CITY OF REDMOND

Solar + Storage Report

Analysis of Four City Buildings on the Potential Incorporation of Solar and Storage Systems to Support Resilient Building Operations

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December 19, 2024

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Executive Summary

This report explores opportunities for the City of Redmond to improve the resilience of its municipal facilities by evaluating the potential for the deployment of solar plus energy storage systems at key facilities to support emergency operations, while also supporting building performance improvements and emissions reductions at the facilities. These strategies are aligned with the City of Redmond's Environmental Sustainability Action Plan and Climate Emergency Declaration. This work was funded by a grant from the Washington Department of Commerce.

The specific goals of the study were to evaluate the degree to which the installation of rooftop solar photovoltaic systems, combined with a battery storage system could support continuous operation of four key facilities in an emergency situation that included loss of grid power, and to identify other potential benefits to resiliency and emissions reduction that such systems might deliver. The four facilities evaluated were Redmond City Hall, the Public Safety Building, Fire Station 17, and the Redmond Senior and Community Center. For each facility, a number of different building energy use and operating scenarios were identified to represent the impact of a solar/storage system on current building operations, potential emergency operating scenarios, and scenarios where building performance improvements were undertaken.

The report provides context of different ways to evaluate and integrate solar/storage systems, and the types of considerations that must be evaluated to deploy effective and dependable resiliency strategies using solar/storage systems at the building scale. Additional potential advantages and opportunities of these systems are discussed in the context of each building. The report also provides recommendations on solar/storage integration opportunities at potential new facilities in the City of Redmond.

At a high level, the report finds that there is significant potential to leverage solar/storage systems for resiliency improvements at each building, though to different degrees.

The Redmond Senior and Community Center represents a significant opportunity to deploy solar/storage to support community resiliency. The building is highly efficient, and a solar/storage system could support off-grid emergency operation of a significant portion of the building completely for roughly 8 months out of the year. Deployment of a modest portable generator to augment the solar/storage system in cold months would provide year-round emergency resiliency at this facility.

The Public Safety Building is directly linked to the adjacent City Hall Garage, and taken together these buildings provide an opportunity for a substantial PV array installation. Linked with a battery this could provide power to support PSB operations completely for several months of the year. However, energy loads at the facility are significant, and currently it is assumed that the entire facility must remain operational at all times. This makes the magnitude of a solar/storage system to provide significant resiliency at this facility significant and costly. There are opportunities to incorporate a solar/storage system to optimize generator capacity and operation, or to deploy solar power to support significant fleet electrification and emergency operation.

Current loads at Fire Station 17 do not align well with the potential capacity of a solar system at this building, and a solar/storage system would not provide enough energy for full facility operation in an emergency. However, a solar/storage system could support more effective and efficient generator operation, and provide resilient charging for electric fire vehicles at all seasons and in an emergency. Significant energy performance improvements at this facility would lead to better alignment between available solar power and daily building loads.

City Hall is a significant energy user, and a solar array would not be large enough to provide significant resiliency at this facility. A solar/storage system could be configured to support a modest EOC at this facility, or could support generator optimization.

Deployment of a solar/storage system at any of these facilities would also provide other benefits to the city, including reduced peak loads, and the ability to participate in time of use pricing and on-site generation to reduce utility costs.

The findings of this analysis also suggest that there are significant advantages to considering solar/storage integration in any new facilities planned for the City of Redmond. By considering potential resiliency strategies in the design process, the city can retain the flexibility to more easily deploy resiliency strategies later, and can more directly align building performance with energy performance, decarbonization, fleet electrification, and resiliency goals.

The potential advantages of solar/storage systems in supporting resilient building operations in the Redmond municipal portfolio warrant specific additional feasibility analysis to zero in on effective emergency strategies. In particular, it is critical that the city identify specific resiliency goals for emergency operation that can guide a more detailed analysis of the potential to meet these goals with the deployment of solar/storage systems at key City of Redmond facilities.

Introduction

The 2020 Environmental Sustainability Action Plan and the Climate Emergency Declaration establish aggressive climate and sustainability goals for Redmond, directing the City to increase community resilience and achieve carbon neutrality. This vision requires Redmond to shift how it manages its facilities and leverage new technologies to support resilient operation.

In response to these goals, the City of Redmond has undertaken a strategic evaluation of its municipal building stock, evaluating building condition and energy performance, developing strategies to reduce carbon impacts, and identifying opportunities to enhance resiliency and emergency operations. The analysis outlined in this grant-funded report is a component of that body of work and provides a preliminary evaluation of solar and battery storage opportunities at four key City of Redmond facilities.

This analysis includes a review of the following facilities:

- Redmond City Hall
- Redmond Public Safety Building
- Fire Station 17
- Redmond Senior and Community Center

The goal of the analysis is to determine whether building-scale installations of rooftop photovoltaic (PV) systems, combined with battery energy storage is a potentially feasible strategy to contribute to emergency operation of these facilities, and to assess how a solar/storage system might be integrated into new infrastructure buildings in the future. The analysis also considers different ways in which a solar/storage system might be integrated into building operation to serve other goals such as carbon reduction, reduced utility and infrastructure costs, and other aligned goals.

This document serves as a first step for resilience planning in City Redmond facilities. While it evaluates the four facilities noted, it also provides a framework to guide City decision making as new facilities are constructed.

Project Approach

To develop this analysis, the following steps were undertaken to assess the potential for solar/storage deployment to support facility resiliency:

- Conduct a site visit at each facility
- Collect electrical drawings and other information
- Collect utility performance data for each facility
- Benchmark energy performance and identify reduced energy use scenarios
- Identify potential emergency energy use scenarios
- Develop daily load shapes for all building operating scenarios
- Evaluate potential roof areas and solar PV capacity
- Develop daily load shapes for PV generation
- Evaluate the potential match between building load scenarios and generating potential for typical seasonal loads

- Identify other potential resiliency scenarios for building operation that a solar/storage system could contribute to
- Provide a building-by-building summary of solar/storage resiliency issues
- Develop recommendations for next steps in evaluating solar/storage potential for these facilities
- Identify solar/storage integration issues for new buildings based on this analysis

Contents

This report begins with a discussion of key concepts that must be considered in evaluating building loads, solar capacity, energy storage, and resiliency. These factors are closely inter-related, and there are many ways to consider and prioritize these different system elements and functions. Various resiliency scenarios are described to set up an approach to evaluation of individual buildings.

Next the characteristics of each building in the study are discussed, including assumptions about emergency operation, and building performance characteristics under various scenarios. This leads to a discussion of the alignment of solar/storage capacity available at each building with the various building load characteristics.

A discussion of alternate approaches to resiliency and other advantages of solar/storage systems is provided, and resiliency strategies and recommendations are summarized for each facility, for new buildings, and for the portfolio as a whole.

Detailed information about building load shapes and daily solar generating potential is provided in the appendices.

Solar, Storage, and Resiliency Context

This section describes the relationships between solar generation, energy storage, and daily building loads in the context of the potential for deployment of a solar generation and energy storage system to support resilient building operation in the event of a grid outage.

Building performance evaluation and scenarios

The first step in this evaluation was to determine the existing building load characteristics. First, we determined current total annual building energy use (for all fuels). Data collected from utility data and Energy Star Portfolio Manager allowed us to identify an annual energy use intensity (EUI) for each building. EUI is a common metric used to compare building performance with peer facilities, and is also the basis of compliance requirements with the Washington Clean Building Performance Standard (CBPS). All commercial buildings over 25,000 square feet are required to document compliance with the CBPS requirements in the next few years, with larger buildings facing earlier and more detailed compliance requirements. The reason CBPS compliance is relevant here is because buildings not in compliance with this standard will be required to implement performance upgrades soon to bring buildings into compliance with the standard. This could have an impact on several Redmond portfolio buildings and would change the way these buildings interact with any solar/storage system that might be implemented to serve resiliency goals.

Because solar/storage systems can provide only electricity to buildings, the electrical energy use component of the buildings is the critical factor in determining how well a solar/storage system will meet building energy loads. Resiliency of natural gas systems is not addressed in this analysis.

Redmond has also adopted carbon reduction goals that might influence any potential building performance upgrades that are undertaken in the future. Achieving carbon reduction goals in buildings typically entails a significant improvement in building energy performance, and the reduction or elimination of fossil fuel consumption on site. Both of these strategies will impact the effective deployment of resiliency strategies served by solar/storage systems.

To account for potential decarbonization efforts, this analysis included a 'best in class' comparison, identifying the EUI associated with the best performing buildings of each type that might represent a high-bar target for Redmond's municipal buildings. In the case of these best in class targets, the energy use was assumed to be 100% electric, to support emission reduction goals.

In the context of decarbonization, both on-site combustion and electricity use have carbon emissions impacts. For fossil fuels, the impact is the combustion exhaust from fuel burned on site, and the upstream impact of gas distribution on emissions (in the form of raw methane leakage). The upstream emissions impacts of natural gas use are significant, but are not always accounted for in building emission accounting. For electricity use, the emissions impact comes from the fossil fuels used by the local utility to generate electricity to feed into the grid. Currently, Redmond's local electricity provider (PSE) generates a significant portion of electricity using fossil fuels. However, under state mandates, the percentage of electricity generated using fossil fuels will decline significantly over the next decade, and eventually be completely phased out. So, the use of electricity at any given building will represent a decreasing impact on emissions over time.

The EUIs of the target buildings in this analysis are shown in Table 1 below. These values represent current total EUI of each building, current electric-only EUI of each building, CBPS target EUI for each building, a target electric EUI based on a similar fuel ratio as current performance, and finally a best in class EUI that is assumed to be all electric. These values will be used to assess the effectiveness of a solar/storage system to meet building loads in the event of a grid emergency. Subsequent graphs showing building load shapes represent electric-only portions of building loads.

Table 1: Building performance scenarios

Building	Current Total EUI	Current Electric EUI	CBPS Target EUI	CBPS Electric EUI (based on similar fuel ratio)	Best in Class EUI (all electric)
City Hall	69	45	66	43	~22
Public Safety Building	79	59	71	54	~30
Fire Station 17	92	68	72	53	~28
Senior Center	15	15	30	30	~24

Notes for Table 1 :

1- *Although the fuel use ratio is kept constant between current and CBPS performance levels, efforts to improve building performance are likely to alter the relative fuel balance in any given building.*
2- *Best in class EUI's are based on industry data but may not directly reflect the mix of services provided in each building in this table.*
3- *Redmond Senior and Community Center performance data includes a time period when the building was not fully occupied and may not reflect a typical operational year.*
4- *For gas heated buildings, resiliency strategies in winter will also depend on continued availability of heating sources for these buildings. This aspect was not evaluated in this report.*

Logically, the lower the electric energy use of a given facility, the larger a percentage of the building load a solar/storage system would be able to meet.

Emergency Operation

For an emergency situation, it may be possible to define a subset of building loads that should be maintained during an emergency, while not necessarily operating the entire building. For example, City Hall includes an emergency operations center (EOC) that represents a small portion of the overall building. In any emergency situation, this area would need to be fully functional, even if some other parts of the building might be shut down.

It is likely that the City of Redmond is developing an official emergency operations plan to describe key operations that must be maintained under different emergency scenarios. However, this information was not available to the project team during this analysis. Instead, a potential emergency operation scenario was identified by the team for each building in the study, and the potential alignment with a solar/storage system was evaluated for these loads.

It should be noted that the project team was not able to determine if specific building loads were isolated on the electrical panels in a way that would allow the building to operate a subset of the electrical system in this way. Additional work would be necessary to assess the possibility of deploying a solar/storage system to operate emergency loads only, and reconfiguration of electrical distribution systems might be necessary to enable this type of operation. It should also be noted that a number of city buildings currently include diesel emergency generators for emergency operation.

Load Shape

Although total energy use provides a good comparison metric in considering the overall match between building energy use and solar/storage capacity, from a resiliency lens a much more important metric is daily load shape.

Daily load shape is the amount of energy used over the course of a day, represented in hourly (or shorter) intervals. This representation shows how much energy is needed to power the building systems at any given hour to keep the building operating as intended. Typically building load shapes peak in the daytime while buildings are occupied and go down at night when the building is unoccupied. Load shapes vary significantly by season based primarily on outside temperature, but length of daylight hours and weather patterns also affect building load shape. Load shapes can be impacted significantly by a variety of building performance issues; system maintenance issues or control anomalies can cause poor operation, a large west facing window area can drive afternoon cooling load spikes, and a host of other performance issues can manifest in building load shapes. Weekend and holiday load shapes are different than weekday load shapes, and even occupant lunch hours can show up on building load shape diagrams. Resiliency strategies depend on an alignment between daily building load shapes and solar/storage system energy availability.

For purposes of this analysis, load shapes for each building from a typical day in each season were identified to show a typical operating pattern for each building. This data was collected from utility interval data (15 minute increment) that was made available to the project team by the utility at the City's request.

As an example of what a load shape plot looks like, Figure 1 below shows daily load shape data for Redmond City Hall. The horizontal axis represents a 24 hour day (midnight to midnight), and the vertical axis represents total energy use. Four typical days representing seasonal variation are shown: a day in January (purple line), April (green), July (blue), and October (red).

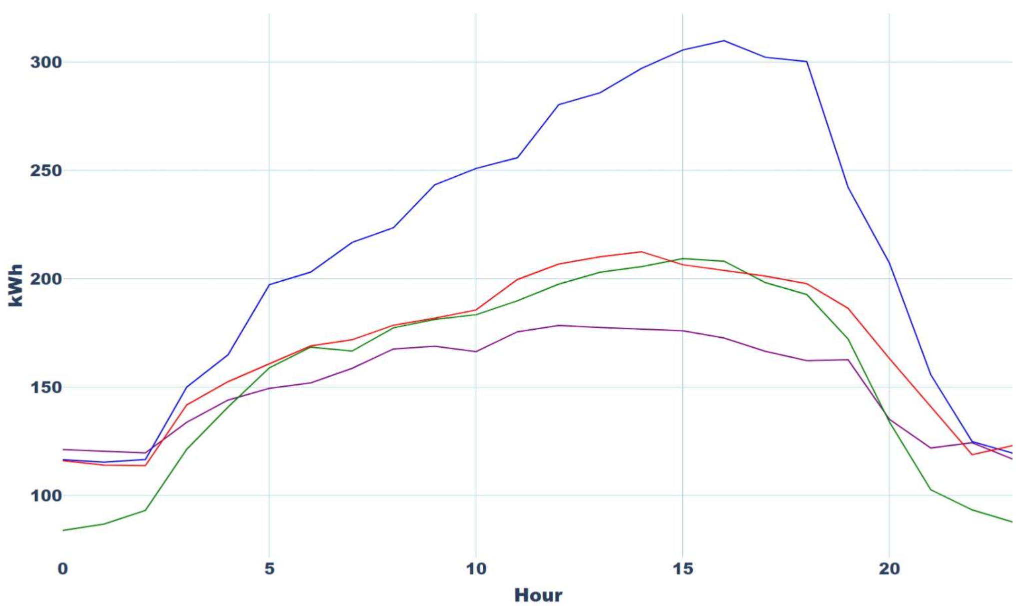

Figure 1: City Hall daily load shape data for typical occupied days in January (purple), April (green), July (blue), and October (red).

Building load shapes provide a wealth of information about building operation. For the building shown above, peak energy use occurs on summer afternoons, while the shoulder and winter months demonstrate relatively smooth and consistent energy use curves throughout the occupied day. This graph also suggests long hours of daily use, since energy use starts rising at 3:00 in the morning and remains high until at least 8:00 pm (represented as hour 20 on this graph). Although it is not unusual for some buildings to be occupied for long hours each day, the early start for increased energy use in this case might suggest that building controls are set for a very early warm-up cycle, well before building occupancy begins each day, and remain active well after business hours.

In the case of this analysis, load shape data was used to compare what could be available from PV energy generation linked with battery capacity to building consumption patterns to assess operating capabilities in a grid outage situation. This is discussed further in subsequent sections of this report.

Current operating patterns for each building, as demonstrated in the load shape data was also used to predict load shapes under the alternate performance scenarios identified above (CBPS compliance and best in class performance). Current load shapes for all of the buildings in this analysis are provided in Appendix A.

A final category of load shape scenario was developed for each building based on assumptions about emergency operation needs. These scenarios considered whether partial operation of each building would serve as an emergency operations plan to better align building energy use with solar/storage capacity constraints. These scenarios are discussed for each building in subsequent sections of this report.

Solar PV Potential and Storage

Daily Generation and Variability

The next step was to evaluate potential for photovoltaic (PV) system deployment and generating potential at each site. PV panels are typically installed on the roof, ideally facing due south at a mild incline. This orientation maximizes total electricity generation over the course of a year. To increase winter production, panels can be mounted at a steeper angle from horizontal. Panels oriented more to the west generate more energy in the afternoon, while panels oriented more to the east generate more energy in the morning. Other than some general assumptions based on roof orientation, the specific orientation of the PV arrays evaluated for this analysis was not considered or optimized.

PV generation occurs only when the sun is shining and is impacted by shadows and cloud cover. Because of shorter days and increased cloud cover in the winter, daily PV generation is significantly lower in the winter than in the summer. This introduces a seasonal impact to any calculations of resilient building operation, as discussed in subsequent sections.

PV arrays are measured in terms of total installed capacity, representing the total peak wattage that could be generated instantaneously under ideal conditions. The vast majority of time the sun is not directly overhead from the panels, but rather is striking the panels at an angle, or impacted by clouds or dirt on the panels, etc. So nominal capacity does not provide much guidance on total energy production. Instead, we can generate a load shape for PV generating systems, just as for building consumption loads. For this analysis, the PVWatts tool was used to predict PV generation for each site based on latitude, typical weather, and PV panel area.

As expected, the load shape of solar generation on a typical day follows a predictable and consistent pattern. Figure 2 below shows electrical generation data collected from the small existing PV array that is currently mounted on City Hall. This graph shows the expected mid-day peak, and the anticipated significant seasonal variation in the power generated on the average day in different times of year.

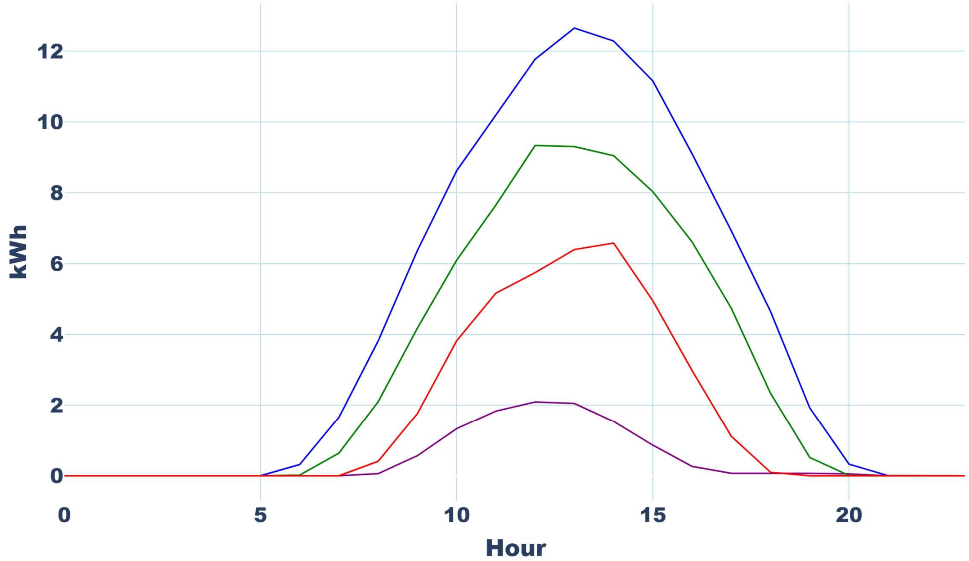

Figure 2: Example of daily solar PV generation by season by currently installed small array at City Hall. January (purple), April (green), July (blue), and October (red).

The generation shapes shown above represent typical days in each season of the year, based on daily data. In this case, the information comes from measured data from an existing installation. The curves are generated as average results for each month represented. This means that the data accounts for whatever sort of cloud cover and weather patterns were present in the year in which this data was collected (2023).

Although we generally consider solar generation as an average daily event, generation is actually subject to significant variation during the day due to weather and obstructions (shadows). These factors can have a critical impact when a building might be relying on daily generation as part of a resiliency strategy. The impact of daily variability in cloud cover can be seen in the example in Figure 3 below, which shows the variability of PV generation over a typical year in Redmond, based on recent historical weather data.

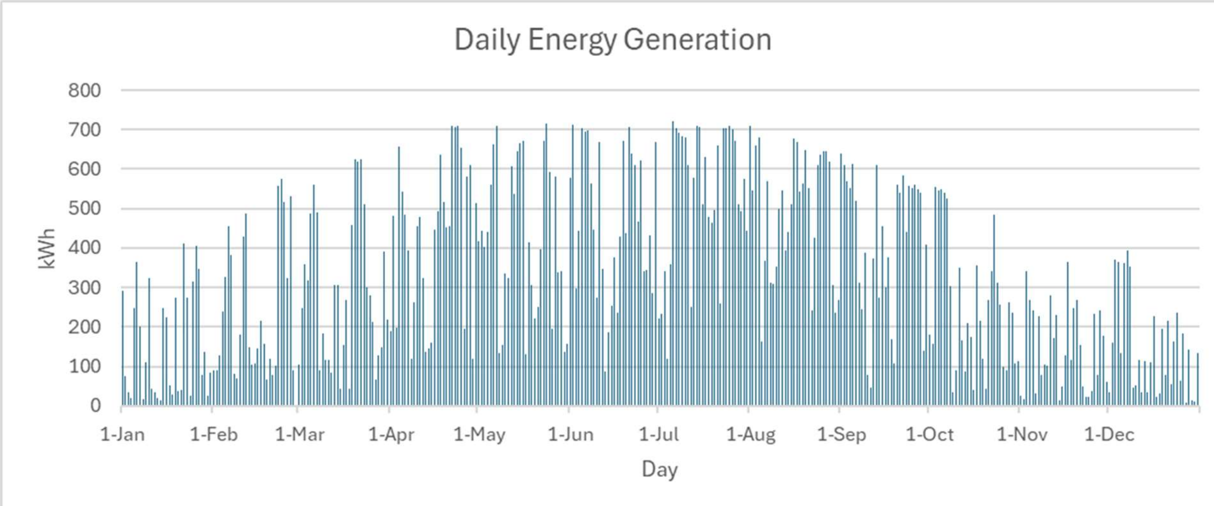

Figure 3: Daily PV generation showing impact of weather variability on daily energy production over the course of a year. (This graph is from an estimate of potential PV generation from a large array that could be installed on City Hall)

Installed PV Capacity

To assess the potential installed PV capacity at each building, total roof areas were evaluated, and a potential PV layout scheme was developed based on available roof space not occupied by mechanical equipment or other roof appurtenances. Note that PV panel installations cannot typically be installed over 100% of roof area, since access and maintenance corridors must be maintained on the roof. Table 2 shows the anticipated roof area and capacity of PV array assumed for each building. Estimated PV installation areas in this study are approximated and would need to be verified if a site were selected for more detailed analysis. PV capacity is a total instantaneous generating capability in full sun; total energy generated over the course of a day must be calculated based on hours of available sun each day. A quick summary of roof area assumptions for PV for each facility is provided in Appendix B, and solar generation load shapes for each building are included in Appendix C.

Table 2: Building floor areas and anticipated PV capacity

Building	Floor Area	PV Installation Area	Estimated PV Capacity (kW)
Public Safety Building	61,523	40,519 (Including Parking Garage)	675
City Hall	107,212	15,556	259
Fire Station 17	19,397	3,375	74
Senior Center	51,986	12,897	215

PV and Battery Integration

Until very recently, PV systems were typically installed on buildings without including electrical energy storage systems. When PV generation occurs for these installations, the energy can be used to offset building electrical loads occurring at the same time, fed back into the grid, or not used. In most larger installations, mid-day PV generation exceeds local building energy demand, so there is surplus power available from the PV system at this time. Although many people think that they can just “run the meter backwards” with PV generation, in fact utilities may be resistant to this outcome for a number of reasons. In particular, it is very difficult for utilities to manage multiple points of generation (distributed generation resources, or DR) because they need to balance individual lines and substations to keep the grid operating smoothly. In commercial buildings the utility may insist on a lower rate for electricity fed back into the grid than they charge for electricity they supply; they may decline to purchase all, or any, of the power made available by PV systems; or they may offer only discounted purchase pricing depending on what time of day the power is generated. For these reasons it may make sense to incorporate energy storage (batteries) into a PV installation even when the grid is supplying power. Batteries allow projects to store excess power generated during the daytime and use it to meet building loads when the sun goes down, or to manage peak loads or participate in demand response programs.

In the context of resiliency, a battery is critical to ‘spread out’ the availability of PV power so that it can be utilized at other times than just the middle of the day. **The best way to think about resiliency in the context of PV plus storage systems is to consider the solar/storage system as a unit that provides a consistent level of power over 24 hours and is recharged each cycle in daylight hours by the PV system on the roof.** In a sustainable resilient system, the PV system generates as much power in a day as it takes to run the building for 24 hours, with a battery system storing the daytime excess PV generation to distribute to the building through the night hours, before the PV system once again takes over building loads and recharges the battery. In this scenario, the solar/storage system is able to run the emergency loads indefinitely, as the system is recharged every day. Note however that both building and PV loads fluctuate seasonally, so what is a sustainable load in the summer may not be a sustainable load in the winter. This relationship can be seen in Figure 4 below.

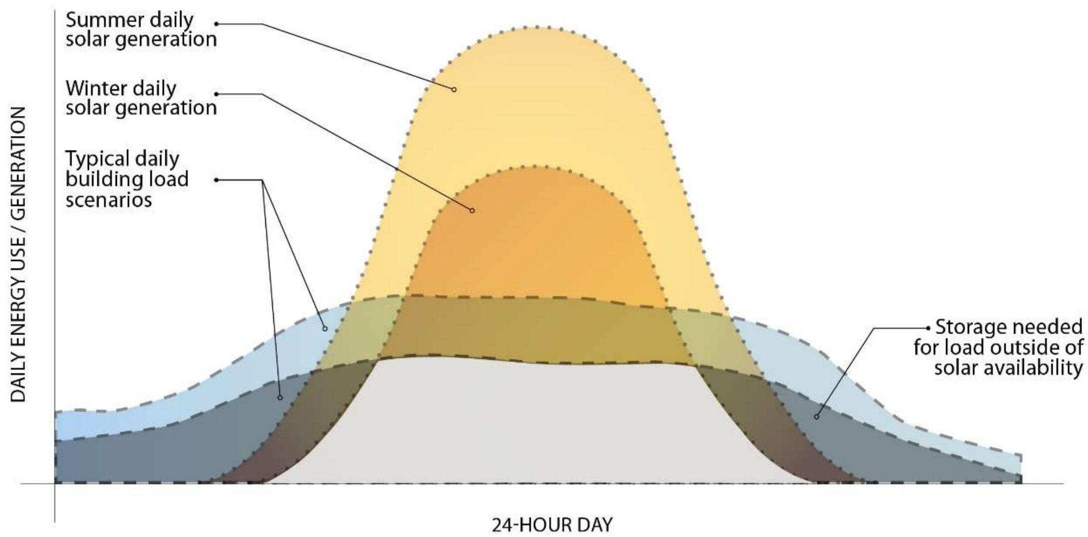

Figure 4: Relationship between daily PV generation, 24 hour building loads, and battery sizing.

Battery Sizing and Storage Duration

It is important to recognize that in the context of building loads, most batteries are not long term storage solutions. The most common battery type, lithium ion is ideally utilized (discharged) over a four to eight hour time period. Over longer terms, these batteries tend to lose a small percentage of their stored power each day, so some sort of regular top-up is required to maintain charge. And although battery costs continue to drop significantly, they are still much more expensive than solar panels. Current commercial building scale batteries cost in the neighborhood of $400/kWh of capacity. For these reasons it is ideal to first consider a primary role for onsite generation, designed to run as much of the building as possible, with enough extra capacity to charge a battery that is sized to provide overnight loads before the solar array comes back online to take over building operation and recharge the battery the next day. Batteries that exceed this sizing criteria can only be used (discharged) once as a resiliency strategy until another source of energy is utilized to recharge the battery.

To support building operation, batteries must be at least as large as the building peak load they need to meet in the short term. Although buildings only run at peak load infrequently and for short duration, the battery capacity must be large enough to meet this short term peak, even if it only lasts for a few minutes.

In addition to supporting resiliency strategies, batteries can provide other advantages to a building, such as reducing building peak loads on the electric grid to reduce demand charges, or to participate in time of use utility pricing strategies that are becoming increasingly common. They can also be used to improve the reliability of a changeover to alternate power sources (like a generator) or to reduce the capacity of generator needed to serve building loads. These issues are discussed in subsequent sections of this report.

Microgrids

Any electrical system designed to power all or part of a building when utility power is not available relies on a 'microgrid' to provide local power to the building. When backup power systems are generators designed to supply the entire building, this can be as simple as a power transfer switch that disconnects utility power and feeds generator power to the building. But with any solar/storge system designed to provide building power or integrate with a generator, a more complicated control and management system (microgrid) is needed. A microgrid also allows for peak load management and time of use control when using a battery.

Resiliency

Resiliency is a broad term with many nuanced interpretations. When designing for resiliency the first question that is asked of the team is "Resilient to what?". Resiliency needs can vary by climate, region, season, and even site. **In the Pacific Northwest we generally consider risks from wildfire smoke, heat events, power outages, and earthquakes as regional resiliency issues.** These risks are more likely to occur in combination. In this analysis, we are focused only on resiliency in the case of utility outages, though the need for emergency operation is likely to be driven by some other event causing a power outage in the first place.

Resiliency Scenarios

The key focus of this study is to determine whether solar/storage systems deployed on the identified buildings can contribute to emergency operation of the building in the event of a power outage. To make this assessment for Redmond municipal facilities, we evaluated several key questions to assess the potential effectiveness of a solar/storage resiliency strategy for each building:

How well do potential daily PV generation estimates align with different building operating scenarios?

PV capacity is relatively inexpensive, but the area available to install these systems is physically limited at each building site. The maximum amount of power that the PV system can generate sets a limit on how much energy use in the building it can support each day. More efficient buildings are more likely to align with PV generating capacity, and likewise if a subset of building loads is considered critical for operation, these loads are easier to meet than total building load. For each building, different operating scenarios based on building efficiency and emergency operation are considered in the context of available PV. Up to four building operating scenarios were considered for each facility:

- Current building electricity use characteristics for full operation
- Building energy performance aligned with CBPS requirements
- Best in class energy performance for each building type
- An emergency operations scenario that might involve partial building operation (depending on the building)

How does seasonal variation in generation and building loads affect resiliency options?

Seasonal power generation varies significantly for PV systems, and a building that can be fully operated day after day on renewable energy and storage in the summer may not be able to operate this way for a full day in the winter. Building loads vary by season as well, and typically do not fluctuate in alignment with solar availability.

What is the minimum battery size needed to meet current building peak loads?

Although different resiliency strategies can be implemented with different levels of battery power, there is a basic minimum battery size that is needed to support building operation. If the battery sees short term loads that exceed its capacity, the system will fault, and no power will be available. Because building peaks are typically short lived, a battery sized for peak load may actually provide a few hours of emergency operation to the building.

Batteries are an expensive component, so this represents a first pass at a reality check as to whether battery storage is a reasonable resiliency strategy for these facilities.

A shorter period of guaranteed emergency operation might be useful to prevent service interruption for shorter duration power outages, or it might allow enough time to marshal other resources to support city operations, bring generators online, or relocate to a central emergency facility.

What other resiliency strategies could be leveraged with a solar/storage systems?

Even if PV storage systems are unable to provide full resiliency to a building, there are a number of ways to leverage solar/storage systems to support resilient building operations. These are discussed in the context of their potential application for each building.

Are building electrical systems currently configured to support partial operation for emergency operation?

Although detailed analysis of electrical system configuration is beyond the scope of this analysis, the team reviewed electrical drawings and visited the building sites to try to assess whether the buildings are currently configured to support full or partial emergency operation.

Individual Building Assessments and Opportunities

In this section the performance characteristics of each building are reviewed, and potential emergency operating scenarios are identified. These are compared to anticipated potential solar generation to assess alignment with the deployment of a solar/storage system at each building. Seasonality of resiliency strategies is also described. Alternate resiliency strategies with solar/storage are described in a subsequent section.

Redmond City Hall

Redmond City Hall is a four story, ~107,212 SF facility housing city offices, council chambers, conference and meeting facilities, public access and information facilities, data and communications, and an emergency operations center for the city on the third floor. The facility already includes a small 20 kW PV array on the roof, although this is not supported by an energy storage system. This analysis evaluates the possibility of expanding that array significantly to a capacity of 259 kw.

The City Hall building currently has an EUI of 69.4, slightly above the requirements of the CBPS which requires the building to achieve an EUIP of 66 or lower. This facility is subject to imminent enforcement of these requirements and will be required to lower its EUI. A lighting upgrade will be completed in Spring 2025 to support CBPS compliance requirements. For comparison, a best in class building of this type would have an EUI of approximately 32 kBtu/SF/yr.

A portion of the City Hall building on the third floor serves as an emergency operations center for the city. This area includes extensive communications capabilities, workstations, and media connections. In an emergency situation, there might also be a need for some public/media interface areas, and elevator capabilities to reach the EOC. As a basis for this analysis we have assumed that emergency operation of this facility includes an area designated for the EOC with associated office areas, lobby, and restroom facilities, as well as vertical transportation. The rest of the building would not be operational in this scenario.

City Hall currently includes a 375 kW emergency generator. This is sized and circuited to run a portion of the existing building in an emergency.

Loads vs. Capacity

Figure 5 below shows how these different building operating scenarios compare to the anticipated production from a rooftop PV array.

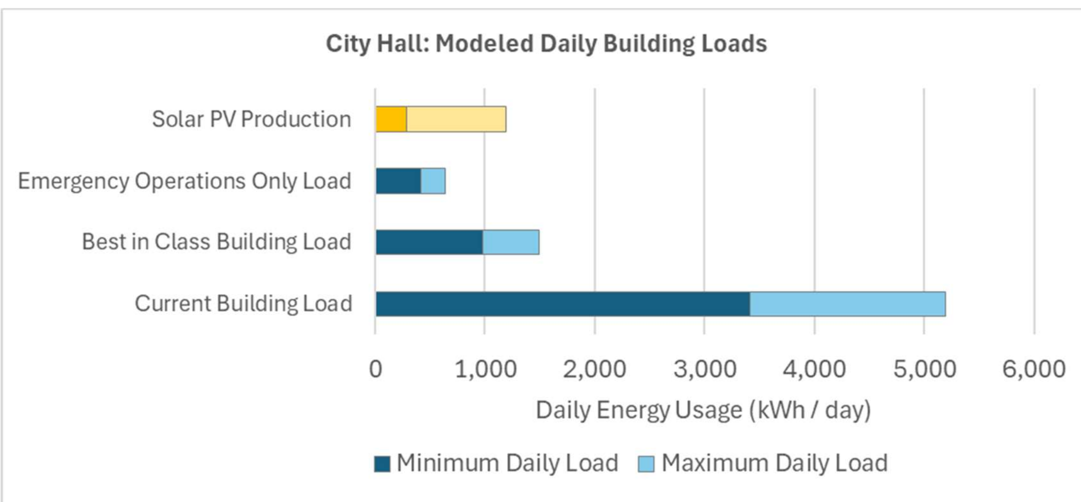

Figure 5: Redmond City Hall load and generation comparison

How to read this graph:

Figure 5 and similar graphs below show a way to consider the alignment of PV generation potential with different building load scenarios. The top bar in the graph ("Solar PV Production") represents the range of total average daily PV generating potential in kWh. The left part of the bar represents a 'minimum' typical day (winter) and the full bar represents the maximum daily generation (summer).

The blue bars below solar generation represent average daily load for different building scenarios, including various combinations of 'emergency operations', 'best in class' building operation, 'CBPS compliance', and current operation. Each building bar also shows a range of daily operating energy representing seasonal variation (Dark and light parts of each bar). Note however that the month when the minimum building energy use occurs may not align with the month when minimum solar energy generation occurs. For example, some buildings use more energy in winter, when solar generation is at its lowest.

Summary

The current loads of the City Hall building are well above what could be supported by the rooftop PV array. Even if the building were performing at a level comparable to best in class, the PV array would not meet building loads in most circumstances. This is not unusual for a four story building, which is generally limited in PV capacity by roof area relative to floor area. However, **the emergency operating scenario evaluated could be supported by a solar/storage system nine months out of the year,** as shown in Figure 6 below. In those months when the PV system is not adequate to fully meet emergency loads over consecutive days, the difference does not exceed 25% of total load. Therefore, it may be possible to tune up this analysis to support either a more detailed emergency operation load analysis or the potential for a somewhat larger PV array, or both.

A solar/storage system could also be integrated to support generator operation and allow the generator to be downsized.

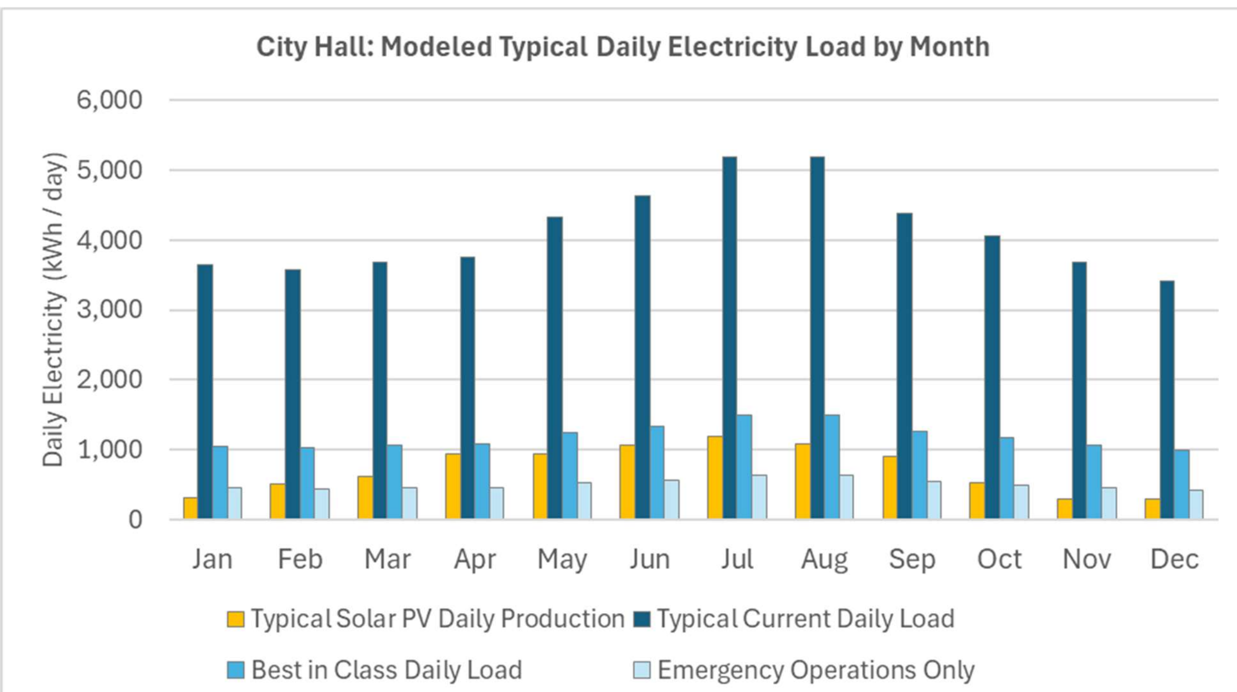

Figure 6: City Hall average daily building loads including potential emergency loads and average daily PV production by month.

Public Safety Building

The 61,523 SF Public Safety Building houses police and other uses, as well as 911 call center, including a backup call center for neighboring communities in an emergency. The building was built in 1988, with some remodeling undertaken in 2009. The building is served by two separate emergency generators associated with different remodels and is connected by a complex electrical system reflecting multiple sequential upgrades. The generators are sized to run the full building, with one generator being a backup for the other. The building is adjacent to the City Hall Parking Garage, to which it is connected by a walkway.

The building has an EUI of 80, above the CBPS performance target of 71.5. Its size makes this building subject to imminent enforcement requirements of the CBPS, and the building is undergoing energy upgrades in 2025 to support CBPS compliance. A lower EUI for this building will support increased viability of solar/storage options for resiliency.

For comparison, a 'best in class' building that includes some level of 24/7 operation might achieve an EUI in the high 20's, depending on what percentage of the facility is operated at all hours.

Because this building houses the police department and the 911 dispatch center, as well as a secondary dispatch center as a back-up for other regions, we anticipated that this building needed to remain fully operational in an emergency. No partial operation plan was considered.

For this evaluation we assumed that PV could be installed on the roof of the building and on the top floor of the adjacent parking garage to serve the Public Safety Building. This led to a substantial size of PV array, and significant available energy on a daily basis. Note that the energy consumption associated with the parking garage was not considered in this analysis.

Loads vs. Capacity

Figure 7 below shows how these different building operating scenarios compare to the anticipated production from a rooftop PV array.

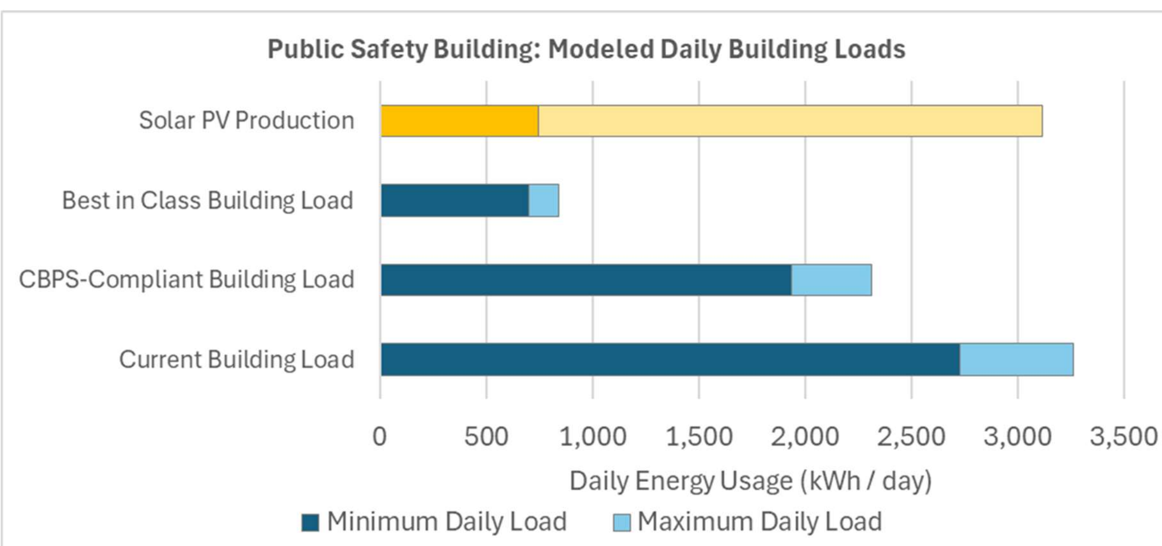

Figure 7:Redmond Public Safety Building loads and generation comparison

Summary

Because of the increased area of PV on the adjacent parking structure, the total peak daily generation from the PV array nearly meets the existing building load, and well exceeds the performance anticipated for the building when CBPS requirements are achieved. However, the generating capacity is seasonal, so a closer examination of seasonal characteristics is warranted.

Figure 8 shows the seasonal variation in typical daily energy generation and use at the Public Safety Building compared to the estimated PV generation from the anticipated array. The blue bars on the graph represent typical daily building load by month for two scenarios: the dark blue bars represent current building energy use, and the medium blue bars represent proportional daily energy use if the building meets CBPS requirements. (Note that performance could also be improved beyond CBPS requirements.) The yellow bars represent typical daily solar energy generation by month.

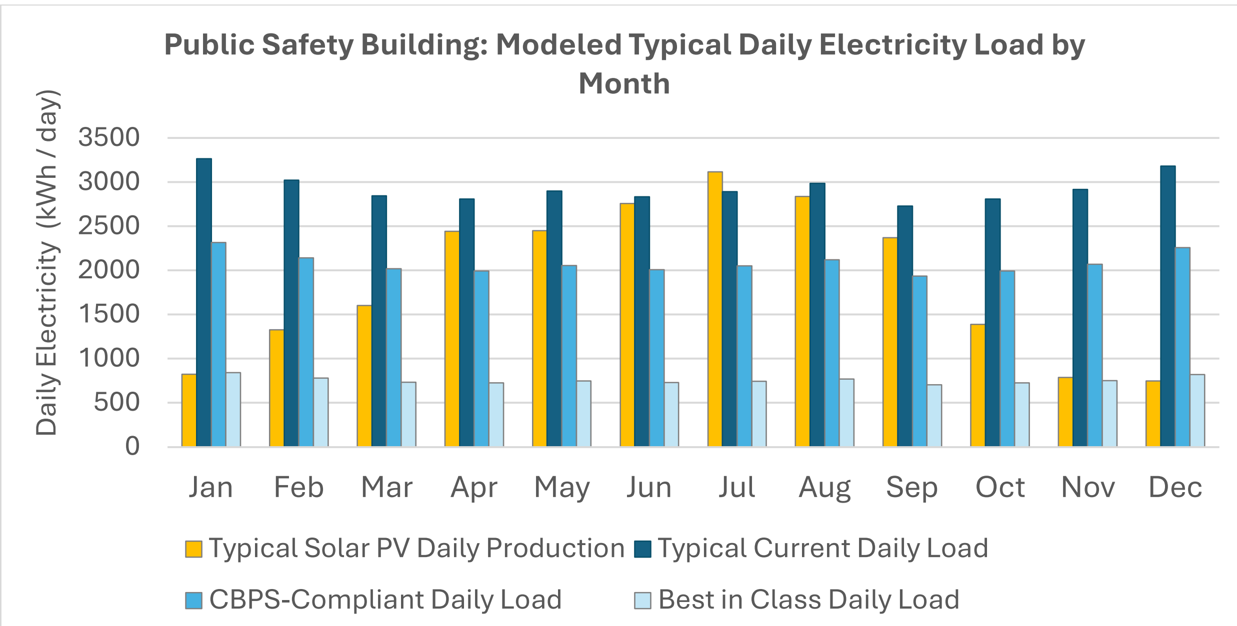

Figure 8:Public Safety Building average daily building loads including potential improved (CBPS) loads, loads, and average daily PV production by month.

In this analysis, solar energy generation is not able to meet current building energy use, except in the peak of summer. Solar generation would exceed CBPS building loads six months out of the year, during the warmer months when solar availability is relatively consistent. If the building were in fact improved to meet CBPS requirements, the solar/storage system would be able to fully run the building continuously in an emergency, if that emergency occurred in warmer months. (Obviously, an emergency strategy is also needed for colder months!)

Although there is significant PV available, the amount of battery capacity needed to match this system and provide 24 hour operation would be significant. And an alternate resiliency solution would be needed for winter months.

This facility is provided with full and redundant generator backup. A combined generator and solar/storage strategy is discussed below and could represent a viable resiliency solution at this facility.

Fire Station 17

FS17 is one of Redmond's newer fire stations, with apparatus bays, living quarters, office area and communications equipment in a two story 19,397 SF facility. Upstairs at the Fire Station is a large classroom/meeting room that is also designated as a backup emergency operations center (EOC) in case the EOC at City Hall is compromised or not operational. Because of this, FS17 is considered a critical facility, and is equipped with a back-up generator for emergency use.

The facility has a large, low-slope roof that would support a substantial PV array. Rough calculations suggest that approximately 74 kw array could be installed on the roof. There is also a significant gravel parking lot to the south of the building which could also support additional PV array installation. (This area was not included in this analysis.) The site is bordered closely by large trees, which would be likely to shade parts of the roof and adversely impact PV generation.

The fire station has a total EUI of 91.4 kBtu/SF/yr, of which three fourths in from electric energy use. Although not immediately subject to CBPS requirements, if compliance were required the building would need to perform at or below an EUI of 71.5 (all fuels). For comparison, a best in class fire station could achieve an EUI of about 28 or lower. Several nearby cities have fire stations operating with EUI's in the low 20's.

Because of its function as a backup EOC, and the emergency response capabilities headquartered at this facility, the emergency operations plan for FS17 in this analysis is for the facility to be fully operational.

Loads vs. Capacity

The alignment of FS17 operational scenarios with potential PV capacity is shown in Figure 9 below.

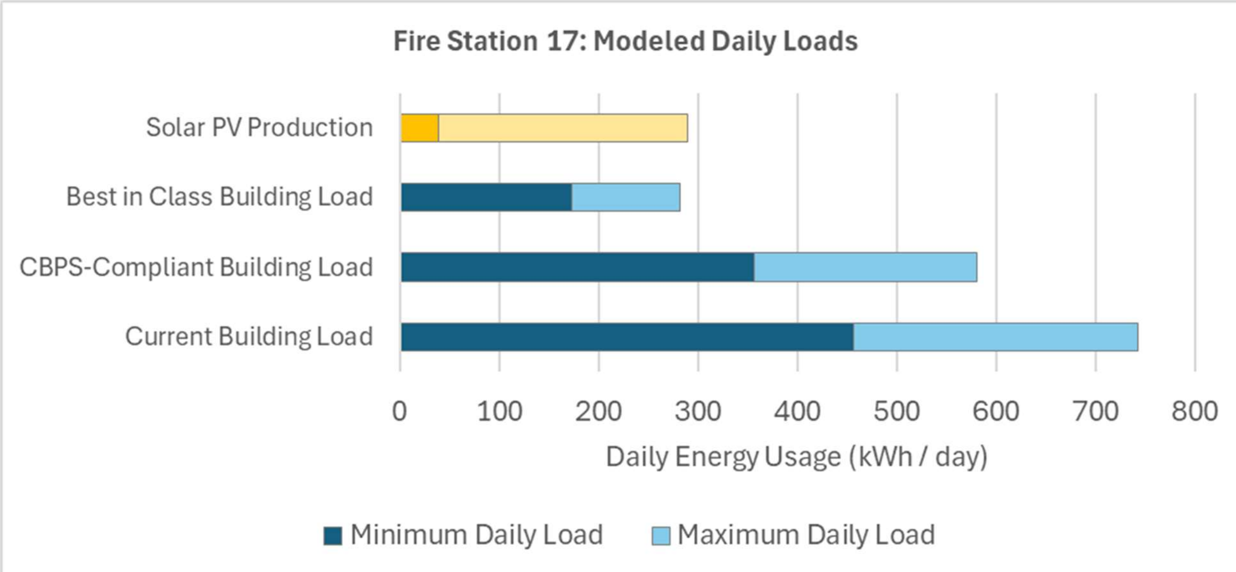

Figure 9: Redmond Fire Station 17 building loads and generation comparison

Summary

The installed PV potential (top bar) represents less than half the total energy use of the existing facility, and barely half of the energy use of the facility if it met CBPS performance requirements. There is also significant seasonal variation in PV array production, in part due to assumptions about the adjacent tree canopy impacting PV generation. These factors suggest that this facility is not a good match for a solar/storage system to provide full resiliency. However, the size of the PV array would fully support facility performing at 'best in class' levels, at least for parts of the year. And the existing electrical system could readily be configured for partial operation if a subset of emergency loads were identified. A solar/storage system could also be integrated with the generator system, as discussed below.

Redmond Senior and Community Center

The City of Redmond recently completed the new Redmond Senior and Community Center (RSCC) located as part of the municipal campus. This two story 51,986 SF facility is all electric, and includes various community activity rooms including a gymnasium, commercial kitchen, shower and restroom facilities, work out areas, and various office and public meeting spaces.

The building has a 156 kW PV array, but the deployment of additional PV capacity was assumed for this analysis.

The RSCC has only been in operation for a bit over a year, and only reached full operation a few months ago. The energy use data we gathered for this facility may not accurately reflect full operation. The facility is currently operating with an EUI of 18, a very low energy use number. Initial energy modeling of the facility suggested an EUI of about 26, very close to what would be considered best in class. Because the facility is all electric, various building components can be supported directly with the electrical energy supplied by a rooftop PV system.

The facility is not considered an emergency facility, but its characteristics make it a potential candidate to support some types of emergency activities. For example, the large gymnasium could serve as an evacuation or emergency bunk center, and the all-electric commercial kitchen could be deployed to prepare emergency meals. The facility also has a number of community amenity spaces like locker rooms and meeting areas that might be useful in an emergency situation. One drawback to this possibility is the facility's location adjacent to the Sammamish River and therefore in a flood zone. Because of this some types of emergencies would render this facility unusable.

For this analysis, we estimated an electrical load to support emergency kitchen operations, a dense occupancy of the main floor gymnasium (for temporary occupied cots), and a portion of the main floor operating normally to support showers, public meetings, etc. Overall, this represents partial operation of the facility in an emergency. We did not evaluate the capability of the existing electrical system to operate in this manner.

Loads vs. Capacity

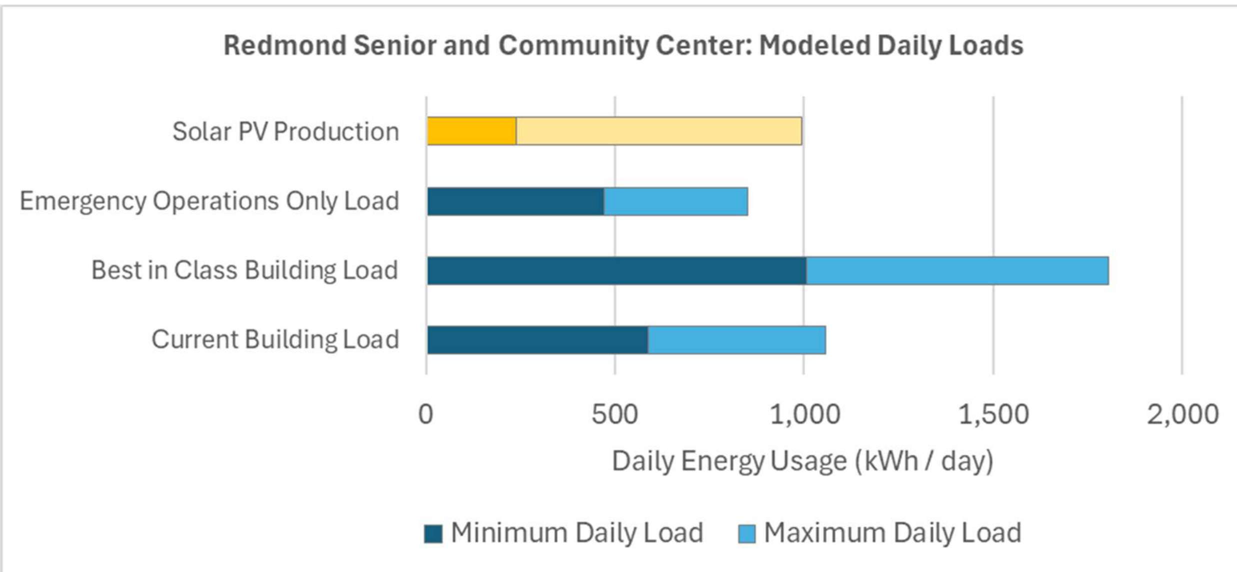

Figure 10: Redmond Senior and Community Center building loads and generation comparison

Summary

An installed PV array on this facility is capable of meeting the full building load in parts of the year. However, it is likely that typical building loads will increase as the facility becomes more fully utilized. It is also possible that an emergency operating scenario for this building could be developed to provide partial operation of the building with a solar/storage system if desired.

Note that in the emergency operating scenario assumed here, there are still some months in the winter when the solar/storage system cannot keep up with daily loads. In the case of this analysis, the PV system cannot keep up for 3 months of the year: November, December, and January.

Alternate Resiliency Opportunities

There are a number of alternate strategies to consider when evaluating the integration of solar/storage systems into these buildings. Incorporating a robust solar/storage system can lead to other benefits, even if the system is not able to fully support year round resiliency.

Seasonal Resiliency and Temporary Operation

Emergency planning needs to include robust solutions for a wide range of conditions. A battery system that only serves emergency loads in the warm months does not represent a complete emergency response plan. However, being able to plan on full resiliency for six months out of the year goes a long way toward supporting resiliency planning. For buildings with significant solar/storage systems, the battery system might represent six our eight hours of emergency operation on a winter day that allows the city to marshal backup resources to support emergency operation without a temporary interruption of services. And some fraction of power outage emergencies are likely to be resolved within the time frame that a battery would be able to support the building.

Generator Integration

Another way to think about the integration of solar/storage systems is to consider the impact such a system could have on emergency generators.

Emergency generators are sized for building peak electricity load, often with a significant oversizing factor built in. This oversizing is arguably justified in case all of the possible building loads are operating simultaneously. This almost never happens, although building startup immediately after a power failure probably represents the largest building load. Most of the time, buildings operate at a much smaller fraction of peak load, as shown in Figure 11 below.

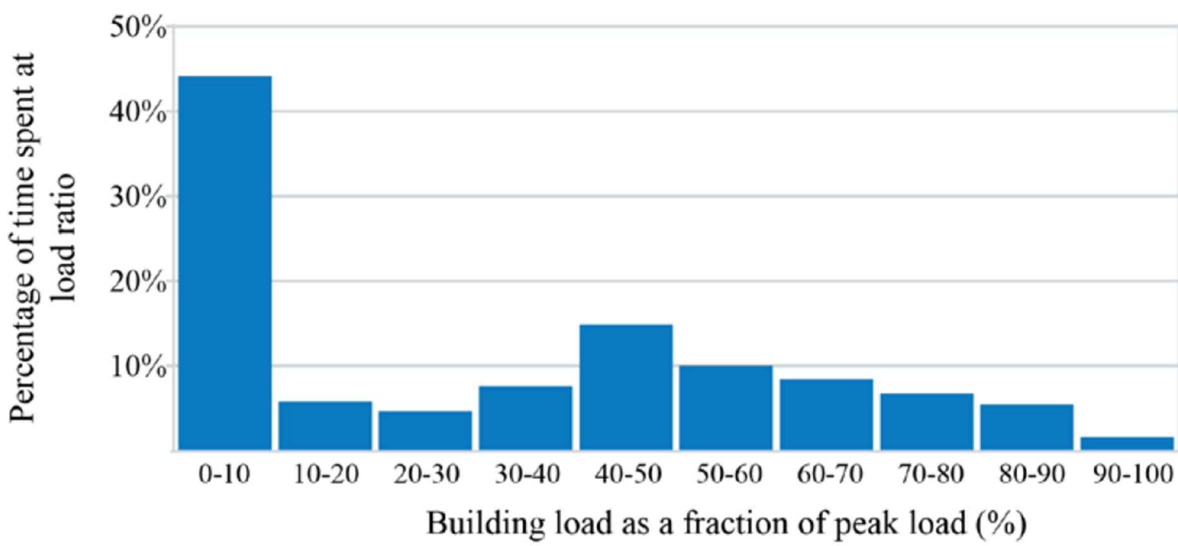

Figure 11: Percent of time buildings operate at partial load. (NREL , 2024)

Generators that operate mostly at part load are significantly less efficient, and part load operation often leads to maintenance and reliability issues for combustion-fired generators. This can also lead to unreliability either at start-up or during operation, a potentially critical problem in an emergency system.

The incorporation of a battery system to support peak loads at start-up can allow for a significant downsizing of the generator, and also allow the generator to run closer to its peak efficiency and performance. In this scenario the battery is used to meet peak loads at startup, or during the few hours when building peak loads occur, and the generator is used to provide enough energy to keep the battery from running out of charge over a 24-hour period. A battery would also prevent a service gap between power failure and generator start-up, and insure against generator starting failures, which is a not uncommon problem for emergency generators.

The combination of generator capacity and runtime scenarios can be optimized based on individual building load characteristics, but some studies suggest that this strategy can lead to reductions in generator capacity of 50% or more, as well as an increase in generator efficiency and reliability, and a reduction in emissions and maintenance.

This strategy might also make a scenario relying on temporary portable generators for emergency use more practical, since the battery system can power the building for short or medium-term emergencies while generators are deployed, and the smaller generator capacity needed represents less expensive and potentially portable infrastructure.

V2G

Another technology that may come into play in Redmond sustainability discussions is two way electric vehicle charging. If Redmond decarbonizes its vehicle fleet, a number of options with respect to electric power will come into play.

Vehicle to Grid, or V2G, is the ability of electric vehicles to feed power back into the grid through specifically designed charging infrastructure. A number of vehicles on the road today have this capability, and significant expansion is anticipated as utilities modernize grid infrastructure. Currently the technology is focused on direct grid integration, but the deployment of a microgrid can allow for more localized building-level support from electric vehicles. For fleet vehicles, this capability could be a significant component of resiliency and emergency operations planning. As an example, if Redmond had a number of electric fleet vehicles housed at the Public Safety Building or the new Municipal Operations Center, these vehicles could be available to buildings as a back-up for building emergency operation, either at their home base or at other buildings in the portfolio. For the buildings in this analysis that have seasonal gaps in resiliency planning (i.e. winter solar generation doesn't meet 24 hour building loads), portable storage in the form of electric vehicles could help fill the gap.

For perspective, currently available Ford Lightning vehicles have battery capacities up to about 230 kWh. This represents about eight hours of operation at Fire Station17. If the city had a central vehicle charging infrastructure for emergencies, electric vehicles with V2G capabilities could be located at or shuttled to specific buildings in an emergency to augment on-site solar storage capacity, as an alternative to generators.

Vehicles are also a critical part of city emergency operation so the provision of emergency vehicle charging capabilities at sites with substantial PV array potential, such as the Public Safety Building, could add a substantial element to city resiliency planning. A PV array at FS17 could also support charging for electric fire trucks, adding some resiliency to this aspect of the city's emergency response capabilities.

Load Shape/Demand Response

Although resiliency is a priority in this analysis, storage systems are more often deployed to mitigate high utility bills. Utility supply constraints around the country result in significant demand charges in many areas, where electricity is priced not only based on total consumption, but also based on peak 15 minute load during the billing period. In some regions demand charges represent more than half of a typical utility bill. Battery systems can be used to smooth out building loads and reduce demand charges. (Similar to the function anticipated in the generator capacity discussion above.)

Some utilities have also adopted time of use pricing models, where electricity becomes significantly more expensive at certain times of day when utility supplies are constrained, and cheaper when power is plentiful.

The PNW has not been subject to significant demand charges or time of use pricing in the past, but regional efforts to shift away from fossil fuels in the generating system are introducing new time and capacity constraints on the utility system based on the availability of wind and solar generating resources. This has resulted in the local adoption of pilot time of use pricing models for many utilities, including PSE which serves Redmond. A battery system would enable Redmond buildings to take advantage of time of use utility pricing by deploying battery storage to reduce building consumption in high peak energy price time periods, and recharge the battery when prices are lower. It would also help insulate the city from anticipated increases in utility demand pricing structures.

An additional advantage of coupling battery storage with solar energy generation is to maximize the value of the PV system. Many utilities limit the amount of surplus power they will accept (or pay for) from building mounted PV arrays. By installing a storage system, the building increases the amount of solar power it can use onsite, without needing to sell power at a discount or shut off surplus daily power from the PV system.

Summary of Building Strategies

Opportunities in Evaluated Buildings

Based on the narrative and evaluation above, the viability of opportunities for different types of solar/storage integration with each building is shown in Figure 12 and discussed for each building below.

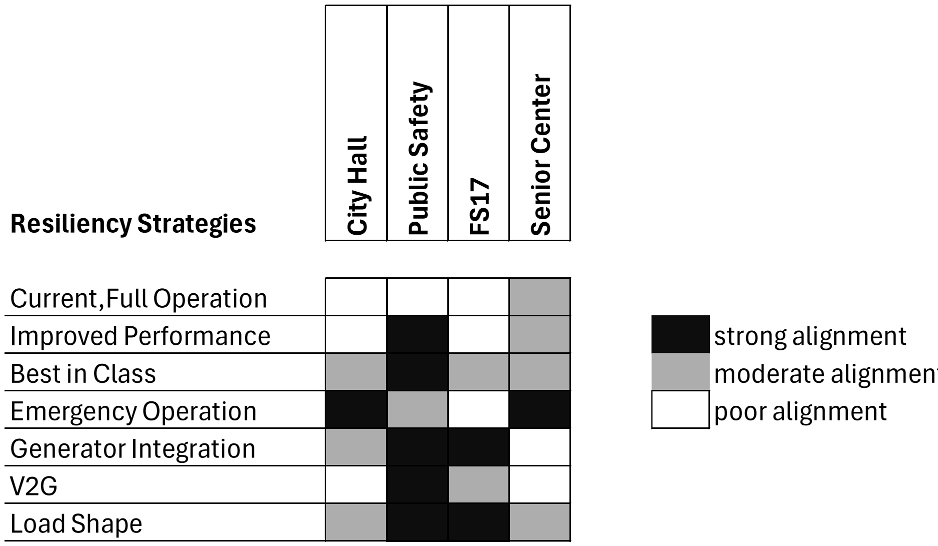

Figure 12: Opportunities by building

City Hall

Though improved building performance makes solar/storage more viable in all cases, the building loads at City Hall do not align well with any whole building operating scenario for the solar/storage system. However, if the building were configured to support the use of an emergency operations center independently of other building elements, a solar/storage system could provide a strong resiliency strategy to meet these loads. The building could also benefit from load shape management and generator integration with a solar/storage system.

Recommendations: Develop a more concise emergency operations plan to zero in on power needs necessary to support this function. Review electrical system in detail to determine viability of subsystem operation or needed upgrades. Consider battery/generator integration to improve generator performance and dependability, and identify options to reduce generator capacity.

Public Safety Building

The potential deployment of a large solar array on the roof of PSB and the adjacent parking garage leads to substantial solar capacity to support PSB operations. However, the high consumption level of the current building exceeds what a solar system could provide. PSB will be subject to improved performance requirements of the CBPS, and the more efficient this building becomes, the more opportunities there are to support resilient operation with a solar/storage system. There are also opportunities to improve emergency operation on generator power and manage load shape fluctuations with this system. The adjacency of the parking garage also provides substantial opportunities for the integration of V2G charging capabilities to serve an integrated strategy for emergency fleet operation and full building emergency power.

Recommendations: Improve building performance to CBPS requirements or beyond to improve resiliency options with solar/storage. Incorporate adjacent parking garage to expand PV capacity and include V2G charging capabilities in garage. Consider generator optimization with integrated battery, which could lead to a single, downsized generator. Significant review of complicated existing electrical system is needed to evaluate any options.

Fire Station 17

The energy loads of FS17 are well above what could be met by a solar/storage system, though if this building were performing at best in class many more opportunities would exist. Partial operation of this building was not considered as an emergency scenario in this analysis. A solar/storage system could support more reliable generator operation and a smaller generator at this site and could also help mitigate the significant load fluctuation apparent in the load shape of this building. A solar system could also be integrated with vehicle charging to make the recharging of fire engines or other fleet vehicles more dependable in an emergency.

Recommendations: Utilize solar/storage system to support electric vehicle charging and to optimize generator performance and capacity. Reduction in total building loads would generate more resiliency options.

Redmond Senior and Community Center

The RSCC is highly efficient, so there are more opportunities for emergency operation based on a solar/storage system at this building. Although the RSCC is not considered an emergency facility, the types of spaces and services that this building could provide might be a good city resource for some types of emergencies. The kitchen, shower/restroom, and gymnasium spaces could combine to provide emergency meals and housing for emergency staff or at-risk community members that could be fully powered by a solar/storage system in emergencies. The small gap in seasonal resiliency capabilities could be overcome with a small portable generator or a temporary V2G connection. The usefulness of these capabilities might be somewhat mitigated by flooding risk at the site.

Recommendations: Evaluate whether potential emergency uses described in this analysis are worth pursuing. Determine whether existing system configuration (electrical/mechanical) support this type of operation, or what modifications would be necessary for partial building operation. Consider V2G input capabilities (or portable generator) to expand seasonal resiliency capabilities.

Considering Solar/Storage Integration in New Buildings

Although specific parameters for new buildings were not evaluated in this report, conclusions can be drawn about how this evaluation can inform opportunities to optimize the incorporation of solar/storage systems in new buildings by addressing issues in the design phase.

Design new buildings as all-electric. In addition to mitigating emissions impacts, all electric buildings can be designed for full resiliency using on-site generation and storage systems as discussed in this report.

Target best in class performance for new buildings. For three of the four buildings evaluated in this report, overall building energy loads were excessive compared to what the solar system could produce. (The fourth building was already performing at best in class levels). Buildings performing at best in class levels are often referred to as 'net zero ready' meaning there is direct alignment between what an on-site solar system can generate annually and the annual energy consumption of the building. With this alignment, the addition of battery capacity to the solar system can provide the opportunity for a range of resilient operating scenarios, potentially including full building operation.

Identify emergency operating scenarios in the design process and provide electrical circuiting and controls to allow for this type of operation. It is costly and complicated to reconfigure building electrical systems to allow for partial building operation if this was not considered during the building design phase and incorporated into construction.

Include solar/storage features in the design. This includes a PV layout plan integrated with mechanical and access requirements on the roof, provision of electrical routing from the roof, microgrid capabilities to support off-grid operation, and the provision of a battery and control room.

Use solar/storage capabilities to offset generator capacity. If a generator is to be deployed at the site, develop an integration plan to minimize generator capacity by utilizing battery storage as a peak load strategy. This will reduce generator size and cost, improve generator reliability and efficiency, and reduce emissions associated with generator operation. Generator solutions can also consider planning for mobile modular generators.

Include two-way vehicle to grid charging capabilities. This allows the building to not only provide emergency vehicle charging/operation, but also to leverage vehicle storage capacity to support building load management and emergency operation.

Summary and Recommendations

The purpose of this analysis is to provide a high level overview of the potential for deployment of solar/storage systems in four Redmond municipal buildings. This analysis has focused on the potential alignment of daily building loads under various scenarios with the daily generating potential of on-site PV systems integrated with battery storage. This analysis has identified alignment between certain types of building loads and solar/storage capacities that can help prioritize a more detailed evaluation of solar/storage deployment strategies in these buildings. This section identifies opportunities and limitations of this analysis and provides recommendations on how to use the findings of this report to identify next steps in this process.

Issues outside the scope of this analysis

This assessment provides a preliminary evaluation of the potential alignment of solar/storage deployment in key Redmond municipal buildings, as a starting point to identify the general feasibility of these strategies, and to prioritize applications with more potential for further evaluation. Several aspects of the implementation of solar+ storage were outside the scope of this evaluation and will require additional evaluation to further clarify the feasibility of these strategies. These issues include the following:

Specific emergency management parameters

In this evaluation the project team made some assumptions about how individual buildings might be used in an emergency situation. For some buildings it was assumed that the entire building would need to remain operational in an emergency. For others, the team speculated on potential emergency operation scenarios and estimated the portions of the building and services that would need to remain functional in an emergency. The scope of emergency operation is not linked to any specific emergency plan developed by the City of Redmond and may not reflect the City's priorities for use of these buildings. Emergency operating scenarios and loads should be revisited to align with official emergency operations plans when these become available.

Electrical system capabilities for partial operation, including microgrid deployment

Each building in the study was visited to assess electrical system characteristics, and electrical plans for each building were reviewed. However, the team was not able to assess the degree to which these systems might have been designed to support emergency operation of a subset of building loads. This capability would be critical to any strategy that planned to operate only part of the building in an emergency. A more detailed evaluation, potentially with circuit tracing and onsite load measurement would be necessary to verify partial building operational capabilities, or to assess the possibility to modify these systems for this purpose.

Buildings with generator backup were assumed to be designed for full operation on generator power. However, specific basis of design and operating parameters of these systems were not evaluated. Any system designed to operate 'off grid' during an outage by definition has some microgrid capabilities. These systems would need to be further evaluated regarding the possibility of integrating solar/storage systems into the existing system, and to identify additional control and management features that might be necessary to integrate solar/storage systems.

Detailed daily load fluctuation

This report highlights seasonal and daily fluctuations in solar availability but does not go into detail about how to size and manage battery capacity in response to daily fluctuation in solar availability. Neither are strategies to optimize battery capacity and extreme use case discussed. Meeting the most extreme long duration winter overcast conditions with a battery system could require alternate backup strategies, just as the statistical risk of emergency generator failure requires a contingency plan.

Battery sizing and location

Although some approximate battery capacities were discussed in the context of each building evaluation, specific sizing criteria were not developed, and identifying an appropriate space in each building to locate batteries was not undertaken. Battery locations need to account for fire safety considerations with current battery technologies. Forthcoming battery technologies may make this less critical.

Gas integration

Some of the buildings in this analysis include gas heating systems. For winter operation, these systems would need to remain operational to support building habitability in an emergency. This analysis did not evaluate the resiliency or control capabilities of these gas systems to determine how they could be integrated into any emergency operations scenarios.

Cost

Anticipated system costs and benefits were not evaluated in this report to inform prioritization among buildings and resiliency strategies.

Shared Resources

Each building in this analysis was evaluated in isolation, even though three of the buildings are directly adjacent to one another on the City Hall campus. If the buildings included a utility connection to each other, additional opportunities for shared storage capacity and emergency operational integration would be available.

Other Critical Facilities

The scope of the analysis focused on critical city buildings. During the report presentation, internal stakeholders requested a similar analysis of city-managed traffic signals, water wells, and sewer lift stations. These are essential facilities that are either inoperable or rely on generators during power outages and may be ideal candidates for solar plus storage.

Recommended Next Steps

Each of the buildings evaluated in this report demonstrates opportunities for the deployment of a solar/storage system to provide some level of resiliency benefit, though at significantly different scales.

The first priority recommended by this evaluation is to more carefully define what emergency operations are desired for each of the facilities in this study. Based on some broad assumptions, it is clear that there is an opportunity for solar/storage systems to contribute to resiliency and emergency operations at several facilities, but a more detailed assessment of what constitutes emergency operation will be necessary to move forward with an effective design of a solar/storage system for resiliency.

The second most compelling recommendation is to consider how emergency operations would be incorporated into the new municipal operations center currently in design, or other upcoming projects. This represents an opportunity to consider this at the front end of a project, and the building typology lends itself to significant resiliency features for the City of Redmond's vehicle fleet. As discussed in the narrative above, electric vehicles with V2G capabilities can also serve as back up storage systems for emergency loads at other buildings, with the right infrastructure.

Finally, based on stakeholder feedback, a similar analysis may be beneficial for other critical city infrastructure (city-managed traffic signals, water wells, and sewer lift stations).

With respect to the specific buildings evaluated in this report, the following recommendations are provided in order of recommended priority for consideration.

The most significant opportunity seems to be at the Public Safety Building, due to the adjacent parking garage which could provide significant additional PV array capacity to the building. Taken together PV arrays on these two structures would produce significant amounts of power to offset building loads. Since an imminent upgrade is planned at the building to meet CBPS requirements, this might be a good time to think about incorporating solar/storage resiliency features associated with lowered energy use at the facility. In conjunction with that analysis, the City should consider how a battery system could integrate with an optimized back-up generator to improve reliability and reduce costs of the generator system.

The potential solar array capacity at City Hall is not adequate to fully operate the building in an emergency, but it is conceivable that such a system could provide power for the part of the building housing the emergency operations center. This would be a much smaller system than the one described above for PSB, so it might be a more manageable project. However, work would be needed to more specifically define EOC loads, and to determine if these loads can in fact be separated from the main building with the current electrical system. Also, this building has a backup generator of its own, and any solar power system would need to be integrated with that system. This would require additional engineering and evaluation work.

Although the Senior Center does not perform a critical function in city operations, the facility characteristics lend themselves to several options to support emergency situations. In particular the facility could be used as a community resource for emergency evacuation housing, or emergency meal preparation in some types of emergencies. The low energy use and all-electric fuel use at this building make solar/storage integration more feasible, especially if the city were able to operate a subset of the building in an emergency.

Fire Station 17 is the most limited opportunity for solar storage integration for resiliency, because of the mis-match between solar capacity and total building loads. Since there is not a partial operation plan for emergency use of this facility, solar deployment could primarily serve for vehicle charging and generator optimization as discussed in this report.

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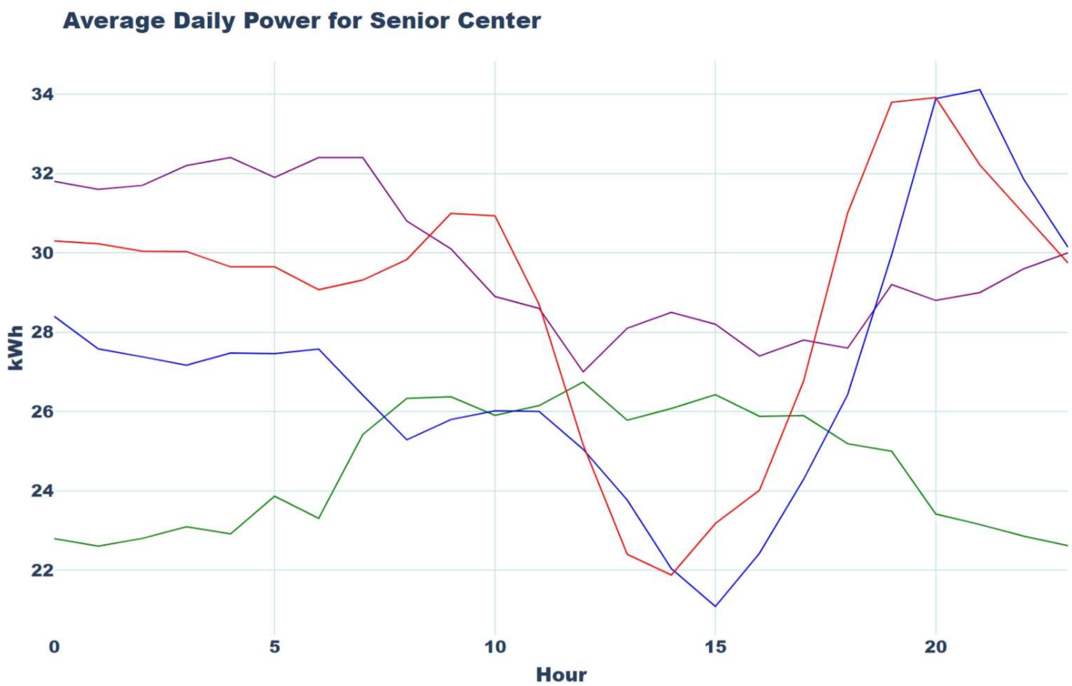
Appendices

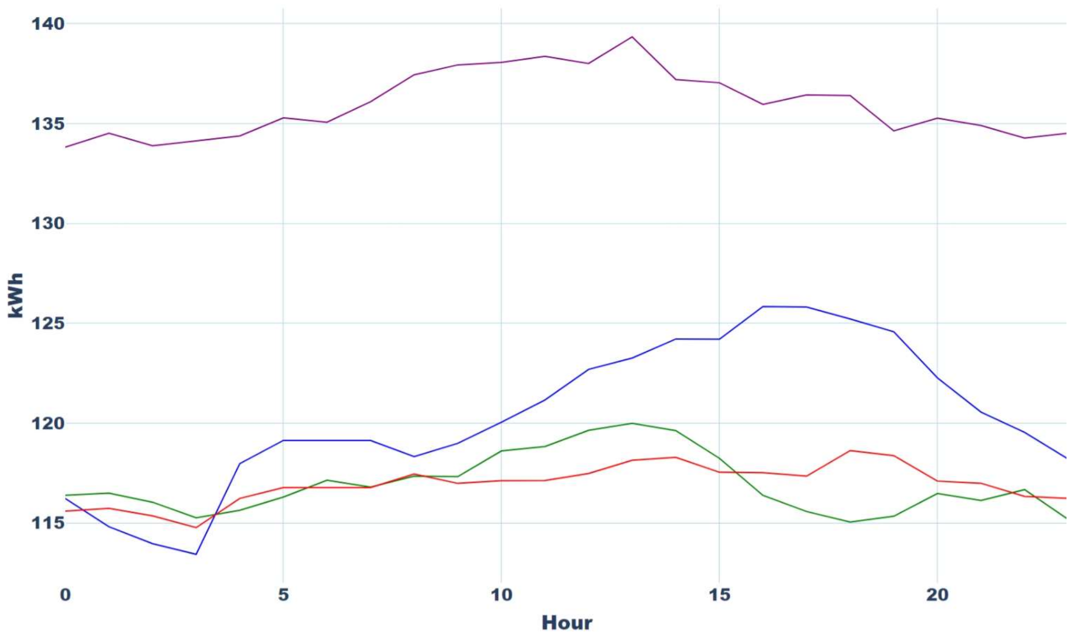
Appendix A: Building Daily Load Shapes by Season

Legend:

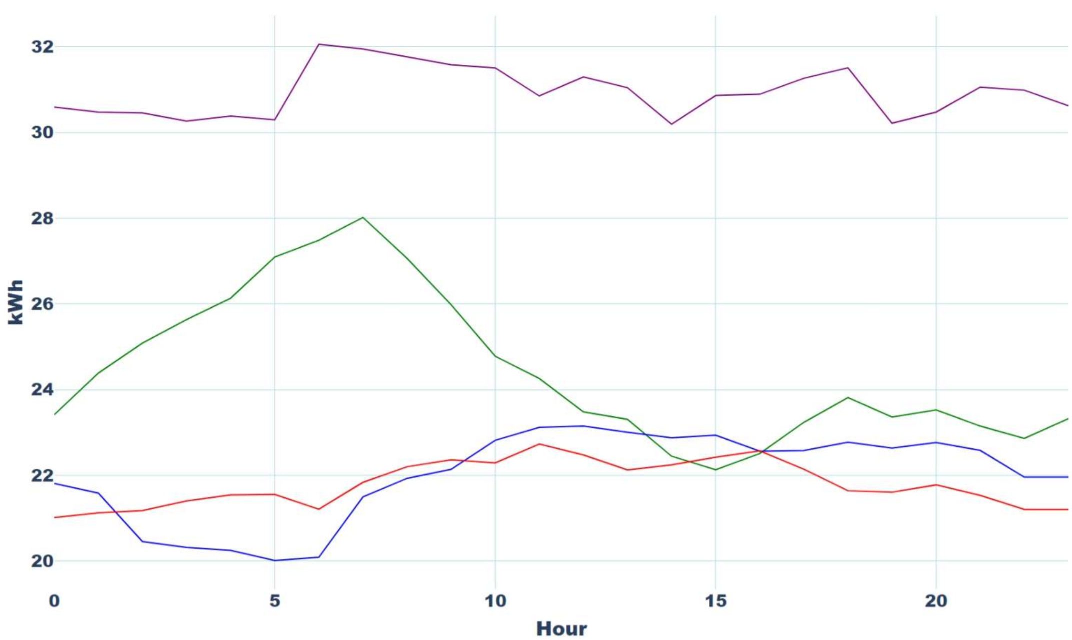
January Building Load
April Building Load
July Building Load
October Building Load

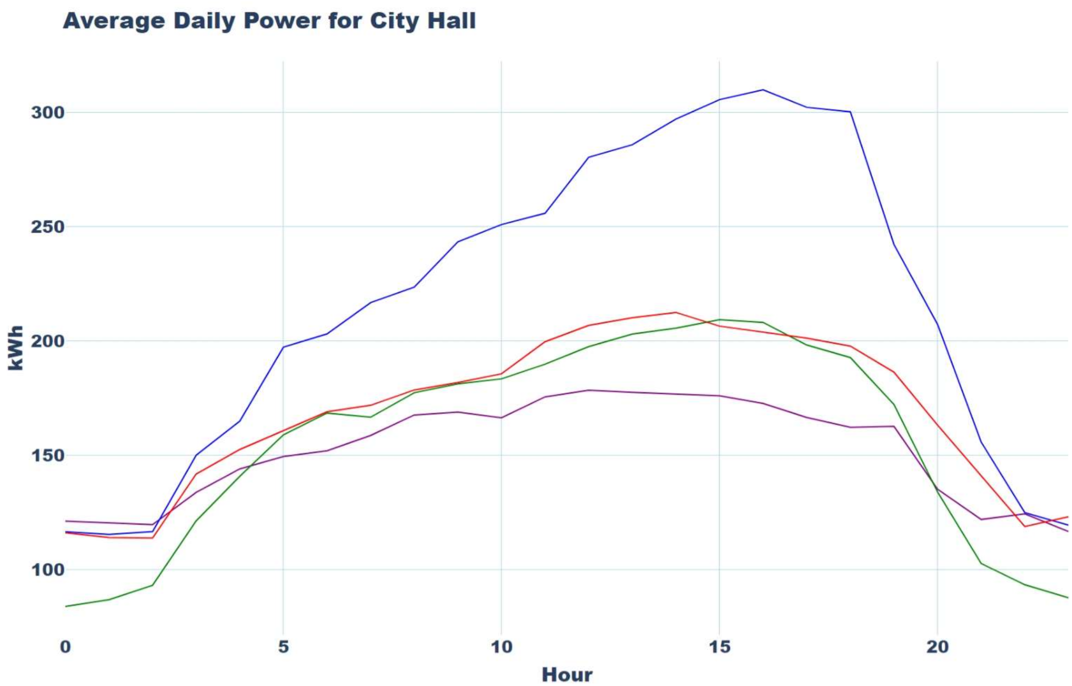


Average Daily Power for Public Safety Building



Average Daily Power for Fire Station 17




Average Daily Power for City Hall
kWh
300
250
200
150
100
0
5
10
15
20
Hour

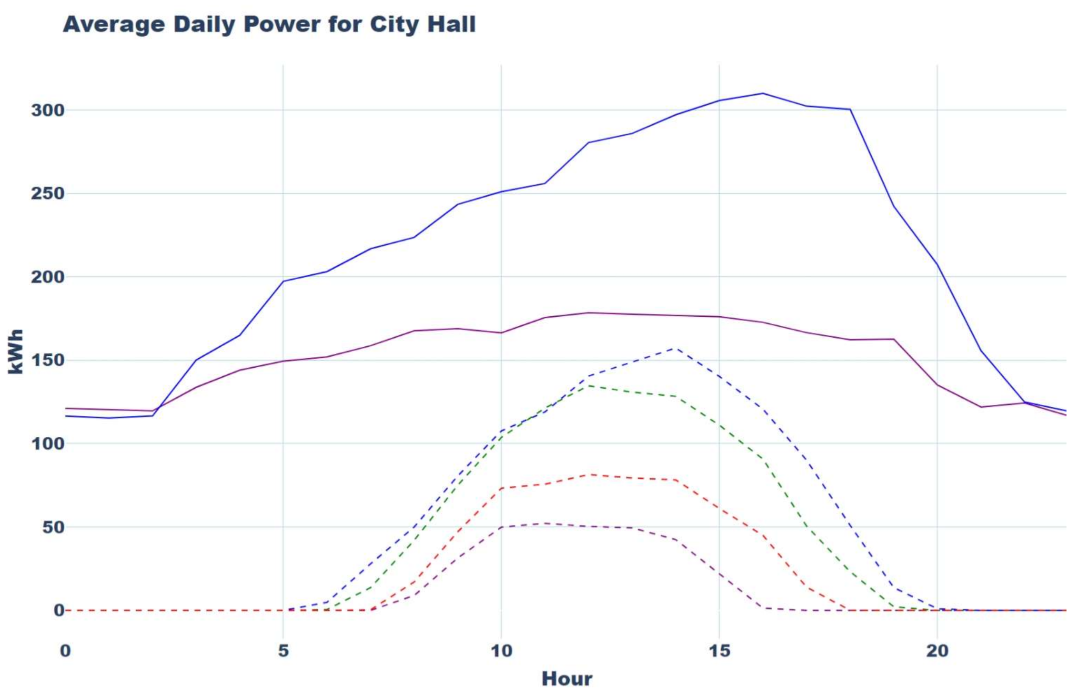
Appendix B: Solar Generation Daily Load Shapes by Season

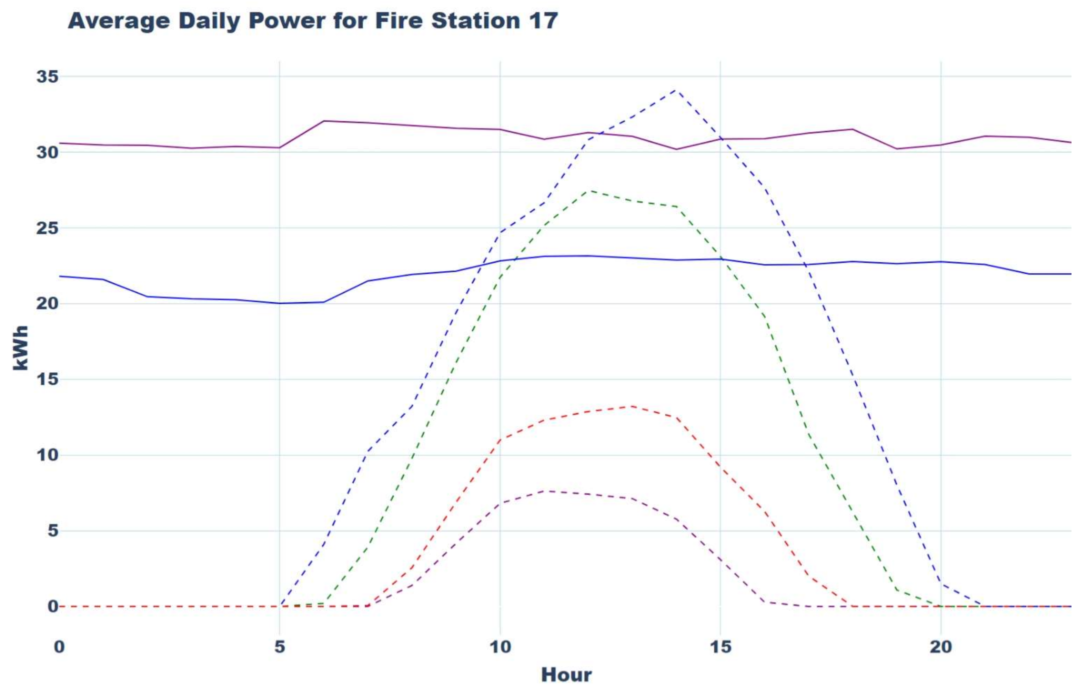
These graphs show the seasonal PV generation for each building, compared to summer and winter building loads.

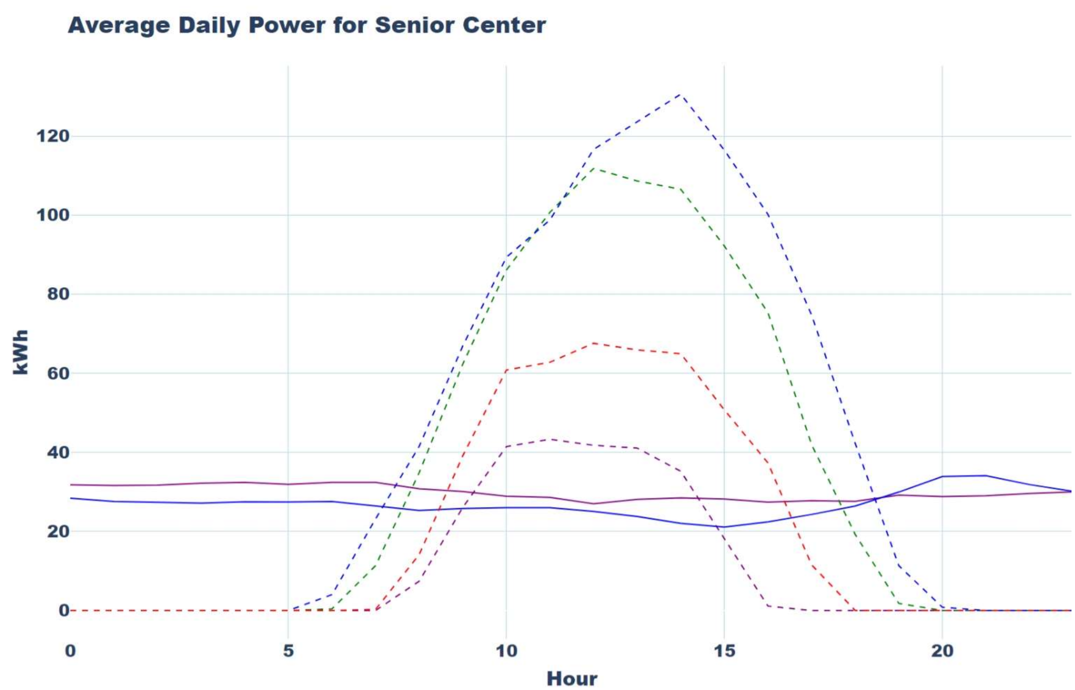
Legend for all graphs:

- - - - - **January PV Generation**
- - - - - **April PV Generation**
- - - - - **July PV Generation**
- - - - - **October PV Generation**

——— **January Building Load**
——— **July Building Load**




Average Daily Power for Fire Station 17
kWh
Hour
0
5
10
15
20
25
30
35

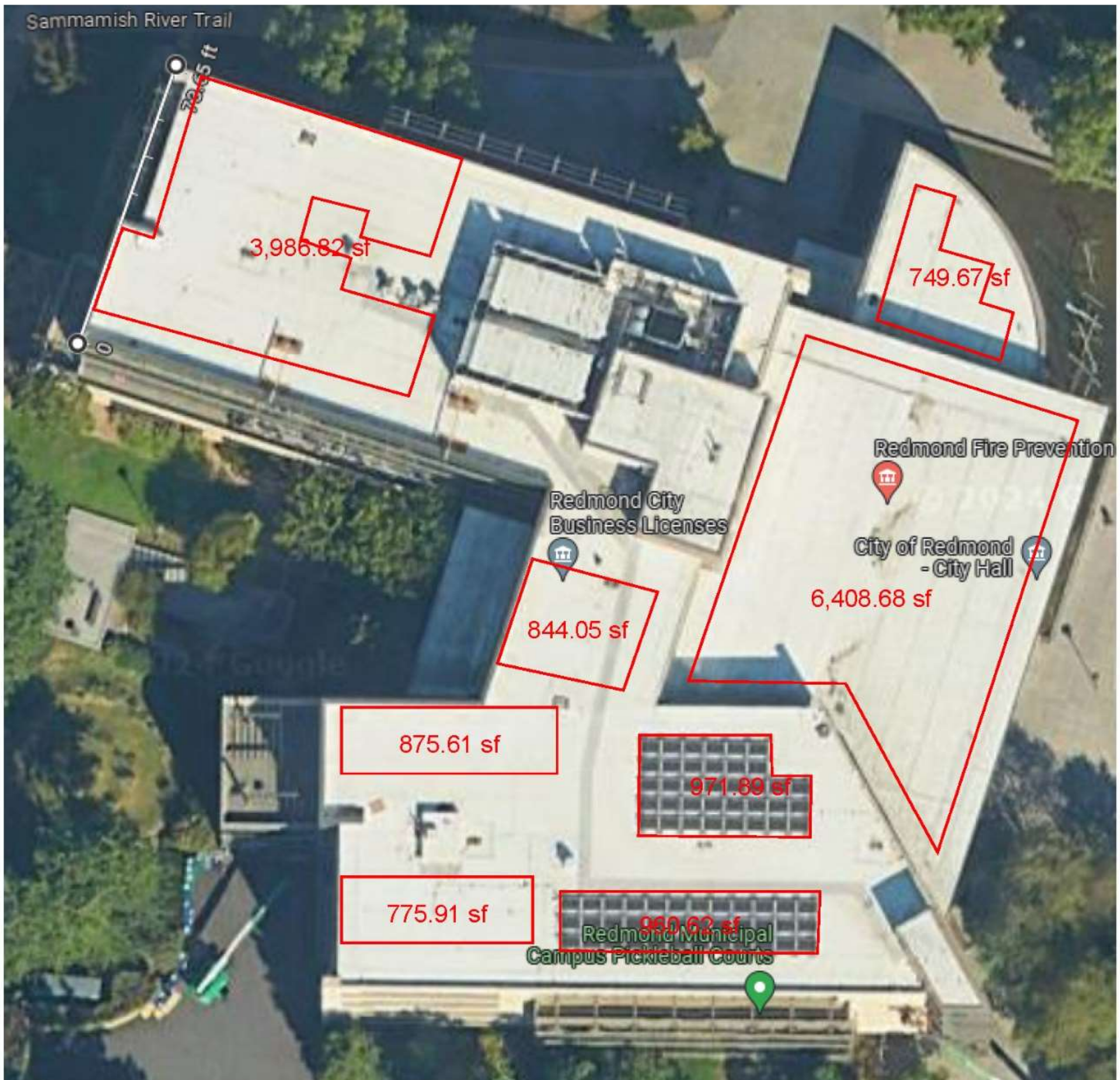

Average Daily Power for Senior Center
kWh
Hour
0
5
10
15
20
40
60
80
100
120

(Includes City Hall Garage roof area)

Appendix C: Assumed Solar Roof Areas by Building

CITY OF REDMOND - SOLAR STUDY

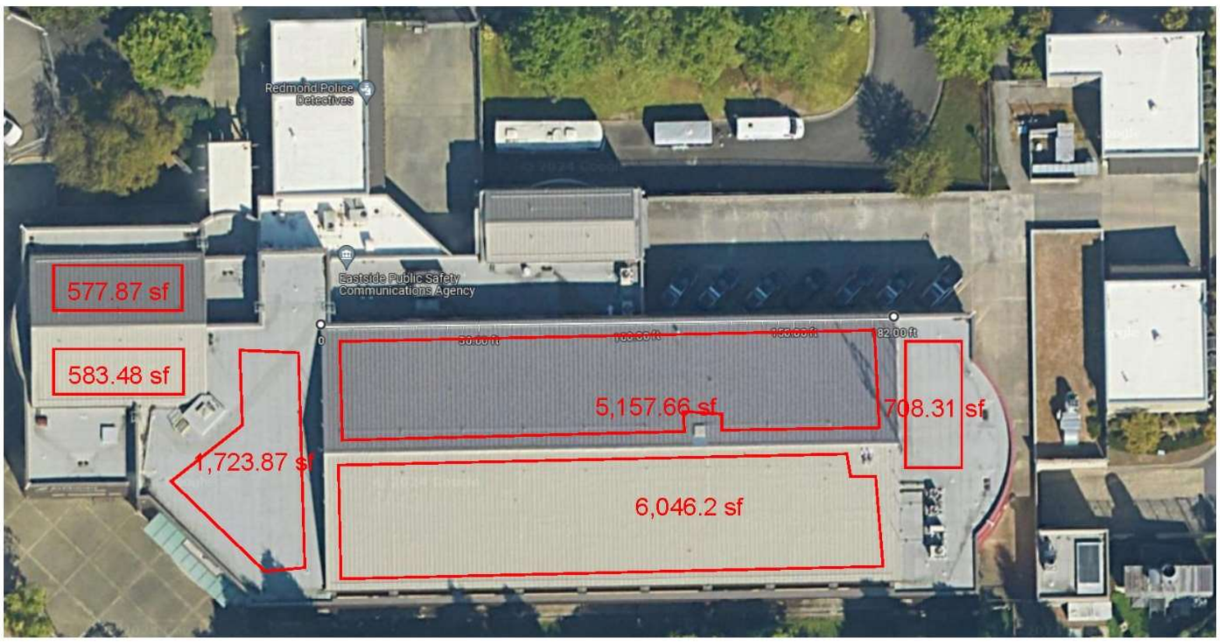
CITY HALL



FIRE STATION 17

REDMOND CITY HALL GARAGE

REDMOND PUBLIC SAFETY BUIDLING



REDMOND SENIOR & COMMUNITY CENTER