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Economics of Solar with Storage for Municipal Sites in the City of San Diego

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- This analysis relies on site information provided to NREL by the San Diego SEIN team that has not been independently validated by NREL.

- The analysis results are not intended to be the sole basis of investment, policy, or regulatory decisions.

- This analysis was conducted using the NREL REopt Model (http://www.reopt.nrel.gov). REopt is a techno-economic decision support model that identifies the cost-optimal set of energy technologies and dispatch strategy to meet site energy requirements at minimum lifecycle cost, based on physical characteristics of the site and assumptions about energy technology costs and electricity and fuel prices.

- The data, results, conclusions, and interpretations presented in this document have not been reviewed by technical experts outside NREL *or* the City of San Diego.

- This analysis was an initial screening and was conducted for limited use to inform further analyses.

Background

- This analysis was conducted under the first round of the Solar Energy Innovation Network (SEIN); a program led by the National Renewable Energy Laboratory (NREL). The program assembles diverse teams of stakeholders to research solutions to real-world challenges associated with solar energy adoption.
- This analysis supported the efforts of the San Diego SEIN team, which consists of the City of San Diego and the Clean Coalition.
- The City of San Diego aims to deploy solar and storage to support energy resiliency, environmental quality, and affordability of the electricity supply. The team has estimated the total potential for solar deployment across the city, designed a program proposal for utilizing the total solar potential, completed detailed economic analysis of solar options on municipal facilities, conducted stakeholder workshops to explore solar compensation options, and is exploring opportunities for solar-plus-storage to improve resiliency at critical facilities.
- This analysis supports the team's work by analyzing the techno-economic potential of solar photovoltaics (PV) and lithium-ion battery energy storage at municipal sites in the City of San Diego.

Solar Energy Innovation Network: https://www.nrel.gov/solar/solar-energy-innovation-network.html
Orlando: Renewable and Resilient: https://www.nrel.gov/solar/solar-energy-innovation-network-round-1.html#paneld10e186_1

Analysis Overview

- As part of the Solar Energy Innovation Network, NREL is using a tool called REopt to evaluate the techno-economic potential of PV and storage at 10 municipal sites in the City of San Diego. In two cases, the loads from two buildings were combined into one site.

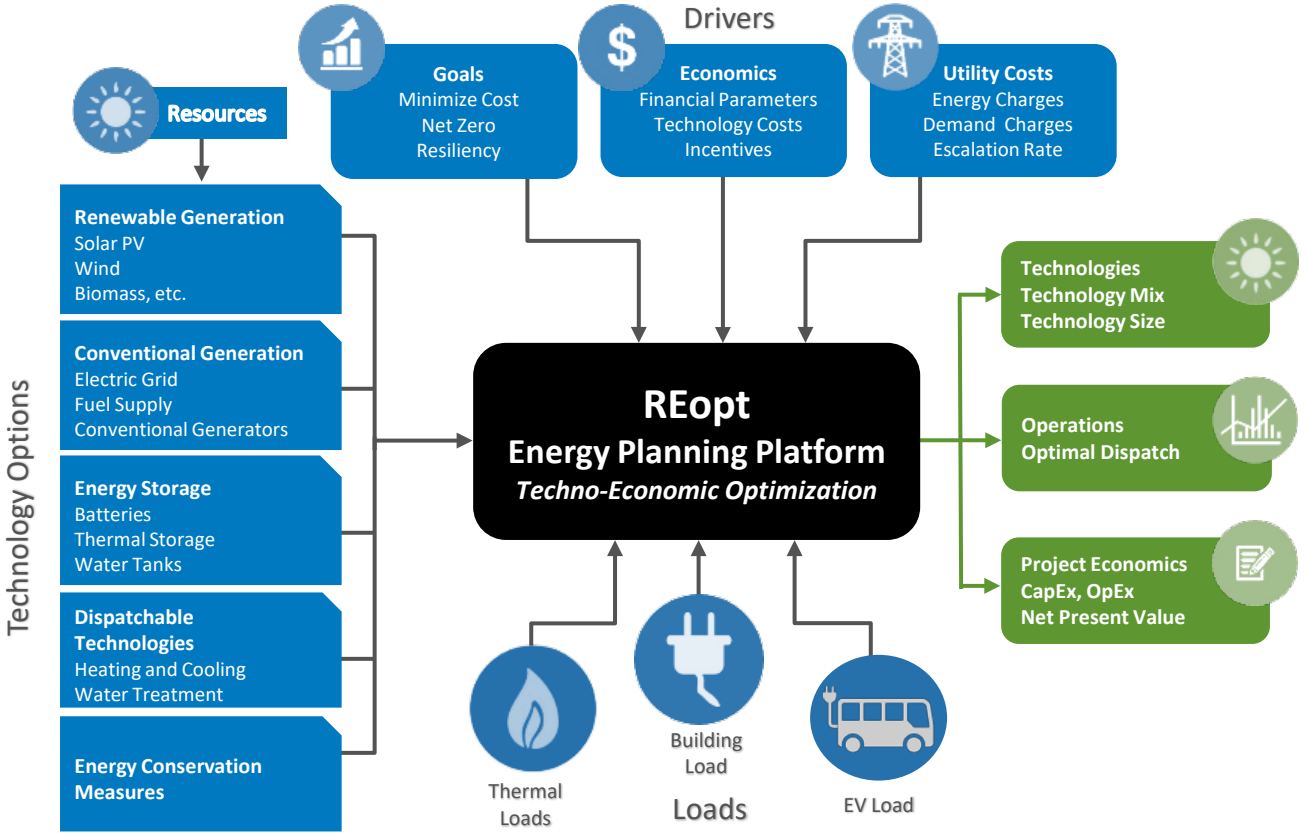
- This analysis considered the 15-minute electric load and complex utility rate structure of each site to recommend the size of PV and storage to minimize the cost of utility electric purchases to the site.

- This screening should be treated as an initial step to prioritize and focus additional, in-depth analysis of potential renewable energy projects.

REopt Model Overview

Formulated as a mixed-integer linear program, the REopt model optimizes the integration and operation of behind-the-meter energy assets.

REopt solves a deterministic optimization problem to determine the optimal selection, sizing, and dispatch strategy of technologies chosen from a candidate pool such that loads are met at every time step at the minimum lifecycle cost.



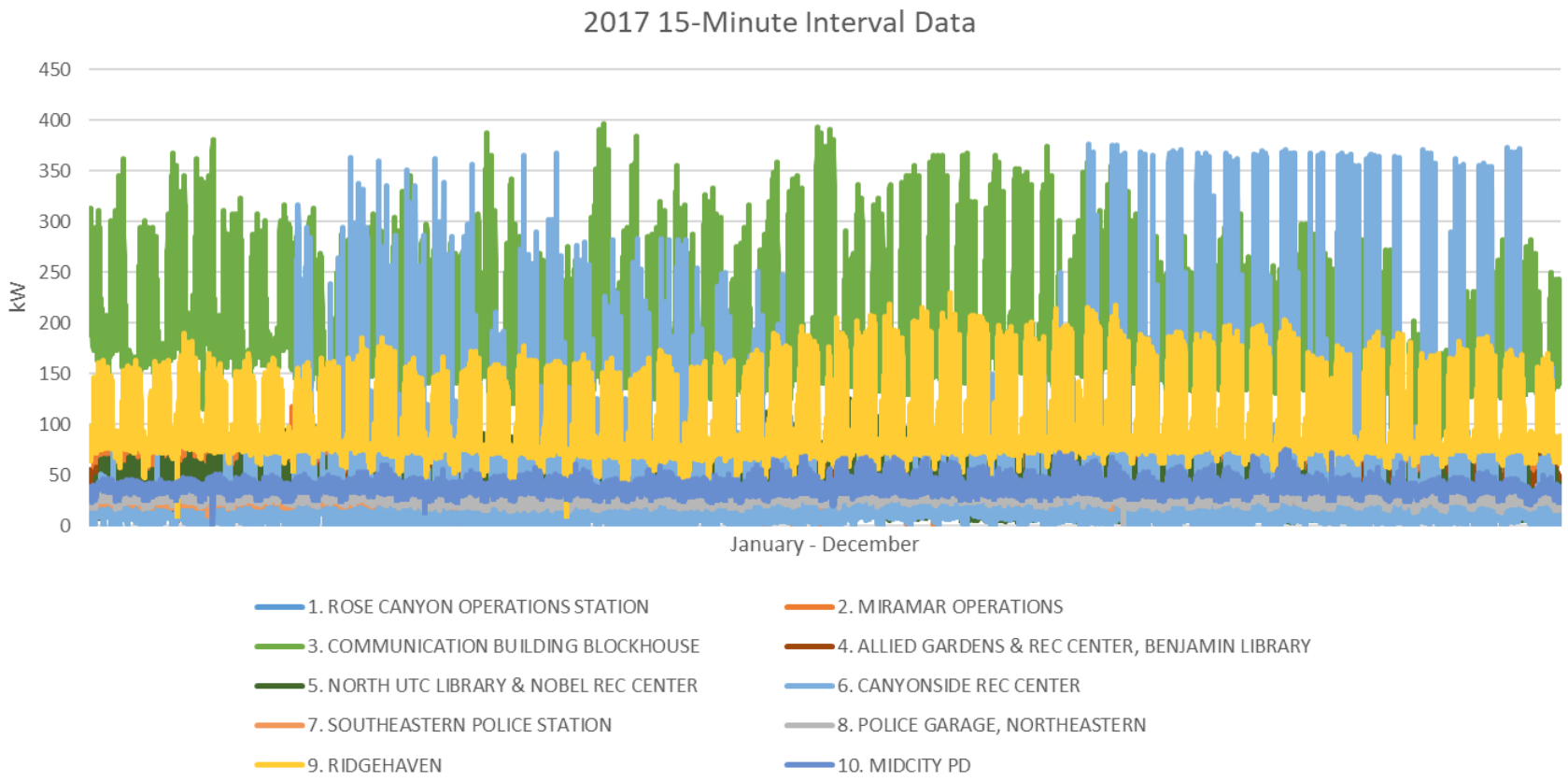
Overview of inputs and outputs of the REopt model

Sites Evaluated

	Facility Name	Address	SDGE Meter Number	SDGE Account Number	Total (kWh)	Average (kW)	Max (kW)
1	ROSE CANYON OPERATIONS STATION	3775 Morena Blvd	06696354	3980273955	358,004	41	106
2	MIRAMAR OPERATIONS	8323 Miramar Place	06693419	2511252914	488,552	56	147
3	COMMUNICATION BUILDING BLOCKHOUSE	5851 College Grove Dr	6692601	9177487052	1,604,535	183	397
4	ALLIED GARDENS POOL[1]	6707 Glenroy St	06580449	3191355640	212,037	183	60
	ALLIED GARDENS RECREATION CENTER[1]	5515 Greenbrier Ave	06561216	8816317421	102,467	12	31
	BENJAMIN LIBRARY[1]	5188 Zion Ave	06575657	7691323302	69,734	8	34
5	NORTH UTC LIBRARY [2]	8820 Judicial Dr	06686329	6171197618	169,948	19	92
	NOBEL RECREATION CENTER[2]	8810 Judicial Dr	06686327	3689127412	178,502	20	89
6	CANYONSIDE RECREATION CENTER	12350 Black Mountain Rd	06704875	8096743607	237,030	27	376
7	SOUTHEASTERN POLICE STATION	7222 Skyline Dr	06695239	2474198502	246,768	28	56
8	POLICE GARAGE, NORTHEASTERN	13396 Salmon River Rd	06691354	3635169400	247,746	28	52
9	RIDGEHAVEN COURT	9601 Ridgehaven	6697555	1341941054	934,615	107	10
10	MID CITY POLICE STATION	4310 Landis St	6693524	6878295700	341,402	39	1

[1]Loads from these buildings are combined
[2]Loads from these buildings are combined

Load Data



Note: 15-minute data was down-sampled to hourly data for analysis.

Estimate of Roof, Land, and Carport Space Available

- For each of the buildings, NREL used Google Earth to obtain an initial estimate of the total roof, land and carport space available for PV deployment (on left and in appendix).
- These estimates were then refined by the City of San Diego to finalize the inputs to REopt.

ROSE CANYON OPERATIONS STATION (Estimate based on Google Earth)	**Area (ft^2)**
Carport	131,560
Roof Total	35,200
Ground Total	161,550
Site Total	**328,310**

Areas Available for PV (inputs to REopt)

	Facility Name	Carport (ft^2)	Roof (ft^2)	Land (ft^2)	Carport Maximum PV size[1] (kW)	Roof Maximum PV size[1] (kW)	Land Maximum PV size[2] (kW)	Total (kW)
1	ROSE CANYON OPERATIONS STATION	26,700	0	0	267	0	0	267
2	MIRAMAR OPERATIONS	33,800	44,000	0	338	440	0	778
3	COMMUNICATION BUILDING BLOCKHOUSE	0	0	274,200	0	0	1,371	1,371
4	ALLIED GARDENS & REC CENTER, BENJAMIN LIBRARY	28,700	0	0	287	0	0	287
5	NORTH UTC LIBRARY & NOBEL REC CENTER	40,900	0	0	409	0	0	409
6	CANYONSIDE REC CENTER	68,800	0	0	688	0	0	688
7	SOUTHEASTERN POLICE STATION	17,000	0	0	170	0	0	170
8	POLICE GARAGE, NORTHEASTERN	14,600	0	0	146	0	0	146
9	RIDGEHAVEN	15,300	6,300	0	153	63	0	216
10	MIDCITY PD	13,320	0	0	133	0	0	133

Notes:
[1]Assumes use of PV panels with a capacity of 10 watts per square foot
[2]Assumes use of PV panels with a capacity of 5 watts per square foot

Electricity Rate

All buildings are billed under San Diego Gas & Electric Company (SDG&E) Schedule AL-TOU General Service Time Metered, Secondary Voltage, 0-500 kW.

		Summer	Winter	Units	Time
Energy Charges	on peak	$0.139	$0.116	/kWh	4 pm - 9 pm
	off peak	$0.117	$0.104	/kWh	6 am - 4 pm; 9 pm – 12 am
	super off peak	$0.089	$0.090	/kWh	12 am – 6 am
Peak Demand Charges		$27.51	$16.61	/kW	4 pm - 9 pm
Non-Coincident Demand Charges		$21.09		/kW	Based on highest monthly peak

Notes:

- Fixed charge of $139.73/month was not included in analysis because PV and storage will not offset these
- Summer: June-October; Winter: November-May
- Summer Peak Demand Charges include $16.63/kW transmission charge and $10.88/kW commodity charge
- The Non-Coincident Demand Charge is based on the higher of the Maximum Monthly Demand or 50% of the Maximum Annual demand
- http://www2.sdge.com/tariff/com-elec/ALTOUSecondary.pdf ; https://openei.org/apps/USURDB/rate/view/5a4fc8075457a3db26fc3f67#3__Energy

Analysis Assumptions

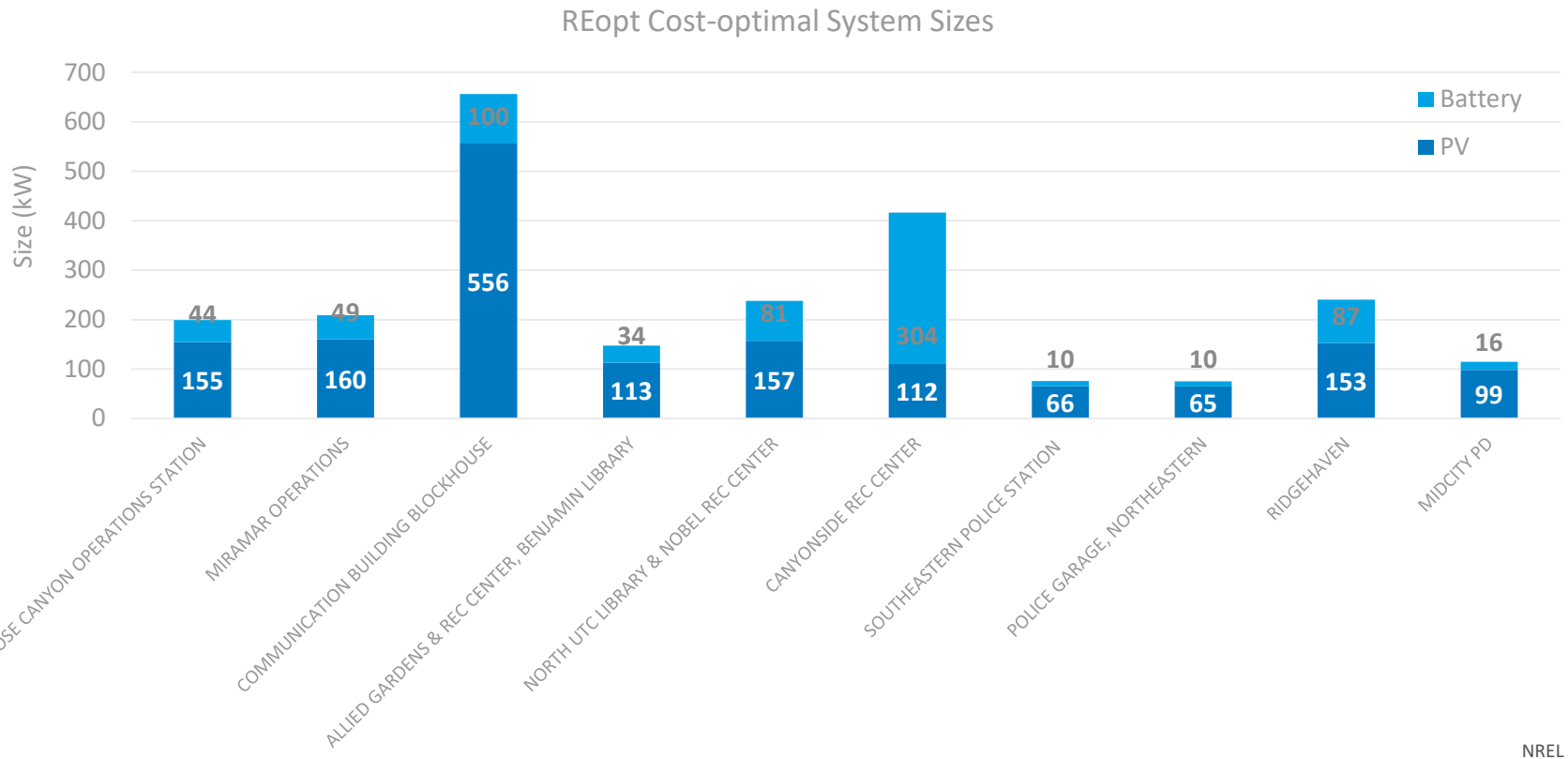
Input	Assumption
Technologies	Solar PV, storage
Objective	Minimize lifecycle cost (cost-effective projects)
Ownership model	3rd party financed
Analysis period	20 years
Discount rate	3% for site/8.1% for developer
Escalation rate	2.60% per EIA utility cost escalation rates
Inflation rate	2% per CBO forecast
Incentives	30% ITC; 5 yr. MACRS for PV. None for battery
Net metering	No Net metering
Electricity sellback rate	$0/kWh
Interconnection limit	None
Technology costs	PV: $2.00/W (commercial size); $15.50/kW/yr. O&M Storage: $500/kWh and $1000/kW; replacement costs in year 10: $230/kWh and $460/kW
Technology resource	TMY3 weather file SAN DIEGO LINDBERGH FIELD, CA
Area for PV	Estimated, see appendix

Results

Base Case Cost of Electricity (calculated by REopt)

	Facility Name	Annual Electricity Use (kWh)	Annual Peak (kW)	Annual Energy Charges ($)	Annual Peak Demand Charges ($)	Annual Non-Coincident Demand Charges ($)	Total Annual Energy Costs ($)	20-Year Cost of Electricity ($)
1	ROSE CANYON OPERATIONS STATION	358,004	100	$37,173	$17,420	$19,753	$76,247	$1,464,260
2	MIRAMAR OPERATIONS	488,552	134	$53,651	$24,992	$28,659	$105,705	$2,029,980
3	COMMUNICATION BUILDING BLOCKHOUSE	1,604,540	390	$171,758	$84,530	$87,229	$341,274	$6,553,880
4	ALLIED GARDENS & REC CENTER, BENJAMIN LIBRARY	384,237	93	$37,581	$18,816	$18,765	$78,673	$1,510,850
5	NORTH UTC LIBRARY & NOBEL REC CENTER	348,450	121	$52,501	$26,221	$26,280	$90,355	$1,735,200
6	CANYONSIDE REC CENTER	237,030	369	$143,121	$71,027	$72,095	$170,213	$3,268,800
7	SOUTHEASTERN POLICE STATION	246,768	52	$20,122	$9,575	$10,547	$46,451	$892,056
8	POLICE GARAGE, NORTHEASTERN	247,746	50	$20,359	$9,596	$10,763	$46,674	$896,331
9	RIDGEHAVEN	934,615	218	$94,629	$46,945	$47,684	$194,510	$3,735,400
10	MIDCITY PD	341,402	72	$29,207	$13,958	$15,249	$65,655	$1,260,850

Cost-Optimal PV and Battery System Sizes
(calculated by REopt)

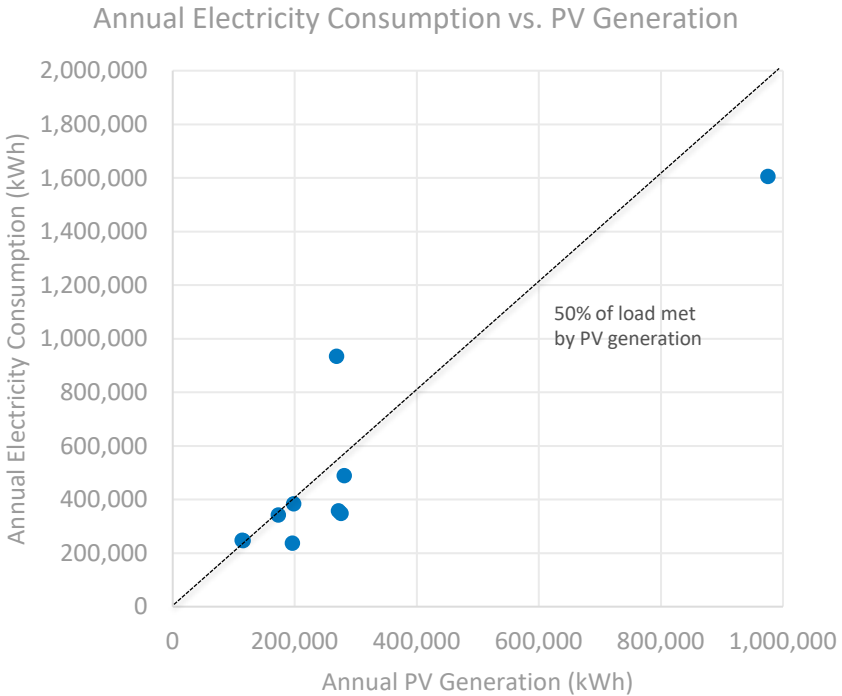


Cost-Optimal System Sizes

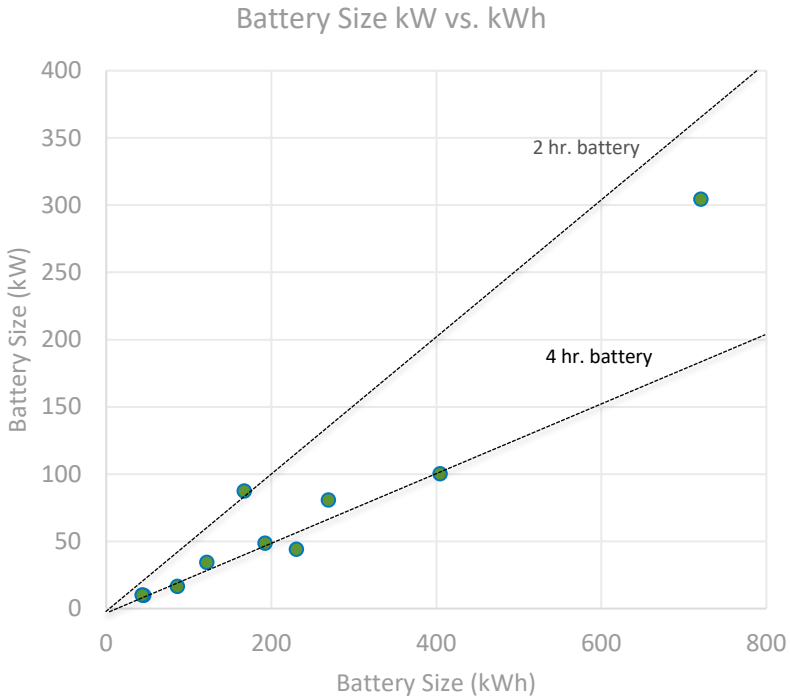
(calculated by REopt)

	Facility Name	PV Size (kW)	Battery Size (kW)	Battery Size (kWh)	Energy Savings ($)	Peak Demand Savings ($)	Coincident Demand Savings ($)	Total Annual Savings ($)	Net Present Value ($)	Savings (%)
1	ROSE CANYON OPERATIONS STATION	155	44	230	$24,849	$10,794	$10,175	$45,818	$319,680	22%
2	MIRAMAR OPERATIONS	160	49	192	$24,698	$15,193	$11,580	$51,471	$445,070	22%
3	COMMUNICATION BUILDING BLOCKHOUSE	556	100	404	$88,275	$45,549	$45,570	$179,394	$1,924,640	29%
4	ALLIED GARDENS & REC CENTER, BENJAMIN LIBRARY	113	34	122	$19,318	$8,021	$6,604	$33,944	$281,200	19%
5	NORTH UTC LIBRARY & NOBEL REC CENTER	157	81	269	$26,246	$18,767	$17,728	$62,741	$537,920	31%
6	CANYONSIDE REC CENTER	112	304	720	$17,936	$58,511	$57,476	$133,923	$1,164,090	36%
7	SOUTHEASTERN POLICE STATION	66	10	45	$11,273	$2,442	$3,079	$16,794	$148,802	17%
8	POLICE GARAGE, NORTHEASTERN	65	10	44	$11,102	$2,415	$3,304	$16,821	$151,693	17%
9	RIDGEHAVEN	153	87	167	$28,919	$26,355	$15,919	$71,192	$788,820	21%
10	MIDCITY PD	99	16	86	$16,647	$4,805	$5,596	$27,048	$239,200	19%

PV Generation and Battery Ratio

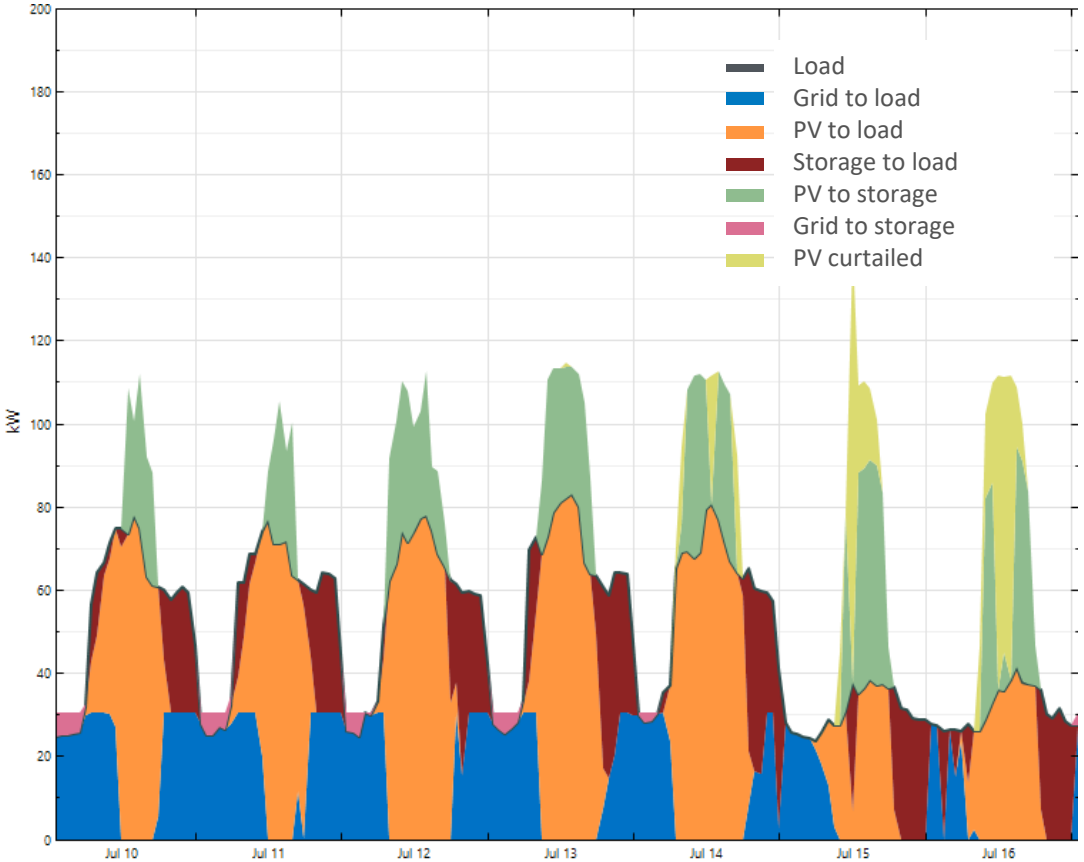


This chart shows the ratio of annual PV generation to annual electricity consumption for the REopt-calculated cost-optimal system sizes at each site. For reference, the dotted line indicates the points at which 50% of the load is served by PV generation. Dots below line indicate >50% of electricity from PV.



This chart shows the ratio of power to energy for the cost-optimal battery sizes, as calculated by REopt. The dotted lines represent the ratio of power to energy for batteries with a maximum discharge of two hours or four hours at rated power. Dots below the line indicate longer than the hour duration.

Rose Canyon Operations Station Dispatch Graph



Note: July 15th and July 16th represent weekend days.

This chart shows modeled dispatch of a combined PV and storage system at the Rose Canyon Operations Station for a representative week in July. The solar PV is meeting the load during the day, and excess generation is used to charge the battery. The battery is being dispatched in the late afternoon when the load is still high, but the solar generation is decreasing. Some PV generation is curtailed during the weekends

Rose Canyon Operations Station Sensitivity Analysis

	0. Base Case	1. PV + Storage	2. PV Only	3. Storage Only	4. City Owned	5. ITC for Battery
PV Size (kW)	-	155	96	-	144	208
Battery Size (kW)	-	44	-	12	48	66
Battery Size (kWh)	-	230	-	47	255	428
Energy Cost ($)	$750,375	$273,167	$465,755	$744,713	$283,623	$147,278
Peak Demand Charges ($)	$334,544	$127,260	$329,676	$285,014	$110,217	$51,019
Non-Coincident Demand Charges ($)	$379,342	$183,935	$331,306	$336,737	$187,272	$153,148
Lifecycle Cost of Electricity ($)	$1,464,260	$1,144,580	$1,294,120	$1,430,340	$1,142,850	$1,003,270
Net Present Value ($)	**$0**	**$319,680**	**$170,140**	**$33,920**	**$321,410**	**$460,990**

This table shows sensitivity analyses for Rose Canyon Operations Station. Each net present value is relative to the base case.

Summary of Results

- PV and storage were assessed to be cost-effective at all buildings evaluated. While PV and storage are both cost-effective on their own, when implemented together, they provide more value.
- The cost-optimal system sizes could save a total of $6 million in aggregate over the 20-year analysis period (26% reduction in electricity costs) for the 10 buildings.
- System sizes and ratios vary based on the load magnitude and shape at each building. The cost-optimal 1.6 MW of PV would generate 2,870,865 kWh annually, contributing 55% of the buildings' electricity consumption.
- All cost-optimal PV system sizes are smaller than the maximum system size that could fit on the ground, roof, and carport areas identified as suitable for PV.

Questions:

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Estimate of Space for PV

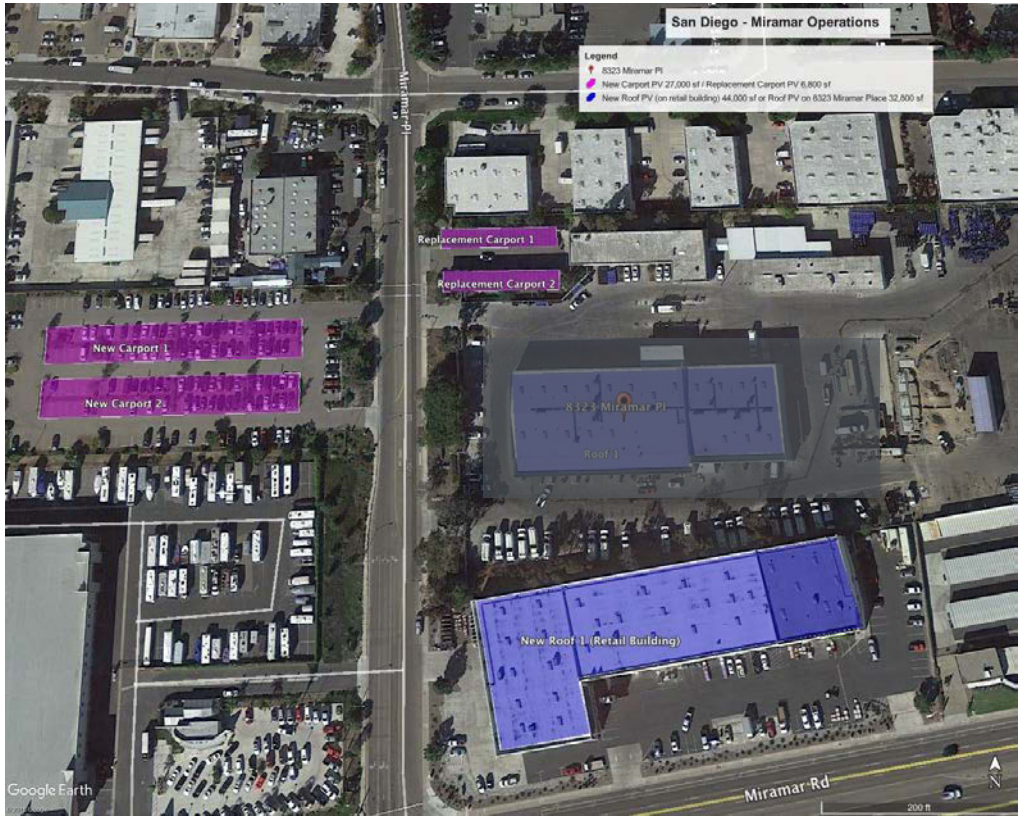
1. ROSE CANYON OPERATIONS STATION

ROSE CANYON OPERATIONS STATION	Sq. ft.
Carport 1	9,900
Carport 2	9,500
Carport 3	7,300
Total	26,700

2. MIRAMAR OPERATIONS

MIRAMAR OPERATIONS	Sq. ft.
Carport 1 - New	13,500
Carport 2 - New	13,500
Carport 3 - Replacement	3,400
Carport 4 - Replacement	3,400
Total	33,800
New Roof (Retail Building)	44,000
Roof 1	32,800
Total	44,000

Note: Roof 1 not included



3. COMMUNICATION BUILDING BLOCKHOUSE

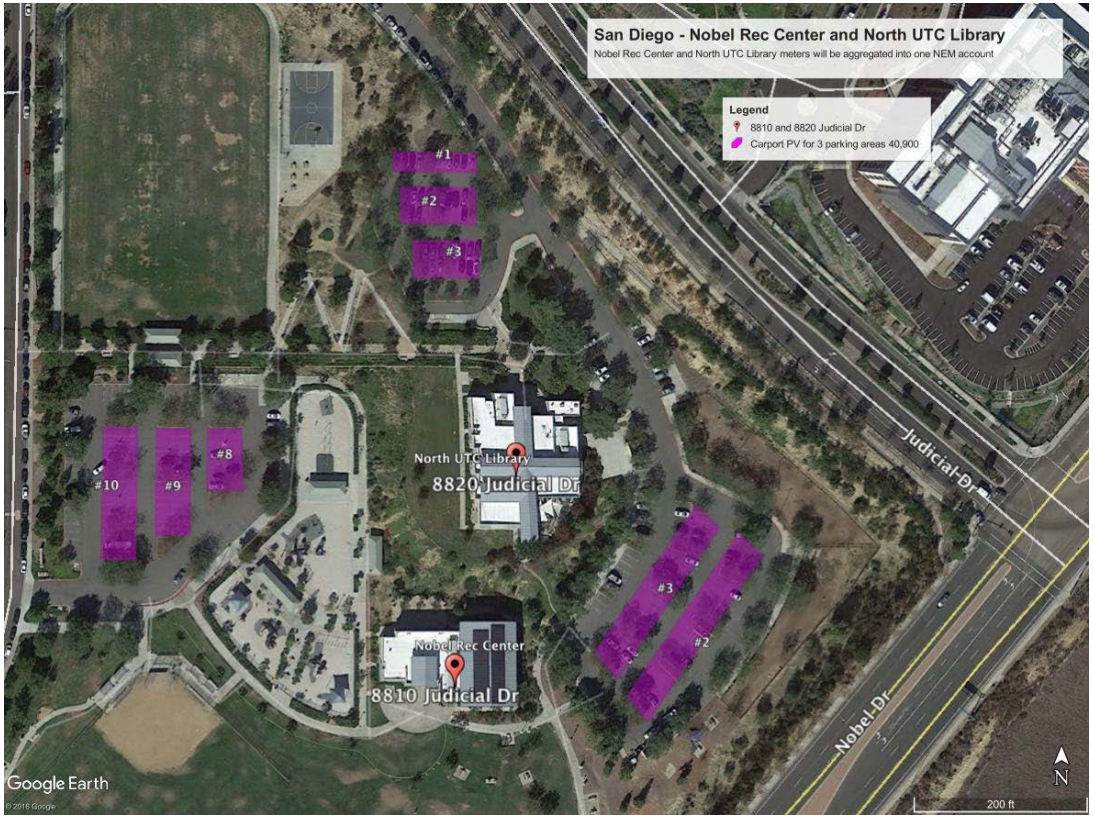
COMMUNICATION BUILDING BLOCKHOUSE (Sq. ft.)	
Ground 1 - New	68,900
Ground 2 - New	205,300
Total	274,200

4. ALLIED GARDENS & REC CENTER, BENJAMIN LIBRARY

ALLIED GARDENS POOL	
ALLIED GARDENS RECREATION CENTER	
BENJAMIN LIBRARY	
	Sq. ft.
Carport 1 - Pool	2,300
Carport 2 - Pool	3,200
Carport 1 - Rec Center	4,000
Carport 2 - Rec Center	6,800
Carport 3 - Rec Center	4,800
Carport 1 - Library	3,500
Carport 2 - Library	1,800
Carport 3 - Library	2,300
Total	28,700

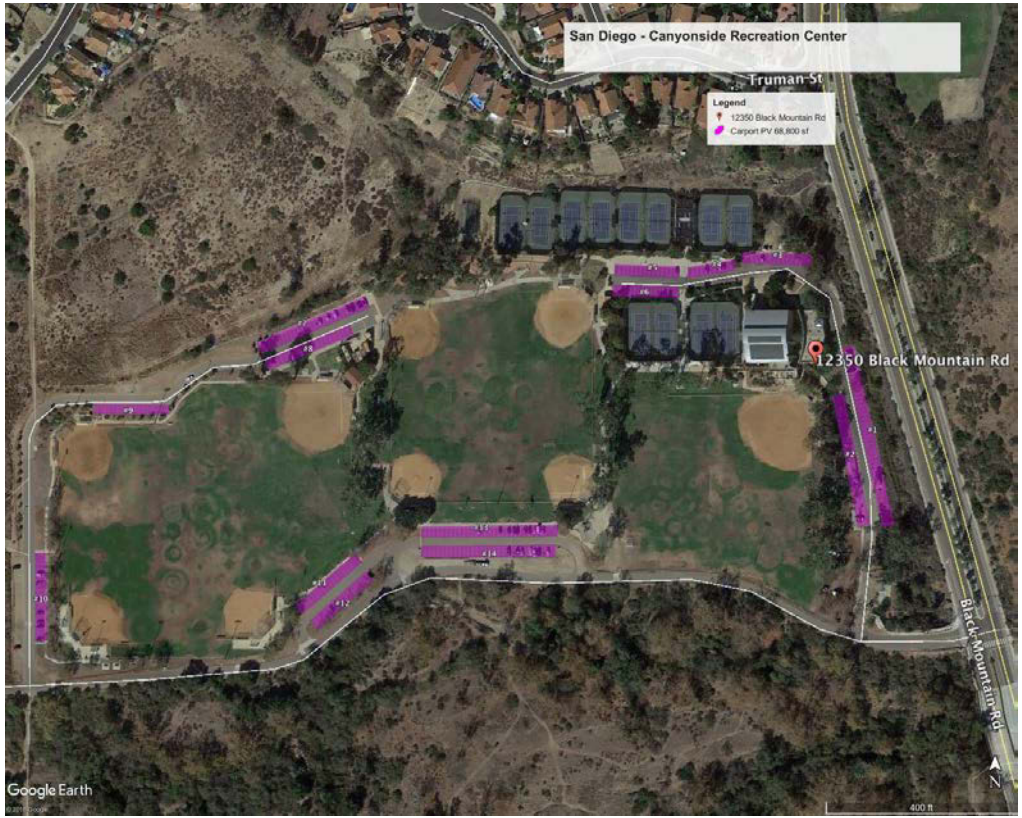
5. NORTH UTC LIBRARY & NOBEL REC CENTER

NORTH UTC LIBRARY	
NOBEL RECREATION CENTER	
	Sq. ft.
Carport 1 - Library	2,200
Carport 2 - Library	3,800
Carport 3 - Library	3,400
Carport 2 - Rec Center	8,900
Carport 3 - Rec Center	8,200
Carport 8 - Rec Center	3,000
Carport 9 - Rec Center	5,100
Carport 10 - Rec Center	6,300
Total	40,900



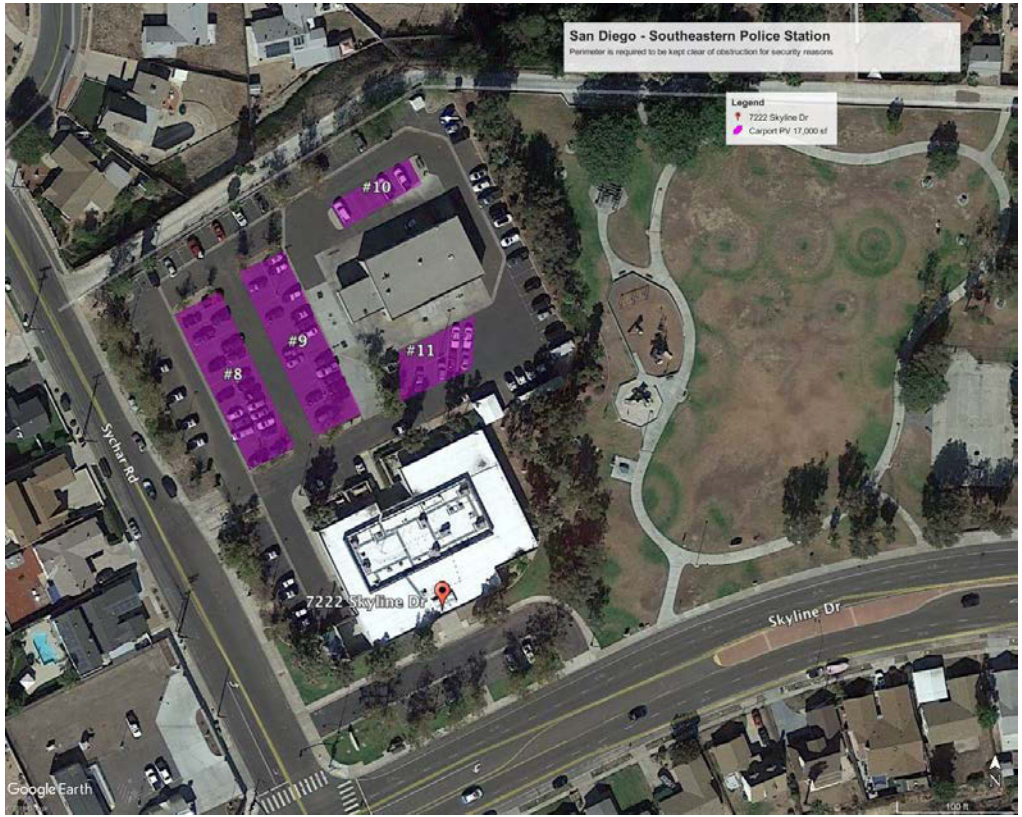
6. CANYONSIDE REC CENTER

CANYONSIDE RECREATION CENTER	
	Sq. ft.
Carport 1	9,400
Carport 2	6,900
Carport 3	3,400
Carport 4	2,300
Carport 5	3,200
Carport 6	3,200
Carport 7	6,500
Carport 8	4,400
Carport 9	3,200
Carport 10	4,600
Carport 11	4,000
Carport 12	3,800
Carport 13	7,000
Carport 14	6,900
Total	68,800



7. SOUTHEASTERN POLICE STATION

SOUTHEASTERN POLICE STATION	
	Sq. ft.
Carport 8	6,100
Carport 9	6,400
Carport 10	1,800
Carport 11	2,700
Total	17,000

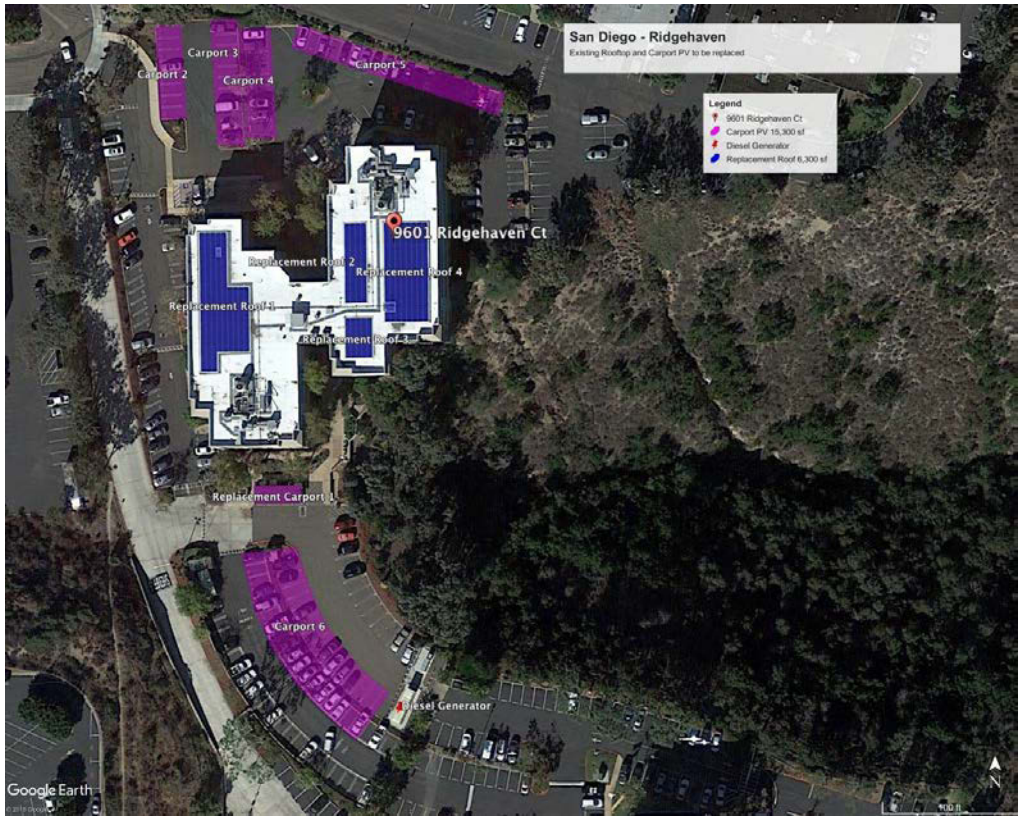


8. POLICE GARAGE, NORTHEASTERN

SOUTHEASTERN POLICE STATION	
	Sq. ft.
Carport 8	6,100
Carport 9	6,400
Carport 10	1,800
Carport 11	2,700
Total	17,000

9. RIDGEHAVEN

Ridgehaven	
	Sq. ft.
Carport 1 - Replacement	500
Carport 2	1,400
Carport 3	2,000
Carport 4	1,900
Carport 5	3,000
Carport 6	6,500
Total	15,300
Roof 1 - Replacement	2,600
Roof 2 - Replacement	900
Roof 3 - Replacement	500
Roof 4 - Replacement	2,300
Total	6,300



10. MIDCITY PD

MID CITY POLICE STATION	
	Sq. ft.
Carport 1	4,440
Carport 2	4,440
Carport 3	4,440
Total	13,320