0.0023	$ 0.0023	/kWh
Demand	$ 20.00	$ 21.00	/kW
Renumeration	$ 0.1044	0.0609	/kWh

The following pie charts show the annual cost breakdown by rate category for the Terminal and Runway Lighting Vault meters under the E7NET rate. As noticed, the annual consumption charge is zero for the Terminal Building, since, in 2023, the solar PV system generated more electricity than consumed by the building. However, the rate structure heavily penalizes the customer through the high demand charges of $20 per kW, totaling $38,959 in 2023. **Thus, finding ways to consistently reduce the peak demand is the most impactful avenue for energy cost savings at the Terminal Building.**

For the Runway Lighting Vault meter, consumption charge is about 45% of the total electricity bill in 2023 due to the solar PV system being offline for the first part of the year. Even still, the demand charge is 49% of the total electricity bill.





Analysis Reports

Terminal Building

Runway Lighting Vault

Aircraft Storage Hangars

Tenant Operated Buildings

Terminal Building

Building Description

The terminal building encompasses approximately 37,550 square feet. The first floor is utilized for check-in, baggage claim, security, rental car services, and gate waiting areas. The second floor consists of airport personnel, office space and a restaurant. The following image shows the floor plan layout for the terminal building.

Abbreivlation	Functional Area	Level 1 (sf)	Level 2 (sf)
Ticketing/Check-In			
TCA	Ticket Counter Area	650	-
TLQ	Ticket Lobby Que Area	1,650	-
TLC	Ticket Lobby Circulation	1,750	-
AO	Airline Ops/Bag Makeup	2,820	-
Security Screening			
SCA	Security Checkpoint Area	2,360	-
SQA	Security Queue Area	1,050	-
Passenger Holdroom			
H	Passenger Holdroom	1,740	-
G	Gate Area/Loading	1,760	-
HC	Holdroom Circulation	850	
Baggage Claim			
BCD	Bag Claim Device	370	-
BCA	Bag Claim Area	300	-
BCL	Bag Claim Lobby/Circulation	1,200	-
Rental Car			
RCC	Counter/Office Area	1,100	-
RCQ	Rental Queue Area	690	-
Public Spaces			
RS	Restrooms (Secure)	280	-
RU	Restrooms (unsecure)	770	415
RC	Restautant/Concessions/Gift Shop	540	4,828
PL	Public Lobby/Waiting Area	3,180	-
PC	Public Circulation	1,670	830
Administrative Space			
AD	Administration Offices	-	1,690
BC	Business Center	230	-
General Building Areas			
GS	General Storage	1,090	-
ME	Mechanical/Electrical	1,530	920
VC	Vertical Circulation/Structural Space	840	450
	Gross Terminal Building Area	28,420	9,130
	Total Area	37,550	

Operational Schedules

The terminal building is open year-round from about 4:30 AM to 9:30 PM during weekdays and 4:30 AM to 11:00 PM on weekends. The rental car service kiosks are open from about 9AM-4PM during weekdays and 9AM-3PM during weekends. The restaurant "Peter Chu's" is open from Tuesday to Saturday from 11AM-2PM and 4:30PM-8:30 PM. On Sunday, the restaurant is only open from 4:30PM-8:30PM and closed on Mondays.

Existing Lighting Systems

The Terminal building has recently replaced the majority of their front of house lighting fixtures with LEDs that include ocucpancy sensors, where applicable. BOH fixtures are a mixture of LED and fluorescent fixtures.

Existing HVAC Systems

The Terminal building is served by three main AHUs:

1. AHU-1 is a constant volume, CHW AHU with belt driven fans located on the second floor. AHU-1 serves the second floor office space and restaurant as well as the south half of the first floor. Based on site observations, AHU-1 is approaching the end of its useful life.
2. AHU-2 is a constant volume, CHW AHU with belt driven fans located on the second floor. AHU-2 serves the north half of the first floor. Based on site observations, AHU-2 is approaching the end of its useful life.
3. AHU-3 is a variable speed, dedicated outdoor air unit located on the second floor above the security checkpoint. This unit provides ventilation air to three, Trane fan coils that serve the security checkpoint and passenger hold room on the first floor. Based on initial site observation, AHU-3 and associated fan coils are in good condition.

A 90-ton Trane Series R RTAA air-cooled chiller provides chilled water to each AHU. The chiller is at least 15 years old and utilizes R-22 refrigerant. R-22 refrigerant has been phases out in the United States, and it is unclear if this chiller has been converted to a different refrigerant. Chilled water is circulated to each AHU utilizing a constant volume CHW pump. Based on the site observations, the pump was maintaining 52 PSI head pressure right after the pump.

There are three CHW storage tanks installed adjacent to the CHW loop. It is unclear if these CHW storage tanks are currently being utilized. Based on the Terminal Building utility analysis, the majority of energy costs are demand charges. CHW storage tanks provide an opportunity to decrease demand charges and reduce overall building energy costs.

The second-floor kitchen is served by a kitchen exhaust fume hood installed above the kitchen grills and stovetops to exhaust fumes from the cooking process. Based on site observations, the kitchen fume hoods are manually controlled to turn on/off by restaurant employees.

Baseline Energy Summary and Calibration

In 2023, the Terminal Building electricity consumption was **943,312 kWh per year**. The solar PV system serving the terminal building generated **1,026,792 kWh per year** and thus generated more electricity than consumed by the building. The annual net consumption was -86,480 kWh per year, and annual electricity cost was **$27,016 per year**. A breakdown of the annual energy usage, solar PV generation, and net electricity usage is shown in the table below.

Summary of Terminal Building Electricity Usage and Costs			
System	Electricity (kWh/year)	Cost ($/year)	Unit Cost ($/kWh)
Terminal Building	943,312	$183,249	$0.19
Solar PV System Generation	-1,026,792	-$156,233	$0.15
Net Electricity Summary	-83,480	$27,016	

Since the Terminal Building includes solar PV generation, the building falls under the E7NET Renewable Resource Net Metering Rate shown in the table below. In 2024, the renumeration rate for excess solar PV generated has been reduced from $0.1044 to $0.0609 per kWh while the demand charge slightly increases from $20,00 per kW to $21.00 per kW.

E7NET Renewable Resource Net Metering Rate			
Category	**2023**	**2024**	**Unit**
Customer	$ 145.00	$ 95.00	month
Consumption	$ 0.1044	$ 0.1065	/kWh
	$ 0.0023	$ 0.0023	/kWh
Demand	$ 20.00	$ 21.00	/kW
Renumeration	$ 0.1044	0.0609	/kWh

The following pie chart shows the annual cost breakdown by rate category for the Terminal Building meter under the E7NET rate. As noticed, the annual consumption charge is zero for the Terminal Building, since, in 2023, the solar PV system generated more electricity than consumed by the building. However, the rate structure heavily penalizes the customer through the demand charge of $20 per kW, totaling $38,959 in 2023 for the terminal building. **Thus, investigating opportunities to reduce the monthly peak demand will be the most impactful avenue for energy cost savings at the Terminal Building.**

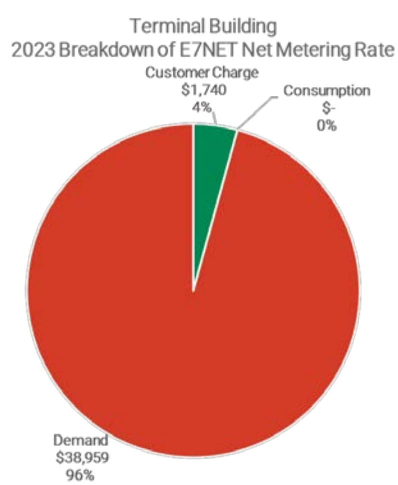


Figure 1: 2023 Utility Cost Breakdown

To understand energy consumption in more detail, a monthly calibration was created utilizing the following information:

1. Weather data
2. Operating hours
3. Onsite observations and information
4. Equipment specifications and anecdotal run hours
5. Monthly electricity data

The following graph shows the result of the energy calibration. The line graph is the aggregated monthly electricity data for the Terminal building. The bar graph is the estimated energy usage by the various end uses in the building including interior lighting, HVAC fans, kitchen equipment, and space cooling. As shown in the graph, there is a constant electrical load throughout the winter (Nov-Feb) comprised of lighting, miscellaneous equipment loads, and kitchen loads. As outdoor air temperatures increase, monthly electricity usage increases from the operation of the chillers and pumps along with increased HVAC fan energy usage.

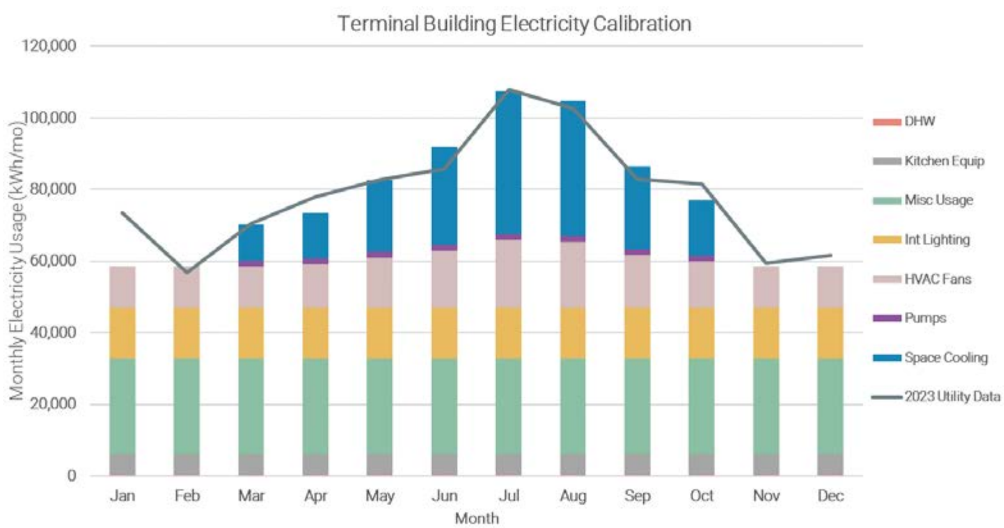


Figure 2: Calibrated Monthly Electricity Usage by End-Use

The following pie chart shows the preliminary energy breakdown by end uses. Kitchen equipment and miscellaneous loads account for over 40% of the total energy consumption. HVAC systems (space cooling, HVAC fans, and pumps) account for ~38% of the total with lighting accounting for almost 20% of the total.

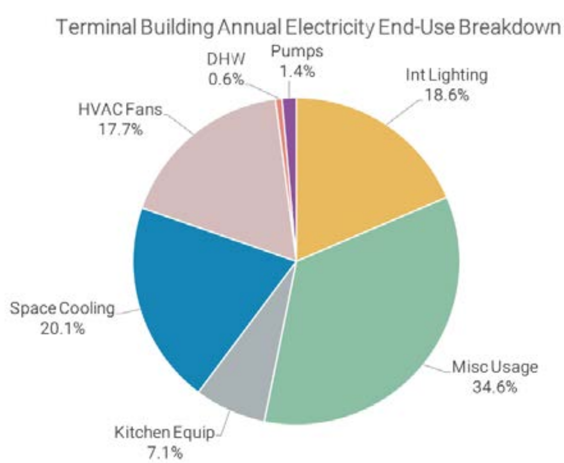


Figure 3: Electricity End-Use Breakdown

Solar PV Analysis for Terminal Building

Based on conversations with facility management, the 600-kW PV System connected to the Terminal building includes 2, 300 kW inverters. During the initial kick-off of the project, it was relayed that one of the inverters was down and in need of repair. According to the solar PV data, this inverter was corrected and back online as of March of 2023. The following graph shows the monthly solar PV production for each of the 300 kW inverters.

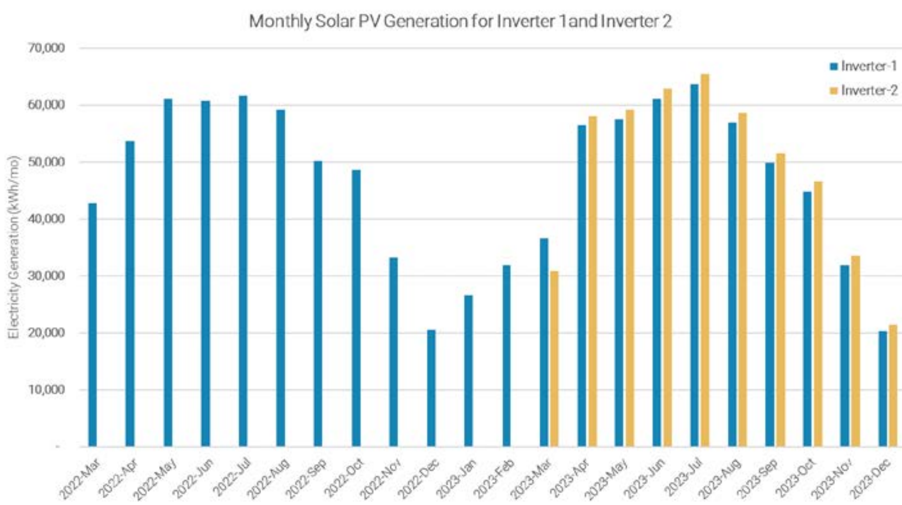


Figure 4: Monthly Solar PV Generation by Inverter

In the calendar year 2023, the 600-kW PV system generated **1,026,792 kWh/year** of electricity even with Inverter-2 offline in January and February. In 2023, the Terminal Building consumed **943,412 kWh per year**; thus, on an annual basis, the solar PV system generated more electricity than consumed by the Terminal Building, achieving Net Zero Energy. The following graph shows the monthly electricity consumed by the Terminal Building and the monthly electricity generated by the 600-kW solar PV system. The blue line graph shows the net electricity generated/consumed. Starting in April of 2023, the solar PV system started to generate more monthly electricity than consumed by the Terminal Building. In May of 2023, the building achieves net zero energy status (shown by the blue line crossing the y-axis). At year's end, the blue line remains negative, indicating the PV system generated more electricity than the building consumed in 2023.

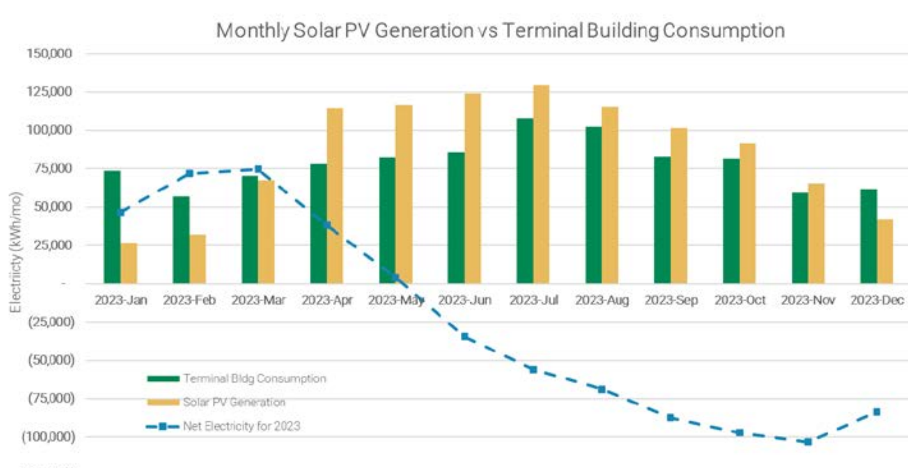


Figure 5: Solar PV Generation vs. Building Consumption

Energy Conservation Measures

Given that the building is net-zero energy and is expected to undergo major expansion in the next couple of years, the following section describes energy efficiency opportunities that can be investigated to enhance energy efficiency and reduce energy costs in the next couple of years. If all the below measures are implemented, energy usage could be reduced by **5%** with cost savings of almost **$13,500 per year.**

Retro-Commission Existing HVAC Systems and Controls

It is recommended that the airport conduct a retro-commissioning scope on existing HVAC equipment every year to evaluate the following:

1. HVAC programming is functioning as designed.
2. All sensors are calibrated and reading correctly.
3. BMS schedules are accurate and updated based on building occupancy.
4. Thermostats include proper scheduling and temperature setbacks.

Retro-commissioning HVAC system and controls can typically yield 1-2% energy savings per year. If so, annual energy savings would be about **18,000 kWh per year** with cost savings of about **$3,500 per year.**

Retro-Commission Chilled Water Storage Tanks for Demand Management Reduction

The terminal building has installed three chilled water (CHW) storage tanks; however, it is unclear if those storage tanks are operational and/or the controls exist to properly utilize the storage capacity for demand management. It is recommended that this system be evaluated and retro-commissioned to provide chilled water storage for use during peak electrical demand periods.

The peak electrical demand typically occurs in the mid-to-late afternoon (i.e., the hottest part of the day) as the CHW system needs to operate at a higher capacity to offset the building's cooling loads. However, overnight, the CHW system typically operates at lower capacity when the cooling load is lower. Thus, there is an opportunity to operate the CHW system at higher capacities overnight and store the excess capacity in the CHW storage tanks. During the day, the system can satisfy the daytime CHW load with the stored CHW capacity, reducing the load (demand) on the chiller itself. Additionally, an air-cooled chiller typically operates more efficiently at cooler ambient conditions; thus, there is additional energy savings by operating the chiller overnight vs during the day.

If the utilization of chilled water storage tanks could reduce peak electrical demand by 30 kW each month, energy savings would be **~25,000 kWh per year** and cost savings would be **$10,000** per year.

Continue to Replace Fluorescent/Halogen Lighting Fixtures with LEDs

The terminal building has mostly changed out all front of house lighting fixtures from fluorescent to LED fixtures. It is recommended that all lighting fixtures in BOH spaces be replaced with LED fixtures. LED lamps output similar lighting levels as fluorescent fixtures at a reduced power draw; thus, minimizing lighting energy usage without compromising performance. Additionally, LED lamps have a longer lifespan minimizing maintenance costs. As a bonus, LED lamps contain no mercury, helping to streamline the recycling process.

New Construction Design Guidelines for the Terminal

The airport is investigating the opportunity to expand the existing terminal building with the goal of adding additional gates, amenities, and doubling the square footage of the terminal building. It is recommended a detailed energy analysis and evaluation be conducted for the Terminal additions to ensure an integrated building design. The energy analysis would compare alternate design concepts for envelope, lighting, and MEP systems to determine the optimal solution to maximize energy efficiency and meet project design goals. The following sections lay out design considerations to optimize energy consumption and should be evaluated during the terminal expansion design process.

Envelope Design

The new construction terminal envelope design should consider the following:

- Meet or exceed Title 24 insulation values for exterior walls, roof, and fenestration based on Redding's climate zone.
- To minimize infiltration, consider the following design options:
  - Vestibules at all main entrances to provide a buffer between the exterior and interior conditions spaces.
  - Utilize automatic sliding doors at vestibules. Ensure that the vestibules are large enough so that sliding doors are not open simultaneously.
  - Install door sweeps and auto closing door mechanisms at all BOH entrances.
  - Install air curtains where applicable to block air from infiltrating into conditioned spaces.
  - For baggage claim carousels, provide a buffer zone (vestibule) between the outdoor and indoor conditioned spaces.
  - Install insulated roll-up doors (dock doors) with automatic closing capabilities for baggage claim and any loading docks.
- The design fenestration system should consider the following concepts:
  - Consider utilizing low SHGC fenestration for east, west, and south facing windows. North facing windows can have a higher SHGC since this orientation does not receive direct sunlight.
  - Utilize exterior shading devices, natural features (plants, trees, etc.), and interior shades to minimize glare and solar heat gain.
  - All fenestration assemblies should utilize thermally broken frames.
- The design roof system should consider the following concepts:
  - Consider increasing roof insulation above local code requirements to reduce heat loss through the roof.
  - Incorporate a green roof to increase roof insulation and minimize solar absorption.
  - Consider painting roofs a light color to minimize solar absorption.
  - For main feature areas, consider the incorporation of skylights to provide natural lighting to the Terminal Building.

Lighting Design

The new construction terminal lighting fixture design should consider the following:

- Utilize light colors on walls and ceilings to reflect light back to the space.
- In high bay spaces (tall ceilings), install lights below scaffolding and ductworks. Install lights as close to the occupied space to minimize quantity and power draw of lighting fixtures.
- Minimize the usage of indirect lighting and/or utilize reflectors on lighting fixtures to redirect light to the space.
- Utilize 100% LED Fixtures with a CRI of 90% or higher.
- Target an LPD that is 10% better than Title 24 space-by-space allowances.
- Conduct lighting level analysis to optimize lighting layouts and minimize excess lighting fixtures. Lighting levels should meet the intended space use.

The new construction terminal lighting controls design should consider the following:

- All lighting fixtures should incorporate auto-continuous (0-10V) dimming capabilities.
- Daylight-responsive controls should be provided to control lighting within 15 feet of windows, openings, and under skylights. Daylight sensors should control lighting fixtures (through continuous dimming) to meet specified lighting levels for the respective space.
- Vacancy/occupancy sensors should be installed in all areas with a vacancy/occupancy timer no longer than 15 minutes.
- Lighting controls should be incorporated in the BMS system for monitoring and scheduling.
- Consider integrating lighting control systems to the BMS system for control of HVAC systems.

DHW Design

The new construction terminal DHW design should consider the following:

- Low flow lavatory faucet fixtures (0.5 GPM or less)
- Low flow urinals (0.125 GPF or less) and toilets (1.28 GPF or less)
- All Kitchen appliances should be low flow and Energy Star rated.
- Consider the following DHW heating sources in place of electric resistance storage tanks:
    - Instantaneous electric water heaters installed at each bathroom to eliminate distribution losses.
    - Centralized DHW heat pump unit for kitchen hot water. Heat pump units are 3x more efficient than electric resistance heaters.

General HVAC Design

When designing the HVAC system for the new terminal, the following recommendations should be considered:

- Perform HVAC load calculations using an engineering software, for example Trane Trace. The loads should be submitted with the DD and CD sets. Design input values should be summarized, including envelope, lighting, equipment, IT and loads per person on btu/sf.
- Right size equipment based on the efficient lighting design and actual plug loads. It is not recommended to use blanket W/SF across all spaces and space types.
- Comply with and do not exceed the ASHRAE 62.1 or local ventilation code requirements.
- Implement Demand Controlled Ventilation (DCV) for the space through the use of CO2 sensors or Indoor Air Quality (IEQ) sensors.

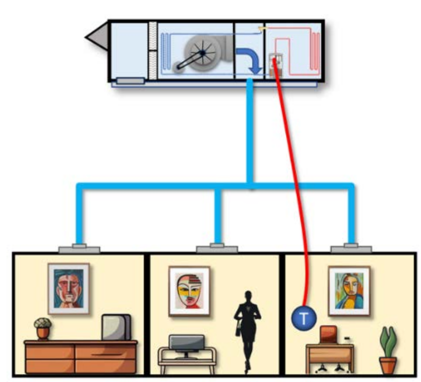
- All HVAC system design and efficiency levels shall exceed local code and the current version of IECC.
- Ensure HVAC design specifications include operational set points and schedule to meet the most recent version of ASHRAE 55 requirements. Controls contractor to ensure set points are programmed as designed.
- Zone controls shall automatically maintain a minimum 5F deadband between space cooling and heating setpoints.
- All sources of heating and cooling within a single space shall be controlled and interlocked together.
- Specify CFC and HCFC-free and low GWP refrigerants.
- A third-party commissioning agent should commission all HVAC equipment to ensure proper installation and programming of equipment.

Airside HVAC Design

Given the highly variable occupancy and operating hours of an airport terminal, the airside HVAC systems should be designed with flexibility and modulation capabilities to meet such variability. Typically, HVAC systems will be sized (cooling, heating, ventilation) based on peak occupancy conditions; however, those conditions may only occur for a couple of hours per day, while the remaining hours will be minimally occupied or even unoccupied. Thus, it is crucial that new HVAC system designs be able to simultaneously meet varying zone conditions, modulate effectively, and operate efficiently at part-loads. The following sections outline four main airside system types for airport terminals and the advantages/disadvantages of those systems. A summary table below compares the four airside systems in terms of part load efficiency, energy savings, first cost, and financial payback. This table can be used as a starting point in the decision process and determination of the optimal airside system.

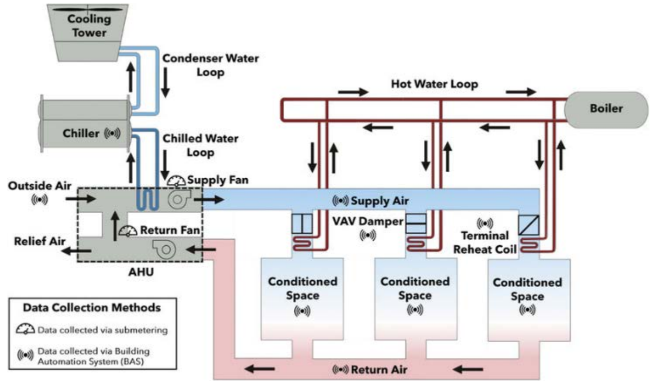
Airside System Types				
Airside System Type	Part Load Efficiency	Energy Savings	First Cost	Financial Payback
Package CV AHU	Poor	Low	Low	Short
VSD AHU w/ VAV	Average	Mid	Mid	Medium
CHW/HW Fan Coils	Good	Mid	Mid	Medium
VRF Fan Coils	Good	High	High	Long

Packaged Rooftop AHUs



Packaged rooftop AHUs utilize a single-speed or two-speed air-cooled compressor to provide cooling and either a heat pump or gas-fired furnace for heating. Fan control is typically two-speed or constant volume. Package rooftop units are the least energy efficient option as they provide poor part load efficiency and have limited modulation capability. The main advantage of packaged rooftop units is that they are cheaper to install than other systems and typically require less maintenance. Overall, it is not recommended that a future design consider packaged rooftop units.

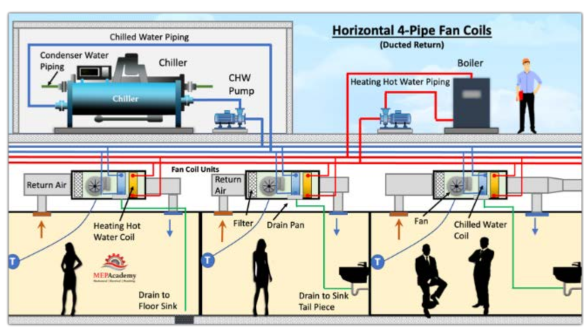
CHW VSD AHUs with HW Reheat



CHW VSD AHUs are centralized units serving multiple zones and utilize variable speed fans and VAV boxes throughout the building to modulate airflow at part load conditions and meet zone space heating/cooling demands. The main source of cooling for this system is a central CHW coil at each AHU. Heating is typically provided via hot water reheat coils at each VAV box. CHW AHUs improves modulation capabilities over Rooftop AHUs; however, there are distribution losses from increased fan power and ductwork. Additionally, to satisfy all zones, these systems will typically cool supply air to meet the most critical zones and reheat portions of the supply air to satisfy other zones leading to excess heating and cooling. To reduce excess heating/cooling, these systems typically require a more sophisticated controls sequence. When considering these system types, it is important to ensure the following are included:

- AHUs and VAV boxes are strategically laid out so that systems reduce overcooling/overheating of spaces. For example, spaces oriented south should be on a separate AHU than spaces oriented north as they have different load profiles. Additionally, holding rooms with variable occupancy should be separated from BOH office spaces that have more constant occupancy.
- HVAC controls should include an ASHRAE G36 sequence or similar. Specifically, controls should include a sophisticated discharge air temperature reset and duct static pressure reset control algorithms to optimize part load efficiency and minimize excess fan power/heating/cooling.
- A robust BMS should be incorporated to monitor AHU performance and conduct fault detection diagnostics of sensors, thermostats, dampers, valves, etc. These systems utilize many moving parts and require vigilant oversight of the system to function in an energy efficient manner.

CHW/HW Fan Coils with Dedicated Outside Air System



CHW/HW Fan Coils are zonal systems, and thus, one fan coil is assigned to each HVAC zone or group of similar HVAC zones. Fan coils utilize three-speed or even variable speed fans to modulate airflow at part load conditions. Each fan coil is equipped with a chilled water coil and hot water coil to heat/cool supply air to meet space demands. Fan coils utilize less ductwork than centralized AHUs, leading to less distribution losses and lower fan powers. As such, fan coils are very efficient units at part-load conditions with the ability to meet all zone space demands.

Outside air for fan coils is typically provided via a dedicated outdoor air system that pretreats and conditions outdoor air and supplies it to the conditioned space. Dedicated outdoor air systems typically utilize variable speed control and CHW/HW coils.

Variable Refrigerant Flow Fan Coils

VRF Fan Coils are also zonal systems and similar to CHW/HW Fan Coils. The main difference is that VRF systems' source of cooling/heating is cold/hot refrigerant instead of CHW/HW. The main advantages over Fan Coils are as follows:

- Eliminate the need for a central plant (chillers, pumps, boilers, etc.)
- Eliminate simultaneous heating and cooling by recovering heat from one part of the building to heat other parts of the building.

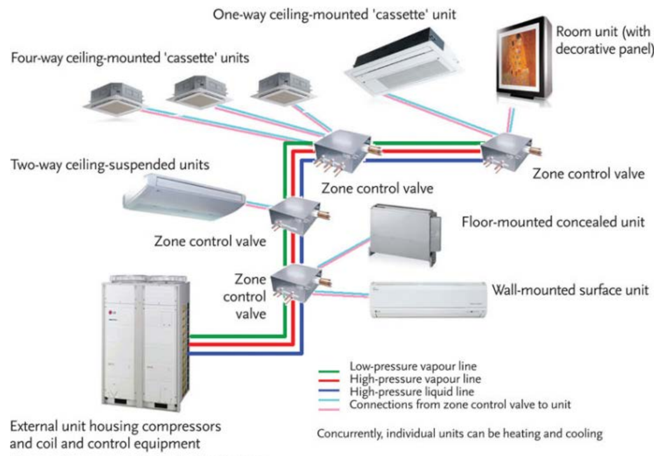


Figure 1: An example three-pipe VRF system

The main disadvantage of VRF Fan Coils is their first costs are typically more expensive than other systems. Additionally, VRF systems require more specialized maintenance and repairs than typical hydronic systems.

For comparison to the central plant systems discussed in the next section, VRF cooling efficiencies range from COP 3.5 in the summer up to COP 7-8 in winter months. VRF heating efficiencies range from COP 6-8 in the summer down to COP 2 during peak cold winter days (OA temperatures less than 17F.).

Additional HVAC Design Considerations

The following additional HVAC design options should be considered for any airport airside HVAC designs.

Demand Control Ventilation

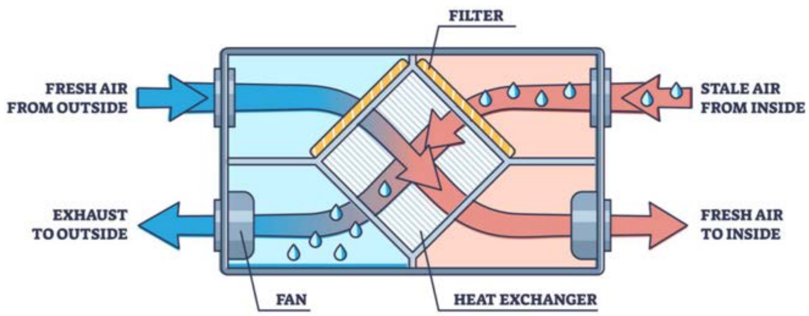
Given the high levels of ventilation required for certain airport spaces, it is recommended the HVAC design utilize demand control ventilation to monitor CO2 levels and occupancy in spaces. As CO2 levels decrease below 700 ppm (for example), outdoor air supply flow modulates below design flow to a DCV minimum flow. As CO2 levels increase towards 700 ppm and above, the outdoor air supply flow modulates up to design flow to maintain proper CO2 levels. Modulating outdoor air flow reduces excess heating/cooling energy consumption while maintaining adequate space CO2 levels for occupants.

Demand Control Ventilation for Kitchen Hoods

For kitchen hood operations, the kitchen exhaust hoods and make-up air units are typically turned on in the morning and operate at 100% flow/speed throughout the day until the systems are turned off in the evening. A more efficient operation of kitchen exhaust hoods is to modulate exhaust air and make up air based on actual kitchen operations. Thus, during cooking operations, the kitchen hoods will operate at 100% flow/speed, but as cooking operations stop or slow down, the kitchen hoods modulate their flow down to 50% (or similar) to reduce the required heating/cooling and fan power while maintaining sufficient pressurization and space conditions.

Energy Recovery Ventilation

Another effective method to reduce heating/cooling energy usage due to increased ventilation rates is to install energy recovery ventilation (ERV) to recover heat from exhausted air to pretreat incoming outdoor air. During peak weather, ERVs can reduce peak heating/cooling demand as well as reduce the HVAC sizing of AHUs, DOAS, chillers, boilers, etc. leading to reduced install costs.



Lighting Controls Integrated into HVAC Controls

To enhance the response of HVAC systems to variable occupancy and loads, it is recommended that lighting controls (specifically occupancy sensors) be integrated with the HVAC controls system. In this way, the lighting systems can notify the HVAC system when spaces are unoccupied, triggering the HVAC system to enter into an 'unoccupied' mode setting. In this setting, the temperature setpoints in the space would be setback, airflow would be minimized, and outdoor air flow would be reduced to zero for those spaces. Controlling HVAC systems based on occupancy is an optimal way to maximize part load efficiency and minimize wasted energy usage for airport terminals.

Waterside HVAC Design

Similar to airside systems, central plant systems should be designed to have high part load performance in both cooling and heating operations. Based on weather data for Redding, CA, there are about 2,400 cooling degree days and 2,600 heating degree days. Thus, it is crucial that potential waterside HVAC systems be able to satisfy significant heating and cooling loads. Additionally, given the variable loads and timing of loads for the airport, central plant systems will need to simultaneously provide heating and cooling to meet different zone conditions. The following sections outline four main waterside system types for airport terminals and the advantages/disadvantages of those systems. General heating and cooling efficiencies (COP) are provided for comparison. This table can be used as a starting point in the decision process and determination of the optimal waterside system.

Waterside System Types							
Central Plant	COP Cooling		COP Heating		Heat Recovery	First Cost	Financial Payback
	Part Load	Full Load	Part Load	Full Load			
AC-Chiller w/ HW Boiler	COP 5.0	COP 3.5	COP 0.8	COP 0.9	No	Low	Low
WC-Chiller w/ HW Boiler	COP 8.0	COP 5.0	COP 0.7	COP 0.8	No	High	High
AC-Heat Pump Chillers	COP 5.0	COP 3.5	COP 5.0	COP 2.0	Yes	Mid	Mid
Geothermal Heat Pumps	COP 8.0	COP 5.5	COP 8.0	COP 4.0	Yes	High	High

Air-Cooled Chillers with Condensing Hot Water Boilers

Chilled water is provided via air cooled chillers with a full load efficiency of about 3.5 COP and a part load efficiency achieving ~5.0 COP. Hot water is provided via condensing boilers with an efficiency between 0.8-0.9 COP. Both CHW and HW are circulated by dedicated, variable speed, primary pumps to airside HVAC systems (fan coil, AHU, etc.).

Air-cooled chillers with condensing boilers are the simplest and lowest first cost system; however, it is not as efficient compared to the remaining systems evaluated in this document.

Water-Cooled Chillers with Condensing Hot Water Boilers

Chilled water is provided via water-cooled chillers with a full load efficiency of about 5.0 COP and a part load efficiency achieving ~8.0 COP. The condenser side of the chiller is connected to a condenser water loop served by cooling towers with variable speed fans. Hot water is provided via condensing boilers with an efficiency between 0.8-0.9 COP. Both CHW and HW are circulated by dedicated, variable speed, primary pumps to airside HVAC systems (fan coil, AHU, etc.).

Compared to air-cooled central plants, water-cooled central plants provided increased full load efficiency and typically provide better part load efficiency. However, if WC-central plants are not controlled properly, they can waste significant amounts of energy and water leading to poor operational efficiency. Additionally, water-cooled plants require significantly more maintenance to clean cooling towers and chemically treat condenser water. Typically, water-cooled central plants are only justified when peak cooling loads in the building exceed 600 tons.

Air-Cooled Heat Pump Chillers

Chilled water is provided via air cooled heat pump chillers with efficiencies ranging between 3.5-5.0 COP depending on outdoor air conditions. In cooling mode, air-cooled heat pump chillers are nearly identical to air-cooled chillers. The major benefit of air-cooled heat pump chillers is that the same machine can provide hot water during heating season, thus removing the need for a separate hot water plant. In heating mode, air-cooled heat pump chillers have heating efficiencies ranging between 2-5 COP depending on outdoor air condition, significantly more efficient than gas-fired or electric resistance boilers.

Additionally, simultaneous air-cooled heat pump chillers can be installed to provide heating and cooling at the same time. This system takes waste heat from the cooling loop and injects it into the hot water loop to provide optimal efficiency during swing/shoulder seasons. For airports, this can be significant as perimeter spaces with infiltration (entrances) may require heating, but densely occupied spaces (security checkpoints) may require cooling at the same time.

Geothermal Heat Pumps

Geothermal heat pump systems utilize the ground as a heat sink in place of outdoor ambient conditions. Geothermal heat pumps provide both chilled water and hot water to air-side systems (similar to air-cooled heat pump chillers). The main difference is that the condenser side of the compression cycle is served by a geothermal loop rather than ambient air. In cooling mode, geothermal heat pump systems can achieve cooling efficiency from 5.5-8.0 COP and 4.0-8.0 COP during heating mode. Similar to air-cooled heat pump chillers, the same machine can provide chilled water in cooling season and hot water during heating season, thus reducing the size of the central plant. Additionally, this system provides heating and cooling simultaneously through the usage of a centralized loop.

The major disadvantage of geothermal loops is the first cost to drill bore holes and the added pumping cost during operation to move water to and from the ground. Detailed energy and financial analysis are needed to understand the viability of including geothermal heat pumps at the Redding Regional Airport.

Runway Lighting Vault

Equipment Description

The two main areas of equipment within the lighting vault meter are the landing lights and the air-conditioned transformer room (lighting vault) located adjacent to the main terminal. The four types of landing lights at the airport are as follows: beacon, runway, signage, and precision approach path indicator (PAPI) lights. The transformer room consists of the transformers serving the landing lights and a packaged AC unit to condition the room.

Operational Schedules

Runway and Signage Light Schedule

- Dusk to Dawn

PAPI Lights Schedule

- 24/7 operation

Lighting Vault Schedule

- HVAC unit cycles on/off to maintain cooling setpoint.

Baseline Energy Summary and Calibration

In 2023, the runway lighting and vault electricity consumption was **217,360 kWh per year.** The solar PV system serving the lighting vault meter offset 91,440 kWh per year; thus, the net consumption from the electrical utility was **125,920 kWh per year** at an annual cost of **$28,626 per year,** or **$0.23 per kWh.** A breakdown of the annual usage, solar PV generation, and net electricity usage is shown in the table below.

Summary of Lighting Vault Electricity Usage and Costs			
System	Electricity (kWh/year)	Cost ($/year)	Unit Cost ($/kWh)
Runway Lighting Vault	217,360	$38,943	$0.18
Solar PV System Generation	-91,440	-$10,317	$0.11
Net Electricity Summary	125,920	$28,626	$0.23

To understand energy consumption in more detail, a monthly calibration was created utilizing the following information:

1. Weather data
2. Operating hours
3. On-site observations and information
4. Equipment specifications and anecdotal run hours
5. Monthly electricity data

The following graph shows the result of the energy calibration. The line graph is the monthly electricity data from the lighting vault meter. The bar graph is the estimated energy usage by the various end uses such as runway lighting, transformers, and space cooling. As shown in the graph, there is a strong dependency on daylight hours throughout the year. In the winter, when daylight hours can be as low as 9 hours per day, there is increased runway lighting consumption. As daylight hours increase in summer, runway lighting consumption decreases proportionally.

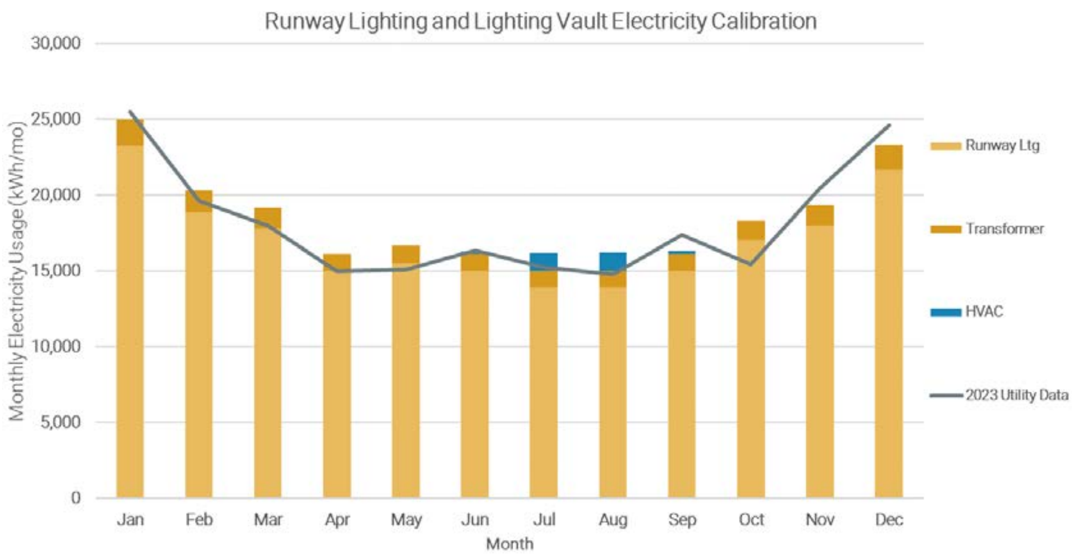


Figure 1: Calibrated Monthly Electricity Usage by End-Use

The following pie chart shows the preliminary energy breakdown by end uses. The pie chart on the left shows total energy consumed whereas the pie chart on the right considers the solar PV generation offset. As shown, solar PV generation offset 41% of the annual electricity usage.

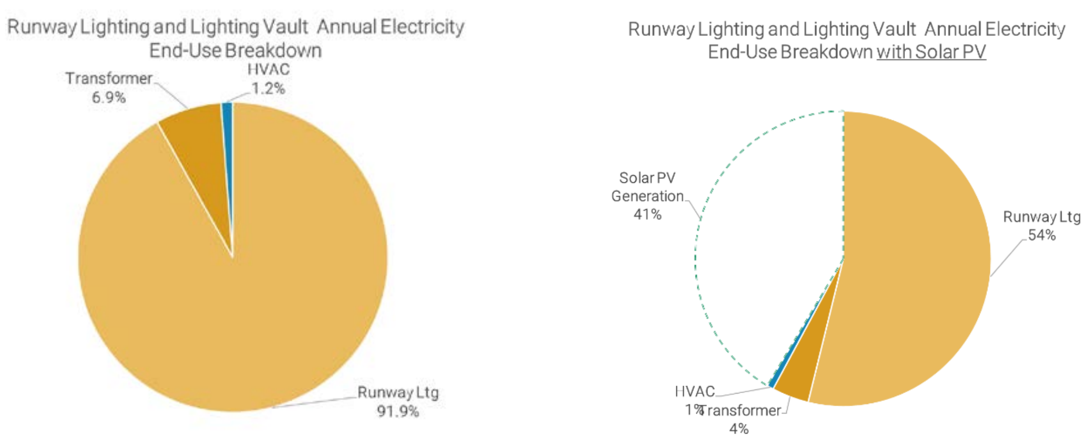
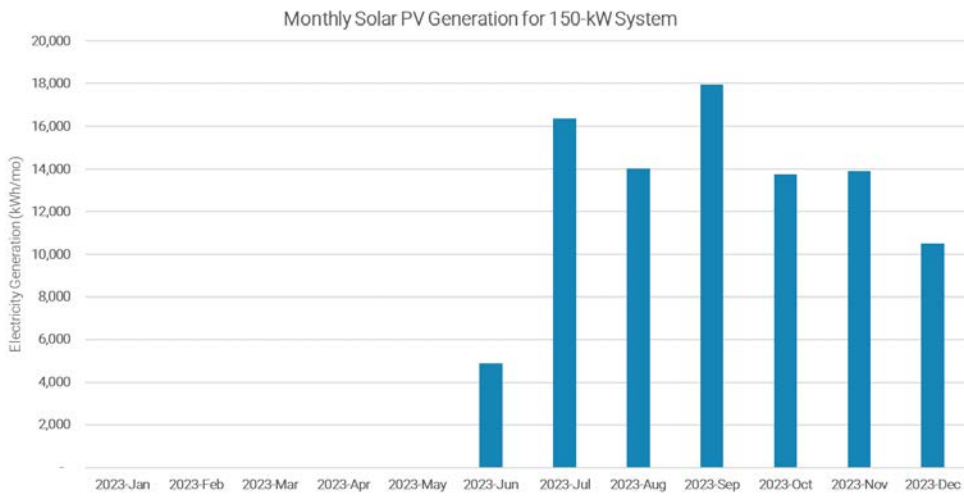


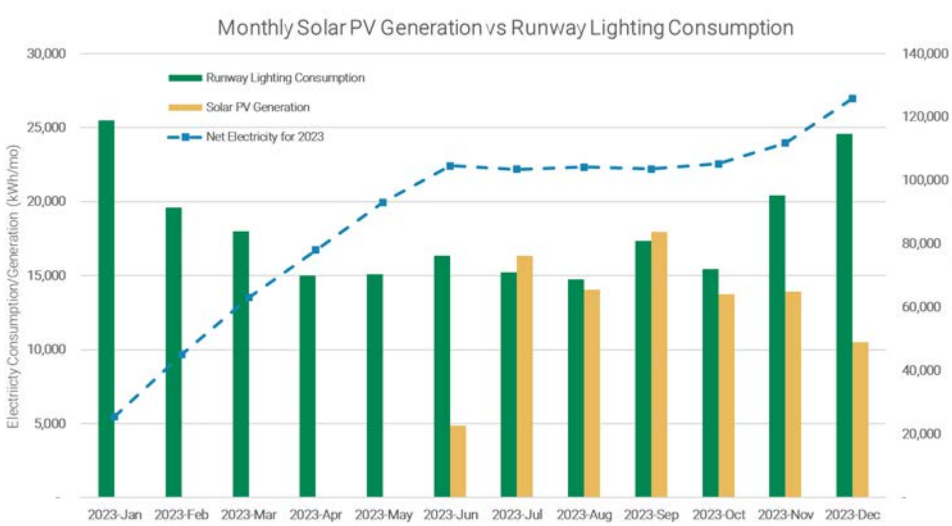
Figure 2: Electricity End-Use Breakdown Considering Solar PV Generation

Solar PV Analysis for Lighting Vault

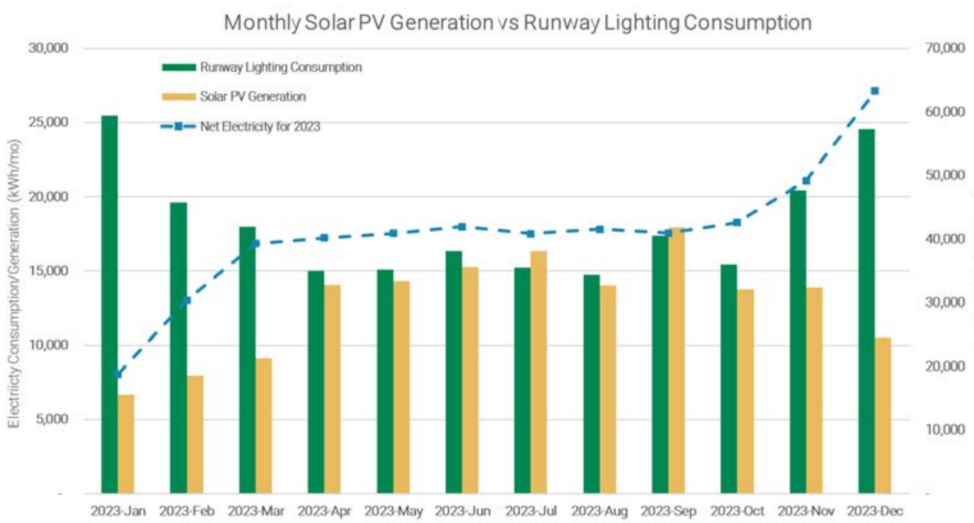
Based on conversations with facility management, there is a 150-kW PV System connected to the runway lighting vault meter. During the initial kick-off of the project, it was relayed that the inverter for this system was down and in need of replacement. Based on data analysis, this inverter was corrected and back online starting in June of 2023. Output data for this system was not able to be retrieved; thus, the following solar PV data was estimated based on utility trends and expected output of the system. The following graph shows the estimated monthly solar PV production for the 150-kW system.



In the calendar year 2023, the 150-kW PV system was estimated to generate **91,440 kWh/year** of electricity. In 2023, the Runway Lighting Vault meter consumed **217,360 kWh per year**; thus, the solar PV system was able to offset **~41%** of the annual runway lighting electrical consumption, resulting in energy cost savings of about **$10,317 per year, or $0.11 per kWh** generated. The following graph shows the monthly electricity consumed by the runway lighting and the monthly electricity generated by the 150-kW solar PV system. The blue line graph shows the net electricity generated/consumed.



The following graph shows the monthly energy breakdown If the solar PV system was online all year. Total solar PV generation would equal about 154,093 kWh/year, offsetting nearly 71% of the annual runway lighting electrical consumption, which would have resulted in energy cost savings of about $16,950 per year, or $0.11 per kWh generated. During summer months, the solar PV system is able to offset the monthly electricity usage; however, during winter months when daylight hours are less, the solar PV system generates less while the runway lights operate longer hours.



If all runway lighting fixtures are replaced with LEDs, the expected annual energy consumption from the Runway Lighting Vault would be 184,507 kWh per year. The existing solar PV system would be able to offset ~84% of the energy consumption.

Installing Solar PV System to offset 100% of Lighting Vault Energy Usage

To achieve 100% offset of the lighting vault energy usage through solar PV generation, an additional 25 kW of solar PV capacity would need to be installed. It is assumed that runway lights would be replaced with LEDs to first reduce energy consumption measured by the Runway Lighting Vault meter.

In 2023, the Runway Lighting Vault utilized the 2023 E7NET rate shown in the table below. However, in 2024 and beyond, the meter will fall under the 2024 E7NET rate shown below. The major change is the renumeration rate for excess electricity generated by the solar PV system. In 2023, the excess electricity from the solar PV systems was credited back to the customer at $0.1044 per kWh for the Runway Lighting Vault. In 2024, this rate will be reduced to $0.0609 per kWh. Thus, the customer will receive less credit for excess electricity generated by the solar PV system at the end of each month.

E7NET Renewable Resource Net Metering Rate			
Category	**2023**	**2024**	**Unit**
Customer	$ 145.00	$ 95.00	month
Consumption	$ 0.1044	$ 0.1065	/kWh
	$ 0.0023	$ 0.0023	/kWh
Demand	$ 20.00	$ 21.00	/kW
Renumeration	$ 0.1044	0.0609	/kWh

The following table shows the financial inputs for the 25-kW ground-mount solar PV system. the initial cost of the PV system is estimated to be **$2.75 per kW**. Federal tax incentives and depreciation tax credits are **NOT** included in the analysis.

Solar PV Cost Inputs		
Input	Value	Units
Solar PV First Cost	$2.75	/Watt
Battery Storage First Cost	N/A	/kWh
Federal Tax Incentive	0%	-
Energy Escalation Rate	2.8%	-
Solar PV Equipment Lifetime	20	years
Battery Equipment Lifetime	N/A	years
Solar Utility Rate	$0.104	$/kWh
Buyback Rate	$0.061	$/kWh

The following table summarizes the financial results for the 25-kW solar PV system. The estimated simple payback is **about 19 years** with an internal rate of return (IRR) of **0.4%.** Based on the initial financial results, it would not make sense to install additional capacity to the existing solar PV system. First cost estimates should be refined to verify the financial viability additional solar PV capacity.

Financial Results		
Input	Value	Units
20-year NPV	-$21,562	-
Straight Line Payback	19.30	years
Year-1 ROI	4.0%	-
IRR	0.4%	-

Consideration of Battery Storage

To increase the energy costs savings from a solar PV system, solar battery storage should be considered. As highlighted in the 'Utility Rate Breakdown', almost half of the energy cost associated with the Runway Lighting Vault meter is from a monthly demand rate of $20 per kW ($21 per kW in 2024). The inclusion and control of batter storage has the potential to reduce both energy consumption costs and demand costs for the client.

For every 1kW reduction in peak demand each month, the resulting cost savings would be about $411 per year. To reduce 1kW in peak demand each month, the battery sizing would need to be 14 kWh. Typical battery first costs are about $500 per kWh.

If the airport were to install a 140-kWh battery system, the peak demand savings would be 10 kW per month, resulting in energy cost savings of **$4,112 per year**. A 140-kWh battery system would cost about $70,000 without including any rebates or incentives. If so, the simple payback would be **17.0 years.** First cost consideration should be investigated in more detail to corroborate initial financial results.

Energy Conservation Measures

The following section describes in detail individual energy conservation measures resulting from the site visit and analysis for the runway lighting and vault. Estimated energy savings, implementation cost, and simple payback are calculated for each conservation measure.

L01: Replace Runway Fixtures with LED Fixtures

Existing Condition

Currently, the runway fixtures that line the landing strip and taxing paths utilize a mixture of LED fixtures and 30W halogen lamps. There is an opportunity to replace all 30W halogen fixtures with LED fixtures that draw significantly less power while also provide the same/better lighting levels.

Figure 3: Runway Replacement Lamp

Recommended Action

It is recommended that the 30W halogen fixtures be replaced with the Navigate Series 861-L 20W LED fixtures, Siemens L861T LED fixture, or similar. Based on FAA regulations, the whole fixture would need to be replaced, not just the lamp. Additionally, staff personnel should consider if the voltage between the new LED fixtures and old incandescent fixtures would change. If so, it is possible the transformers could need to be replaced as well.

Figure 4: LED Runway Fixture

Energy Savings

Replacing all incandescent/halogen runway fixtures with LED fixtures could result in electricity savings of about **33,000 kWh per year** and cost savings of **$3,500 per year.**

L02: Replace PAPI Fixtures with LED Fixtures

Existing Condition

Based on site observation and conversation with facility personnel, the facility utilizes 105W and 200W PAPI halogen lamps. The PAPI lamps are required to operate 24/7 to guide pilots during their descent into the airport. There is an opportunity to replace the 105W/200W lamps with LED fixtures that draw significantly less power while also provide the same/better lighting levels.

Figure 5: 200W Lamp

Recommended Action

It is recommended that 105W/200W PAPI fixtures be replaced with LED fixtures (AV-PAPI Series 3 or similar). Based on FAA regulations, the whole fixture would need to be replaced, not just the lamp. Additionally, staff personnel should consider if the voltage between the new LED fixtures and old incandescent fixtures would change. If so, it is possible the transformers would need to be replaced as well.

Energy Savings

Replacing the halogen PAPI fixtures with LED fixtures would result in electricity savings of about **5,600 kWh per year** and cost savings of **$600 per year.**

New Construction Design Guidelines for Runway Lighting

When considering the expansion and/or addition of runway lighting, consider the following energy efficient opportunities:

- Specify 100% LEDs fixtures for beacon, runway, signage, and precision approach path indicator (PAPI) lights. LED lamps use 30-50% less energy to provide similar lighting output. Additionally, LED lamps have much longer run hours than halogen/incandescent lamps.
- Install high efficiency transformers, to reduce efficiency losses. Consult with electrical engineer/designer to determine the optimal transformer type and size to minimize electrical losses across the transformer. Reference Energy Star documentation (or similar) https://www.energystar.gov/sites/default/files/asset/document/Transformers%20Buyer%27s%20GuideFinal10-16-17.pdf.
- Consider expanding the size of the solar PV array to offset the expansion or increased power draw from a new runway design.
- Evaluate the effectiveness of including battery storage in the solar PV design to increase energy and demand savings.

Aircraft Hangars

Building Description

The following table summarizes the Hangar buildings included in the analysis. Based on the site visit, Hangar buildings A-E and H-M are comprised of 99 individual T-Hangars and Box Hangars. The total number of Hangars included in this section is 119 with a total square footage of 157,850 SF.

Summary of Aircraft Hangars			
Building	Type of Hangar	# of Individual Hangars	Square Footage (SF)
Hangar A	T-Hangar	10	
Hangar B	T-Hangar	10	
Hangar C	T-Hangar	10	
Hangar D	T-Hangar	10	
Hangar E	T-Hangar	10	
Hangar H	T-Hangar	8	134,250
Hangar I	T-Hangar	10	
Hangar J	T-Hangar	10	
Hangar K	T-Hangar	10	
Hangar L	Box Hangars	6	
Hangar M	T-Hangar	11	
Twin Hangars	Twin Hangars	8	11,600
Peri Hangar	Port-A-Ports	6	12,000
Total		119	157,850

Operational Schedules

The Hangars are available all year-around. However, on a typical day, the hangars are infrequently occupied.

Existing Lighting Systems

The T-Hangars include a single lighting fixture (LED or CFL bulb) that is controlled via an on/off switch. It is unclear if all T-Hangars have been transitioned to LED fixtures. Each hangar also utilize a skylight to provide natural lighting to the space.

The Hangars utilize a mixture of exterior fixtures to provide proper lighting levels overnight. During the site visit, it was noticed that a couple fixtures remained on during the daytime, indicating a opportunity for improved daylighting controls.

Existing HVAC Systems

The majority of Hangars are unconditioned. Occupants in the Peri Hangars and Twin Hangars utilize portable electric heaters in the cold, winter months to provide space heating.

Baseline Energy Summary and Calibration

In 2023, the Hangars consumed **116,640 kWh per year** with an annual electricity cost of **$25,610 per year**, or **$0.22 per kWh**. A summary table of annual usage by each Hangar is shown in the table below.

Summary of Aircraft Hangar Electricity Costs				
Building	Meter Account #	Electricity Usage (kWh/year)	Total Cost ($/year)	Unit Cost ($/kWh)
Hangar A	37678	5,367	$1,367	$0.25
Hangar B	260607-7	3,586	$1,069	$0.30
Hangar C	260608-5	11,929	$2,466	$0.21
Hangar D	260609-3	4,603	$1,239	$0.27
Hangar E	260610-1	5,558	$1,399	$0.25
Hangar H	260611-9	13,656	$2,753	$0.20
Hangar I	260612-7	3,389	$1,036	$0.31
Hangar J	260613-5	4,663	$1,249	$0.27
Hangar K	260614-3	6,245	$1,514	$0.24
Hangar L	262288-4	2,993	$970	$0.32
Hangar M	192721-9	11,308	$2,361	$0.21
Twin Hangars	37837-2	8,894	$1,957	$0.22
Peri Hangar	199734-5	34,449	$6,230	$0.18
Total		**116,640**	**$25,610**	**$0.22**

The following pie chart breaks down electricity usage by Hangar electricity meter. As noticed, the Peri Hangar comprises 29% of the total hangar electricity being considered in this section. Hangars H, C, and M comprise over 10% each of the total hangar electricity usage.

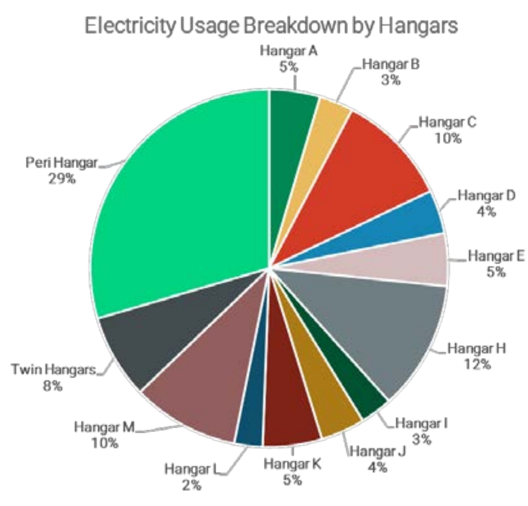


Figure 1: Electricity Breakdown by Hangars

To understand energy consumption in more detail, a monthly calibration was created utilizing the following information:

1. Weather data
2. Operating hours
3. On-site observations and information
4. Equipment specifications and anecdotal run hours
5. Monthly electricity data

The following graph shows the result of the energy calibration. The line graph is the aggregated monthly electricity data of all Hangar electrical utility meters. The bar graph is the estimated energy usage by the various end uses in the Hangars including interior lighting, exterior lighting, and electric heating. As shown in the graph, there is a constant electrical load throughout the summer (May-Oct) comprised of lighting and miscellaneous equipment loads. There is an increase in monthly electricity usage during the colder winter months, indicating the usage of electric space heating in the Hangars.

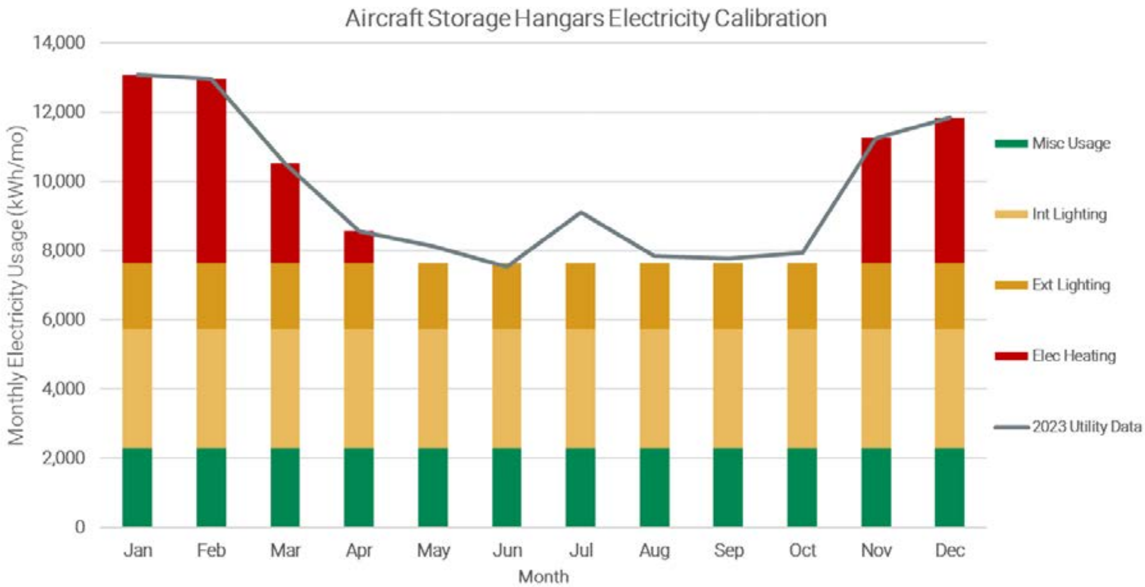


Figure 2: Calibrated Monthly Electricity Usage by End-Use

The following pie chart shows the preliminary energy breakdown by end uses. Interior + exterior lighting comprises ~56.2% of annual usage. Space Heating from the portable electric space heaters comprise 19.6% of total electricity consumption while the remaining electricity consumption is due to miscellaneous equipment in the hangars.

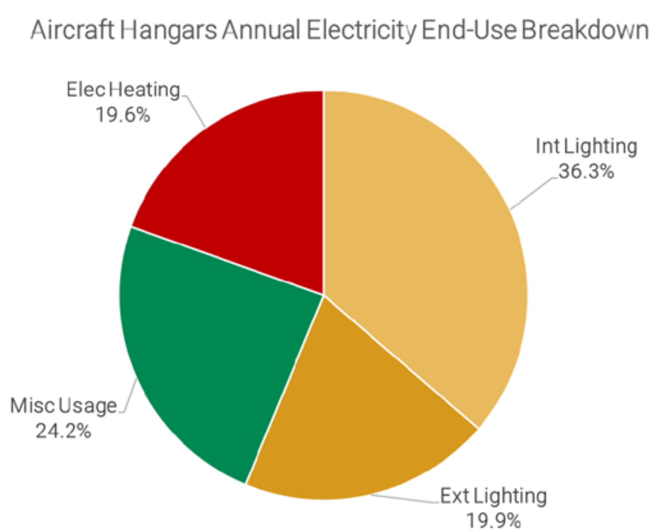


Figure 3: Electricity End-Use Breakdown

Energy Conservation Measures

The following section describes in detail individual energy conservation measures resulting from the site visit. Estimated energy savings, implementation cost, and simple payback are calculated for each conservation measure.

H01: Replace Interior and Exterior Compact Fluorescents with LED Bulbs

Savings		Financial Analysis				
Electricity	Cost Savings	Maintenance Costs	First Cost	Simple Payback	IRR	20-year NPV
(kWh/year)	($/year)	($year)	($)	(years)	(%)	($)
21,747	$4,784	$0	$5,680	1.2	87.0%	$76,906

Existing Condition

The hangars utilize a mixture of LED and compact fluorescent fixtures for interior lighting. Each lighting bulb has the opportunity to be upgraded to LED bulb that draw significantly less power while also providing same/better lighting levels for occupants.

Recommended Action

It is recommended that existing fluorescent lighting bulbs in the hangars be replaced like-for-like LED bulbs. The replacement of the full fixture should only be completed when deemed aesthetically or electrically necessary.

LED lamps output similar lighting levels as fluorescent fixtures at a reduced power draw; thus, minimizing lighting energy usage without compromising performance. Additionally, LED lamps have a longer lifespan minimizing maintenance costs. As a bonus, LED lamps contain no mercury, helping to streamline the recycling process.

Energy and Cost Savings

Replacing all compact fluorescent bulbs in the hangars with LED fixtures would result in electrical energy savings of about 21,747 kWh per year and cost savings of about $4,784 per year.

It is assumed that replacing each lamp would take about three days at a labor rate of $50 per hour (which assumes internal staff). Utilizing this information and cost data for the recommended lamps, the implementation cost is estimated to be about $5,680, and the simple payback would be 1.2 years.

H02: Retro-Commissioning Exterior Lighting Controls

Savings		Financial Analysis				
Electricity	Cost Savings	Maintenance Costs	First Cost	Simple Payback	IRR	20-year NPV
(kWh/year)	($/year)	($year)	($)	(years)	(%)	($)
1,168	$257	$0	$1,000	3.7	28.2%	$3,436

Existing Condition

The Hangars utilize a mixture of exterior fixtures to provide proper lighting levels overnight. During the site visit, it was noticed that a couple fixtures remained on during the daytime, indicating a opportunity to review and improve exterior lighting controls. Typically, exterior lighting will be controlled by a photosensor to detect natural light. When there is sufficient natural light (daytime), the photsensor will turn off the exterior lighting fixtures and turn on the fixtures when natural light is insufficient (nighttime).

Recommended Action

It is recommended that facility maintenance review and repair the existing photosensors for exterior lighting serving the hangar roadways. If photosensors are not installed, it is recommended that photosensors be installed to turn on/off exterior lighting fixtures based on detection of natural light.

Energy and Cost Savings

Repairing and installing photosensors for exterior lighting controls would result in electrical energy savings of about **1,168 kWh per year** and cost savings of about **$257 per year**.

It is assumed that about five photosensors would need to be replaced, requiring two days of work for an electrician. If so, the implementation cost is estimated to be about **$1,000**, and the simple payback would be **3.7 years.**

Solar Photovoltaic Installation Potential for Hangars

The following sections evaluate the opportunity of solar PV installations to offset electricity consumption for the various hangar buildings on the property.

T-Hangars and Box Hangars A-M

The hangars are expected to operate all year with the majority of energy consumption comprised of miscellaneous equipment and interior lighting utilized during daytime periods. Additional daytime space heating electricity is utilized during the cold, winter months.

Currently, each row of T-Hangars (A-M) has its own electrical meter. This means that each row of T-Hangars would require its own solar PV system, resulting in 13 PV systems and increased first cost due to the smaller size PV systems and duplication of equipment.

The first step in considering a solar PV installation is to discuss with the utility company (Redding Electric Utility) the opportunity of meter consolidation. Thus, instead of having 13 separate meters, the T-Hangars and Box Hangars would be consolidated under a single electrical meter, minimizing duplication of equipment and systems. If so, only a single PV system would need to be installed to serve all T-Hangars and Box Hangars.

The second major consideration for the PV system is its location and orientation. There is little ground area to install a ground mounted solar PV system; thus, it would be expected that any PV system would be installed on the hangar roofs. The majority of hangars are oriented east-west with a small roof pitch. However, it is estimated that the slight pitch would not cause significant electrical generation loss by the system. It is additionally unclear if the hangar roofs are adequate to support the load of a solar PV system. The roof structure would need to be evaluated.

Based on the 2023 utility data, the T-Hangars and Box Hangars consumed about **73,297 kWh per year** of electricity. Based on the location, a fixed tilt, roof mounted PV system, oriented east, would produce approximately **1,287 kWh/kW** of installed capacity per year. To offset the total energy consumption for the T-Hangars and Box Hangars, a **57-kW** solar PV array would need to be installed, requiring about **5,700 square feet** of roof area. The hangars have an overall roof area of about 119,000 SF. The following image shows the potential size of a 57-kW rooftop solar PV structure (outlined in red). Overall, the system would cover about half the roof area of a single row of hangars.

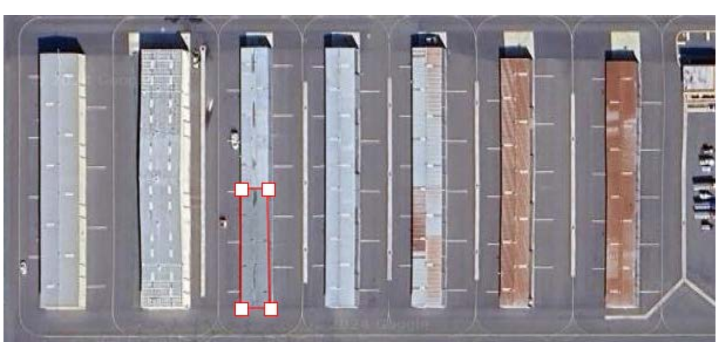


Figure 4: Potential Location and Size for 57-kW Solar PV Array

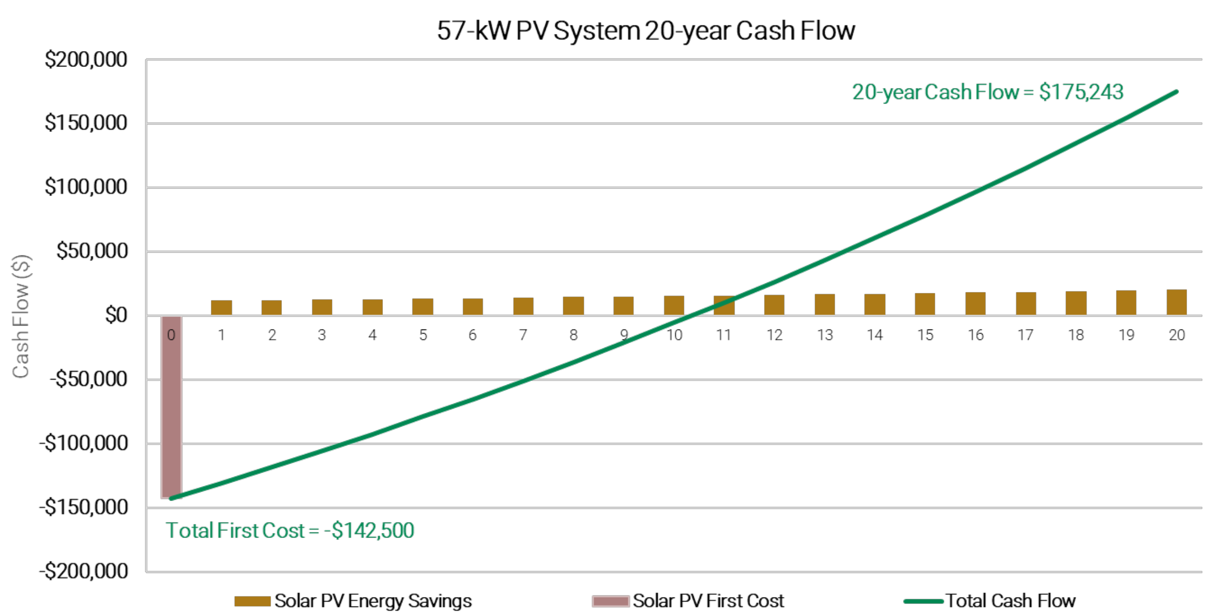
The following table shows the financial inputs for the 57-kW rooftop solar PV system. Based on the utility rate, the consumption cost and buyback rate are about **$0.1645/kWh.** Given the rooftop design and size, the initial cost of the PV system is estimated to be **$2.50 per kW**. Federal tax incentives and depreciation tax credits are **NOT** included in the analysis.

Solar PV Cost Inputs		
Input	Value	Units
Solar PV First Cost	$2.50	/Watt
Battery Storage First Cost	N/A	/kWh
Federal Tax Incentive	0%	-
Energy Escalation Rate	2.8%	-
Solar PV Equipment Lifetime	25	years
Battery Equipment Lifetime	N/A	years
Solar Utility Rate	$0.165	$/kWh
Buyback Rate	$0.165	$/kWh

The following table summarizes the financial results for the 57-kW solar PV system. The estimated simple payback is **about 10.3 years** with an internal rate of return (IRR) if **8.3%.**

Financial Results		
Input	Value	Units
20-year NPV	$65,808	-
Straight Line Payback	10.34	years
Year-1 ROI	8.5%	-
IRR	8.3%	-

The following graph shows the 20-year cash flow for the solar PV system incorporating first cost and energy cost savings. The total first cost of the system is about **$142,500 for a 57-kW solar PV system.**



Peri Hangars

A similar analysis was conducted for the Peri Hangar. Based on the 2023 utility data, the Peri Hangar consumed about **34,449 kWh per year** of electricity. Based on the location, a fixed tilt, roof mounted PV system, oriented south, would produce approximately **1,323 kWh/kW** of installed capacity per year. To offset the total energy consumption for the Peri Hangar, a **26-kW** solar PV array would need to be installed, requiring about **2,600 square feet** of roof area. The Peri Hangar is listed with a square footage of about 12,000 SF. The following image shows the potential size of a 26-kW rooftop solar PV structure (outlined in red) on the Peri Hangar. Overall, the system would cover about a quarter of the roof area.

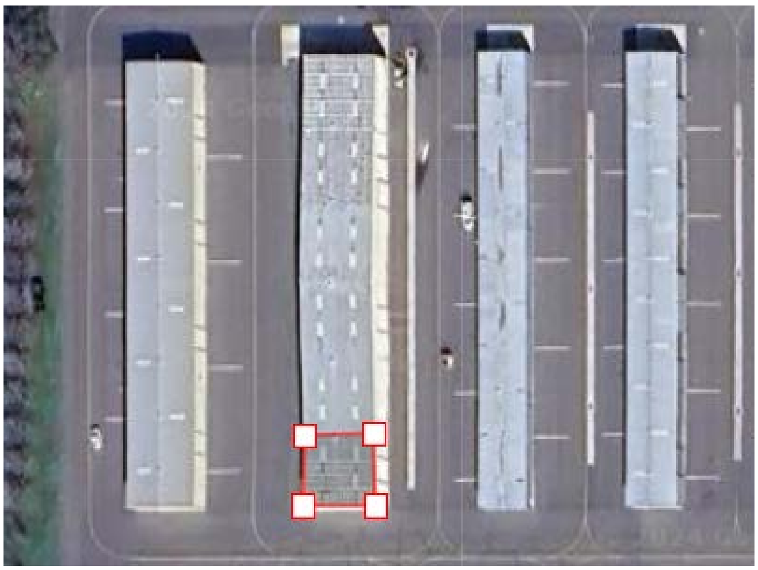


Figure 5: Potential Location and Size for 26-kW Solar PV Array

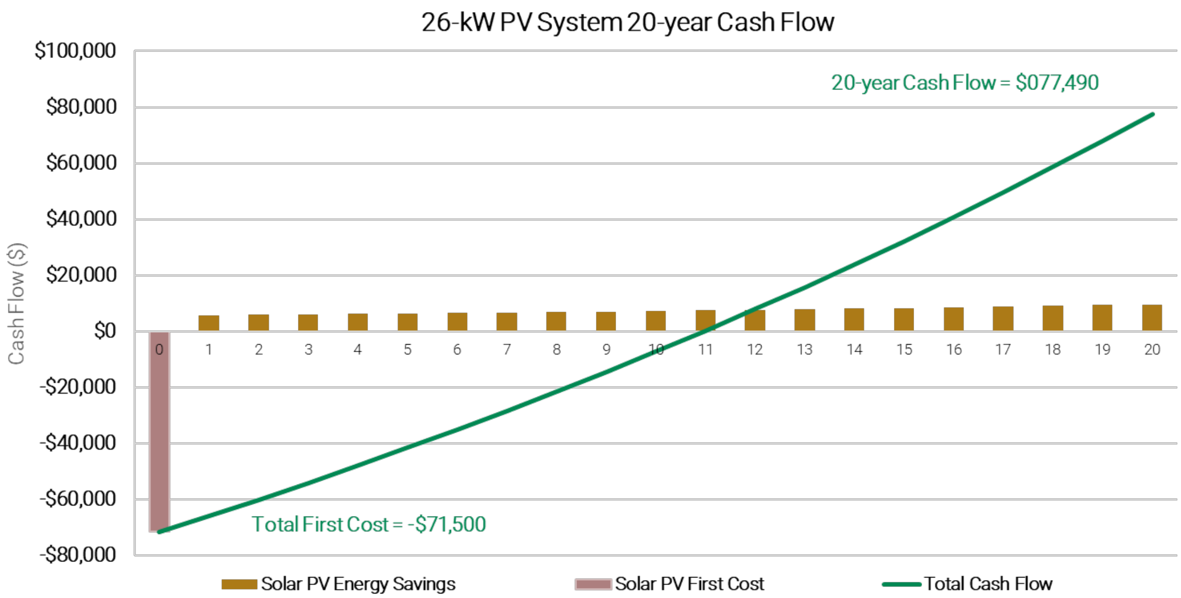
The following table shows the financial inputs for the 26-kW car park solar PV system. Based on the utility rate, the consumption cost and buyback rate are about **$0.1645/kWh.** Given the rooftop design and size, the initial cost of the PV system is estimated to be **$2.75 per kW**. Federal tax incentives and depreciation tax credits are **NOT** included in the analysis.

Solar PV Cost Inputs		
Input	Value	Units
Solar PV First Cost	$2.75	/Watt
Battery Storage First Cost	N/A	/kWh
Federal Tax Incentive	0%	-
Energy Escalation Rate	2.8%	-
Solar PV Equipment Lifetime	25	years
Battery Equipment Lifetime	N/A	years
Solar Utility Rate	$0.165	$/kWh
Buyback Rate	$0.165	$/kWh

The following table summarizes the financial results for the 26-kW solar PV system. The estimated simple payback is **about 11 years** with an internal rate of return (IRR) of **7.4%.**

Financial Results		
Input	Value	Units
20-year NPV	$26,176	-
Straight Line Payback	10.97	years
Year-1 ROI	7.9%	-
IRR	7.4%	-

The following graph shows the 20-year cash flow for the solar PV system incorporating first cost and energy cost savings. The total first cost of the system is about **$71,500 for a 26-kW solar PV system.**



New Construction Design Guidelines for Hangars

The hangar electricity usage is comprised of interior lighting, exterior lighting, miscellaneous loads, and occasional space heating. When considering the construction of a new Hangar, it is recommended the project team consider the following design narratives.

Envelope Design

The hangar envelope design should consider the following if new hangars are built with space conditioning:

- Envelope insulation should meet local envelope code requirements.
- Consider increasing roof insulation above local code requirements to reduce heat loss through the roof.
- The roof structure should be built to support the installation of a solar PV system.
- Consider insulated (R-10) and thermally broken hangar bay doors.
- Consider the utilization of automatic hangar doors to limit the amount of infiltration into the space.
- To increase natural lighting and maintain envelope insulation, consider the installation of Kalwall translucent panels, or similar construction.

If hangars are not built with space conditioning, the envelope design would only consider the following:

- Maximize natural lighting entering the space through skylights and curtain wall windows.
- The roof structure should be designed to support the installation of a solar PV system.

Lighting Design

Interior lighting serving the hangar space should include the following:

- 100% LED Fixtures
- Lighting levels should meet the intended space use.
  - Storage hangars should achieve a lighting level near 30-40 FC.
  - Repair and maintenance hangars should achieve between 50-100 FC depending on the type of work being performed
- Occupancy sensors should be considered where applicable. Blind spots and line of sight should be considered when designing locations of occupancy sensors.
- Daylight sensors should be considered when/if skylights/translucent panels are included in the envelope design.

Exterior lighting for the hangar area should include the following:

- 100% LED Fixtures
- Lighting levels should meet the intended usage.
- Daylight sensors or timers should be installed to turn off/on exterior lights based on daytime/nighttime conditions.

Plumbing Design

If new hangars are built to include bathrooms and/or a small kitchenette, the plumbing design should consider the following:

- Low flow lavatory faucet fixtures (0.5 GPM or less)
- Low flow urinals (0.125 GPF or less) and toilets (1.28 GPF or less)

- Instantaneous, electric water heaters to eliminate distribution losses.

HVAC Design

If space conditioning is being considered for a new hangar, the following design options should be considered:

- Space heating setpoint should be no higher than 65F and space cooling setpoint should be no lower than 80F.
- Utilize electric radiant space heating where possible to eliminate infiltration losses.
- Install destratification fans to eliminate stratification of air in high bay hangar scenarios.
- Utilize evaporative cooling unit in place of mechanical cooling where applicable.
- If hangars are designed with small office areas or breakrooms, utilize high efficiency heat pumps to provide both heating and cooling to the space.

Tenant Operated Buildings

Building Descriptions

The Redding Regional Airport property includes buildings that are leased to and operated by tenants. The building utility data and information were not available; however, a high-level walk through was conducted for the majority of the buildings. The following table summarizes general building information, where known.

#	Building	Building Area (SF)	Operating Schedule	Lighting System	HVAC	DHW
1	ARFF (Fire Station)	12,000	24/7	LED	Heat Pump	Gas Boiler
2	Air Chasta (FBO-Helicopter Services0	10,500	M-F 8AM-5PM	LED	Heat Pump	Electric Resistance
3	FedEx (Cargo Operator)	13,200	M-F 6AM-9PM, Sat 7AM-5PM	LED	Heat Pump	Electric Resistance
4	REACH Air Ambulance Service	1,200	24/7	MH/Fluorescent	AC-DX, Electric Heat	Electric Resistance
5	Redding Jet Center (FBO)	20,000	M-F 5AM-7:30PM, Sat-Su 7AM-7:30 PM	MH/Fluorescent	Heat Pump AHUs	Electric Resistance
6	Baker-Barr Hangar (Corporate Hangar)	11,200	Occupancy Based	Unknown	N/A	Electric Resistance
7	Sierra Pacific (Corporate Hangar)	17,400	Occupancy Based	Unknown	Heat Pump	Electric Resistance
8	Stringer Hangar (Corporate Hangar)	6,400	Occupancy Based	Unknown	Unknown	Unknown
9	Tullis Hangar (Corporate Hangar)	8,000	Occupancy Based	Fluorescents	N/A	Electric Resistance
10	Wong Hangar (Corporate Hangar)	6,400	Occupancy Based	Fluorescents	N/A	Electric Resistance
	Total	106,300				

Operational Schedules

Operating schedules for each building are listed in the table above. The Hangars are only operated when occupants are in the space.

Existing Lighting Systems

Only the ARFF, Air Chasta, and FedEx buildings have fully switched to LED lighting fixtures. The remaining buildings utilize a mixture of metal halide and fluorescent fixtures. Few spaces incorporate automatic lighting controls (occupancy sensors or daylight sensors).

Existing HVAC Systems

The majority of Hangars are unconditioned, except where small offices exist within the hangar space. Most other building utilizes packaged and/or split heat pumps to provide both heating and cooling to the respective spaces. Based on the site visit, the majority of equipment looks to be in good condition, except for a couple rooftop heat pumps at the Redding Jet Center. Most HVAC equipment is controlled via a local thermostat. Based on the site visit, only Air Chasta has incorporated smart thermostat(s).

Existing DHW Systems

Where DHW systems exist, the majority utilize electric resistance storage tank heaters. The ARFF building utilizes a gas-fired DHW heater to provide hot water for showers, lavatories, and kitchen operations.

Energy Conservation Measures

The following table provides a specific list of potential energy conservation measures (ECM) for tenant operated buildings. The table provides a simple payback range as a starting point for understanding the potential impact for each ECM. Key takeaways include:

- All metal halide and fluorescent fixtures should be replaced with LED lighting fixtures.
- The hangars have significant skylights; however, a number of skylights are dirty. It is recommended to clean skylights and installing daylight dimming controls on existing LED fixtures.
- Most buildings have an opportunity to improve HVAC control by implementing smart thermostats that can automatically control temperature setpoints based on schedule/occupancy.
- Point of Use (POU) electric DHW units should be evaluated in locations with low hot water demand (hangars, small offices, etc.)
- The ARFF should consider replacing their gas-fired DHW heater (COP 0.8) with an air-source heat pump (COP 3).

Summary of Aircraft Hangar Electricity Costs				
#	Building (s)	Energy System	ECM Description	Simple Payback
1	Redding Jet Center	Lighting	Replace 480W and 1000W Metal Halide Lighting Fixtures with LED Fixtures in the Hangar	1-2 years
2	Redding Jet Center	Lighting	Clean Skylights and Implement Daylighting Controls on Fixtures in the Hangar	3-5 years
3	Redding Jet Center	Lighting	Replace T12/T8 Lighting Fixtures with LED Fixtures in the Hangar and Office Spaces	3-5 years
4	Redding Jet Center	HVAC	Install Smart Thermostats to Control Roofop Heat Pumps	5+ years
5	Redding Jet Center	HVAC	Replace Old Rooftop Heat Pumps with High Efficiency RHEEM RQPL (or similar) heat pumps	5+ years
6	Redding Jet Center	Renewable Energy	Install Solar PV System on South Facing Hangar Roof	5+ years
7	Air Shasta	Lighting	Clean Skylights and Implement Daylighting Controls on Fixtures in the Hangar	3-5 years
8	ARFF	HVAC	Retro Commission Purafil, FC-1, and FC-2 HVAC Units	1-2 years
9	ARFF	Lighting	Clean Skylights and Implement Daylighting Controls on Fixtures in the High Bay	3-5 years
10	ARFF	HVAC	Install Smart Thermostats to Control Roofop Heat Pumps	3-5 years
11	ARFF	DHW	Replace Gas Hot Water Heater with Air Source Heat Pump	5+ years
12	REACH Air Ambulance	Lighting	Replace 480W Metal Halide Lighting Fixtures with LED Fixtures in the Hangar	1-2 years
13	REACH Air Ambulance	DHW	Instal POU DHW or Heat Pump to Replace Electric Resitance DHW Storage Tank	5+
14	Rental Car Service	Lighting	Replace T12/T8 Lighting Fixtures with LED Fixtures	3-5 years
15	Tullis Hangar	Lighting	Clean Skylights and Implement Daylighting Controls on Fixtures in the Hangar	3-5 years
16	Tullis Hangar	DHW	Instal POU DHW or Heat Pump to Replace Electric Resitance DHW Storage Tank	5+
17	Sierra Pacific Hangar	DHW	Instal POU DHW or Heat Pump to Replace Electric Resitance DHW Storage Tank	5+

For new tenant buildings under consideration and/or design, it is recommended that the project team reference and consider the recommendations outlined in 'New Construction Design Guidelines for the Terminal' and 'New Construction Design Guidelines for Hangars' section of this Energy Audit Report.

Tenant High Performance Sustainability Guidelines

Significant building square footage within the Redding Regional Airport consists of tenant occupied spaces with their own envelope, lighting, and HVAC designs. To support energy efficiency in tenant spaces, it is recommended the City of Redding consider instituting 'High Performance Sustainability Guidelines' for tenant renovations to ensure that tenants are meeting the airport's goals and expectations for sustainability. The following sections outline an example of sustainability guidelines that can be incorporated into tenant leases.

General Guidelines

- Exceed local energy code (IECC 2018, Title 24, etc.) standards.
- Comply with Energy Star for Tenant Spaces requirements for design and construction.
- Perform a design analysis to evaluate energy optimization measures and design alternatives to be considered in the final design and construction. Utilize an energy model or other standard methods to perform energy calculations and analysis.

Envelope Design Considerations

- Meet or exceed Title 24 insulation values for exterior walls, roof, and fenestration based on location.
- Design exterior fenestration systems to optimize occupant view while minimizing solar heat gain. Consider utilizing low SHGC fenestration for east, west, and south facing windows.
- Where significant fenestration is designed, utilize exterior shading devices, natural features, and interior shades to minimize glare and solar heat gain.
- All fenestration assemblies should utilize thermally broken frames.

Lighting Design Considerations

- Target an LPD that is 10% better than Title 24 space-by-space allowances through the utilization of the following:
    - Specify 100% LED lamps.
    - Reflective surfaces and LED task lighting, when applicable.
- Conduct lighting level analysis to optimize lighting layouts and minimize excess lighting fixtures.
- Implement lighting controls
    - Vacancy sensors should be installed in all areas with a vacancy timer no more than 15 minutes.
    - Daylight sensors with continuous dimming controls should be installed in all daylit areas. Daylight-responsive controls should be provided to control lighting within 15 feet of windows, openings, and under skylights.
    - Consider tying in lighting controls to a BMS system and integrating controls with HVAC operations.

DHW Design Considerations

- Low flow lavatory faucet fixtures (0.5 GPM or less)
- Low flow urinals (0.125 GPF or less) and toilets (1.28 GPF or less)
- All Kitchen appliances should be low flow and Energy Star rated.
- Consider the following DHW heating sources in place of electric resistance storage tanks:
    - Instantaneous electric water heaters were installed at each bathroom to eliminate distribution losses.
    - Centralized DHW heat pump unit for kitchen hot water. Heat pump units are 3x more efficient than electric resistance heaters.

HVAC Design Considerations

- When replacing HVAC systems, reference ‘New Construction Design Guidelines for the Terminal’ and ‘New Construction Design Guidelines for Hangars’ section of this Energy Audit Report.
- Perform HVAC load calculations using engineering software, for example Trane Trace. The loads should be submitted with the DD and CD sets. Design input values should be summarized, including envelope, lighting, equipment, IT and loads per person on btu/sf.
- Right size equipment based on the efficient lighting design and actual plug loads. It is not recommended to use blanket W/SF across all spaces and space types.
- Comply with and do not exceed the ASHRAE 62.1 or local ventilation code requirements.
- All HVAC system design and efficiency levels shall exceed local code and the current version of IECC.
- All sources of heating and cooling within a single space shall be controlled and interlocked together.
- Ensure HVAC design specifications include operational set points and schedule to meet the most recent version of ASHRAE 55 requirements. Controls contractor to ensure set points are programmed as designed.
- Zone controls shall automatically maintain a minimum 5F deadband between space cooling and heating setpoints.
- Implement Demand Controlled Ventilation (DCV) for the space through the use of CO2 sensors or Indoor Air Quality (IEQ) sensors.
- Specify CFC and HCFC-free and low GWP refrigerants.
- A third-party commissioning agent should commission all HVAC equipment to ensure proper installation and programming of equipment.