Greenhouse Gas Reduction and Cost Effectiveness Estimates to Inform Project Funding Decisions

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Prepared for

Preserve Calavera
Coastal North San Diego County

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About EPIC

The Energy Policy Initiatives Center is a research center of the USD School of Law that studies energy policy issues affecting California and the San Diego region. Energy Policy Initiatives Center's mission is to increase awareness and understanding of energy- and climate-related policy issues by conducting research and analysis to inform decision makers and educating law students.

For more information, please visit the Energy Policy Initiatives Center website at www.sandiego.edu/epic.

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1 INTRODUCTION

Preserve Calavera retained the Energy Policy Initiatives Center (EPIC) to evaluate a range of project types to determine greenhouse gas (GHG) emissions impacts and cost effectiveness. Results will help identify potential projects for grant funding. EPIC estimated the following metrics to compare project types: metric tons carbon-dioxide equivalent (CO_2e) reduced or removed, net present value (NPV), NPV per metric ton CO_2e reduced or removed, benefit cost ratio (BCR), and discounted payback.

Preserve Calavera identified twelve project types. Table 1 presents the original list of project types to be analyzed in addition to standalone battery storage project on a single-family residential building, which was added. Several project types were removed from consideration for a range of reasons, including implementation challenges, limited GHG reduction potential, and cost. For five project types, we conducted a detailed GHG and cost analysis. For four measures, we completed a more limited analysis that comprising a literature review, high level quantitative estimates, and qualitative evaluation. All projects are assumed to be in the City of Oceanside.

Table 1 Project Types Included or Excluded from Project

Measure Type	Analysis Completed
Heat Pump Water Heaters in Single-Family Buildings	GHG Reduction and Cost
Heat Pump HVAC in Single-Family Buildings	
Photovoltaics on High Schools	
Photovoltaics on Small Commercial Buildings	
Stand-Alone Battery Storage in Single-Family Buildings	
Photovoltaics on Multifamily Buildings	Qualitative and Limited Quantitative
Opt-up CARE/FERA Customers to 100% Carbon-Free Electricity	
Wetland Restoration	
Other Habitat Restoration	
Agricultural Land Easements	N/A
Electric Vehicles and Chargers	N/A
Energy Efficiency Audits and Measures	N/A
Urban Trees Planting	N/A

While the analysis focuses on GHG emission impacts and cost, we recognize that the project types considered here can have other benefits, including habitat preservation, community enhancement, and public health improvements. Preserve Calavera also indicated a desire to evaluate projects that could be implemented in disadvantaged Communities. We did not conduct a comprehensive co-benefits analysis for this project.

1.1 Organization of Report

Section 2 presents key findings of the analysis completed for this project, including overall results of the GHG reduction and cost analyses, and a summary for each project type. Section 3 discusses the methods used in the analysis, including electric emission rates, energy use patterns for the project types included here, and the benefit-cost analysis completed. A summary of results from the GHG and cost analyses are presented in Section 4. The following sections present a more detailed discussion of each project type: Opt-Up CARE and FERA Customers (Section 5), Heat Pumps in Single-Family Residential Buildings (Section 6), Photovoltaics on High Schools (Section 7), Photovoltaics on Small Commercial Buildings (Section 8), and Standalone Battery Storage (Section 9). We include a brief overview of several other project types (Section 10), including Photovoltaics on Low-Rise Multifamily Buildings, Wetland Restoration, and Other Habitat Restoration. The final section (Section 11) summarizes considerations for monitoring projects.

2 KEY FINDINGS

This section summarizes the key findings from the analysis completed for this project. The first two subsections present overall findings for GHG reductions and cost analysis. The following subsections present findings specific to each project type analyzed.

2.1 GHG Reduction Analysis

Table 2 compares the GHG reduction estimates in 2030 for each project type using two different electric emission rates: short-run marginal emission rate (SRMER) and annual average emission rate (AAER). While it is problematic to directly compare the GHG impacts from these project types given the scale of the activity (e.g., one home compared to a high school) and the total amount of emissions reduced depends on the number of project completed, several key findings emerge.

Table 2 Comparison of GHG Results for 2030 Using Different Electric Emission Rates

Project Type	Short-Run Marginal Emission Rate (MT CO_2e Reduced)	Annual Average Emission Rate (MT CO_2e Reduced)
Residental Heat Pump Water Heater (Single Family)*	-0.14	0.37
Residential Electric Heat Pump HVAC (Single Family)*	-0.05	0.02
Small Commercial Photovoltaics	6.08	4.02
Small Commercial Photovoltaics + Battery Storage**	6.37	N/A
High School Photovoltaics	233	152
High School Photovoltaics + Battery Storage**	444	N/A
Standalone Residential Energy Battery Storage (Single Family)**	0.1	N/A

* A negative value represents an increase in emissions.

** It is not possible to estimate the impact of battery storage using an annual average emission rate.

- Heat Pump Technology Likely Would Have Modest GHG Impacts – Based on our hourly analysis, switching to heat pump technology results in a slight increase or reduction in GHG emissions for a typical home in Oceanside, depending on the electric emission rate used. Estimates using SRMER show slight increase in GHG emissions; those using AAER shows slight reduction. These results are due in part to the usage patterns of water heaters and space heating and cooling equipment, and because of the mild climate in Oceanside. (See Section 6.3.1) Nonetheless, replacing natural gas appliances and equipment in buildings is a key strategy to reach overall GHG emission targets.
- Solar Projects Could Reduce GHG Emissions with and without Battery Storage – Installing photovoltaics (PV) on small commercial buildings and schools would reduce GHG emissions. Adding battery storage can increase the amount of GHG emission reductions but increases project costs. We also found that the optimal sized system in the PV only scenario may differ from the PV and battery storage scenario. The most effective system sizing depends on the energy usage pattern of the building, customer rate schedule, and battery behavior.

- **Hourly Analysis Needed to Estimate Impacts of Battery Storage** – The newest revision to net energy metering rules, called net billing tariff (NBT), uses an hourly schedule of values to compensate customers for solar electricity exported to the grid and requires customers to take electric service on a time-of-use rate. Further, changes in GHG emissions would result from comparing the emissions rate during the day when the battery is importing electricity from the grid to charge and the evening when the battery is serving customer load, thus avoiding grid power. Given these factors, an hourly approach is necessary to estimate the costs and benefits of a standalone battery system or adding battery storage to a PV system using an hourly approach. As presented in Table 2, GHG emission reductions from battery only projects in single-family residential buildings are minimal. This is discussed further in Section 2.6.

2.2 Cost Analysis

Table 3 summarizes results of the cost analysis, including benefit-cost ratio, discounted payback, and net present value per metric ton of CO_2e reduced (NPV/MT CO_2e) using results from two electric emission rates. A benefit-cost ratio greater than one means the benefits are greater than the cost over the life of the project. Discounted payback, measured in years, determines when the discounted benefits equal the discounted costs, signifying the payback time of the project. A positive NPV/MT CO_2e reduced means that there is a *net benefit* over the lifetime of the project for each ton reduced. A negative value represents a *net cost.*

Table 3 Comparison of Cost Analysis Results

Project Type	Benefit-Cost Ratio	Discounted Payback (years)	NPV/MT CO2e Reduced (SRMER)**	NPV/MT CO2e Reduced (AAER)
Residental Heat Pump Water Heater (Single Family)*	N/A	N/A	N/A	(3,166)
Residential Electric Heat Pump HVAC (Single Family)	N/A	N/A	N/A	4,789
Small Commercial Photovoltaics	2.24	5	468	800
Small Commercial Photovoltaics + Battery Storage	1.44	7	261	474
High School Photovoltaics	1.90	6	310	540
High School Photovoltaics + Battery Storage	1.64	8	274	514
Standalone Residential Energy Battery Storage (Single Family)	1.21	10	1,230	N/A

*Total upfront cost/incremental cost compared to baseline appliance.

**These values cannot be reported for heat pumps since they increase emissions in our analysis.

- **Residential Heat Pump Technology is Not Cost Effective in Climate Zone 7** - For residential heat pump technology, the net present value over the life of the project is negative. In this case, there are no financial benefits to installing new technology, so no BCR or payback can be calculated. This is, in part, because switching from natural gas appliances to electric heat pump technologies leads to higher energy bills. Also, residential heat pump water heaters cost more than natural gas storage versions; thus, the upfront cost is higher and the ongoing cost to operate is higher. This leads to a negative net present value, and hence, a net cost of several thousand dollars per MT CO_2e reduced (at least using the AAER). Alternatively, the cost to replace both a natural gas furnace and electric air conditioner with an electric heat pump HVAC system is lower. Even with a higher operating cost, the difference in upfront costs contributes to a positive net present value over the life of the project.

- Photovoltaics Project are Cost Effective with and without Batteries – All PV project types analyzed, including those with battery storage, had a BCR greater than one, meaning benefits are higher than costs over the life of the project. They also have relatively short payback times (5-8 years) relative to the project life of 25 years. For each MT of CO2e reduced, a PV project has a net benefit over this period.
- Battery-Only Projects are Marginally Cost Effective – While these projects have a benefit-cost ratio greater than one, the discounted payback time (10 years) is closer to the project lifetime. Also, given the relatively minimal GHG reductions, the cost per MT CO_2e is relatively high among the projects we analyzed. It is not possible to estimate the GHG impacts using an annual average emission rate, so not results are provided.

2.3 Opting Up Care and FERA Customers to 100% Carbon-Free Electricity

This project type would provide grant funding to cover the cost of moving certain income-qualified customers from the default electric service to a 100% carbon-free electricity option.

- Opting Up CARE and FERA Customers Could Cost about $600,000 per year – Given the published rate impact of opting up to the 100% renewable content service option for Clean Energy Alliance, we estimate that a program to opt up all CARE and FERA customers could cost about $600,000 annually.[1] It is not clear how many years this program could be funded by Preserve Calavera, or whether a few years of such funding would lead to additional renewable generation capacity.
- It is not Clear Whether Opting Up Customers Would Reduce GHG Emissions – Depending on the amount of carbon-free electricity currently under contract, moving customers to a service option that has a higher renewable or carbon-free electricity content may not reduce GHG emissions. For example, if a retail supplier has purchased more carbon-free supply than needed, additional renewable procurement could be allocated to the customer that opt up. For our purposes here, we assume that if no additional generation capacity is added, no GHG reductions would occur.
- An Hourly Matching Approach May More Accurately Estimate GHG Impacts – Given conventional accounting approaches, it is assumed that a customer opting for the 100% renewable or carbon-free electricity service options is being supplied with such energy every hour of the year, and that the resulting GHG emissions would be zero. This would not be the case since most renewable generation occurs in the middle of the day and evening usage is supplied mostly by natural gas power pants. An accounting approach that matches customer usage to carbon-free electricity supply on an hourly basis would more accurately estimate GHG impacts.

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[1] Clean Energy Alliance. Adopted Rates Effective February 1, 2023.

2.4 Building Electrification

This project type would provide grant funding to single-family residential building owners to replace natural gas water and space heaters and traditional air conditioners with electric heat pump technologies. This analysis did not consider a whole home electrification option.

- Energy and GHG Impacts of Heat Pump Heating and Cooling Technologies are Likely Minimal in Climate Zone 7 – Given the mild climate along the coast, GHG reductions from replacing a natural gas furnace and traditional air conditioner with a heat pump technologies would reduce GHG emissions minimally. Replacing a natural gas storage water heater with an electric heat pump water heater yields larger reductions, though still relatively modest. Given the need to replace nearly all water heaters and HVAC systems with electric heat pumps, the aggregate impact of this project type could be significant over time.
- Hourly Short-Run Marginal Emission Rates Likely Underestimate GHG Impacts of Heat Pump Technology – Short-run marginal emission rates (SRMER) likely underestimate GHG reductions from switching to heat pump water heaters and heat pump heating and cooling systems. This is because SRMER overestimates emissions from the grid since the long-run structural changes that likely will occur to serve additional load and to comply with policy directives are not fully considered. Because, in this case, heat pump technologies are always compared to natural gas as the baseline fuel for water and space heating, higher emissions estimate from grid result in lower reductions.
- Load Shifting Could Improve the Cost and GHG Impacts of Heat Pump Water Heaters – Our initial results suggest that electrification alone may not be the best method to reduce GHG emissions. It may be necessary to include some level of energy storage or a way to shift energy usage, like water heater controls that would lower electric demand during high emission/rate periods. Additional research would be needed to determine the impact to emissions of combining energy storage or controls with building electrification interventions. Nonetheless, adding additional technologies, particularly battery storage, would increase cost.
- Heat Pump Technology is More Expensive to Operate – Heat pump water heaters and HVAC systems generally increase electric usage, since natural gas consumption is replaced with electricity. And, since San Diego region has among highest electricity rates in California and the U.S., replacing natural gas technologies with heat pumps likely will increase energy bills. Heat pump water heaters have a higher upfront cost than natural gas versions and cost more to operate. Heat pump HVAC systems have a lower upfront cost than the combined cost of a natural gas furnace and electric air conditioner but cost more to operate.

2.5 Photovoltaics – High Schools and Small Commercial Buildings

This project type would provide grant funding to high schools and non-profits to install solar and battery storage equipment. We estimated the GHG and cost impacts of two project scenarios: PV only and PV with battery storage.

- Photovoltaic Production Overlaps with Consumption Patterns – Based on analysis for this project, the hourly load shapes of a typical high school and small commercial buildings generally align well with solar PV generation. This indicates that a PV-only system can potentially offset significant electricity use, resulting in cost savings and GHG emissions reductions. However, the number of high schools in Oceanside limits the total potential of this project type.

- **Both Scenarios are Cost Effective but Adding Battery Storage Has a Higher Upfront Cost and Reduces More GHG Emissions** – High school energy use typically extends into the evening and overnight due to after-school activities and other minimal consumption. Battery storage can shift surplus solar energy generation into the evening to reduce evening peak demand, lowering GHG emissions and electricity costs. However, our study suggests that while adding storage to solar PV projects on high schools and small commercial buildings is economically feasible, it is less cost-effective than the PV-only scenarios and has higher upfront costs.
- **The Ownership of the Small Commercial Buildings and PV System Affects Benefits and Costs of the Participants** – The ownership structure of both the building and the PV system significantly influences the benefits and costs incurred by participants. In scenarios where participants own both the building and the PV system, they may experience direct financial benefits, such as reduced energy costs and potential credits generation from exporting excess electricity production. However, in the case where the occupant is not the building owner, there is a split incentive between the owner who controls the building but may not benefit financially, and the tenant, who may benefit from installation of PV but does not have control of the building.

2.6 Standalone Battery Storage

This project type would provide grant funding to single-family residential building owners to install standalone battery projects.

- **Standalone Batteries on Single-Family Residential Buildings are Cost Effective with Current Incentives** – Considering current incentives, nearly all installation cost and operation and maintenance cost scenarios would have a benefit-cost ratio greater than one. This means benefits are greater than costs over the lifetime of the project. However, without current incentives, standalone batteries would need to achieve the low end of the installation cost range (i.e., $700/kWh) to result in a benefit-cost ratio greater than one.

Table 4 Benefit Cost Ratio for Stand Alone Storage – With Incentives

		Installation Cost ($/kWh)						
		$ 700	$ 800	$ 900	$ 1,000	$ 1,100	$ 1,200	$ 1,300
O&M ($/kWh)	$100	1.96	1.70	1.50	1.34	1.21	1.11	1.02
	$150	1.81	1.59	1.41	1.27	1.16	1.06	0.98
	$200	1.69	1.49	1.34	1.21	1.10	1.02	0.94
	$250	1.58	1.41	1.27	1.15	1.06	0.98	0.91

- **GHG Reductions from Standalone Battery Systems are Relatively Small** – Because the difference in the rate of emissions when it is most cost effective to charge is not significantly lower than the period it is cost effective to discharge, the GHG reduction from a standalone battery on a typical single-family building in climate zone 7 is relatively small. The GHG reduction over the 15-year life of a battery installation is about the same as the *annual* reductions associated with switching from a gasoline to an electric vehicle.

- Incentive Programs for Battery Storage Focus on Equity Outcomes – California Self-Generation Incentive Program (SGIP) will no longer provide financial incentives for general market battery storage projects and focus funding on projects that improve resilience and equity. Similarly, the federal investment tax credit provides a base credit and possible adders based on achieving certain labor- and equity-related factors.

2.7 Other Project Types

The key findings for the following other project types are based on a limited literature review and qualitative evaluation.

2.7.1 Low-Rise Multifamily Buildings

- **The Split Incentive Dilemma Also Applies to Solar on Multifamily** – As with solar on small commercial buildings, policies and programs related to energy use in buildings that lease or rent units often face the "split incentive" dilemma. Building owners often do not pay utility bills and have no incentive to address building energy, while renters pay the utility bills and have an incentive to improve energy use but do not own the building or the main energy-consuming appliances and equipment.
- **Recent Reforms to Virtual Net Energy Metering May Adversely Affect Cost Effectiveness of Multifamily Solar Projects** – Virtual Net Energy Metering (VNEM) allows a building owner to size a PV system based on the entire load of the building, including tenant loads. This allows for a much larger PV system and a process for the building owner to share the energy cost savings with tenants. The California Public Utilities Commission (CPUC) recently modified VNEM. Now multifamily projects are netted at the 15-minute interval and, if there is a net export during the 15-minute interval, will receive credit for solar electricity exported to the grid at the Net Billing Tariff export rate, which is lower than previous compensation rates. This may affect the cost effectiveness of these projects.

2.7.2 Wetland Restoration

- **Wetlands Restoration Likely Has Limited GHG Sequestration Potential** – Wetlands can sequester carbon, but they also can emit methane, a more powerful GHG than carbon. To assess the GHG impacts of wetlands, it is necessary to assess net emissions; that is, the amount of carbon removed and stored *in addition to* methane emitted. Not all wetland types sequester carbon; some are net emitters. Brackish tidal wetlands have the highest potential for net GHG sequestration with rate of about -3.3 MT CO2e/acre/year. Freshwater tidelands also show a modest sequestration potential on the low end of the estimated range. Given the relatively limited area of wetlands in Oceanside, potential to remove and store carbon from restoration project is limited.
- **GHG Impact is Determined by Comparing the Baseline Condition to a Restored Condition** - To assess the potential of wetland restoration as a GHG reduction measure, it would be necessary to first determine the amount of GHG sequestration (or emissions) prior to restoration, then the amount of GHG sequestration (or emissions) after the restoration. The difference between these two represents the GHG impact attributable to the restoration project.

2.7.3 Other Habitat Restoration

- **Habitat Restoration Results in Relatively Low GHG Impacts** – Similar to wetland restoration, restoring other types of habitats can remove carbon from the atmosphere. Based previous research on this topic, mixed conifer and Douglas fir forests have the highest rate of sequestration at about 2 metric tons of carbon per acre per year (MT C/acre/yr.). Oak woodlands and grasslands sequester carbon at a rate about 1 MT C/acre/yr. Most of the remaining vegetation types have a rate less than 0.5 MT C/acre/yr. and several types have the potential to be net emitters (e.g., coastal sage scrub, chaparral, and pinyon juniper). Also, like wetland restoration, determining the net impact of habitat restoration would require determining a baseline and then comparing that to the restored condition.

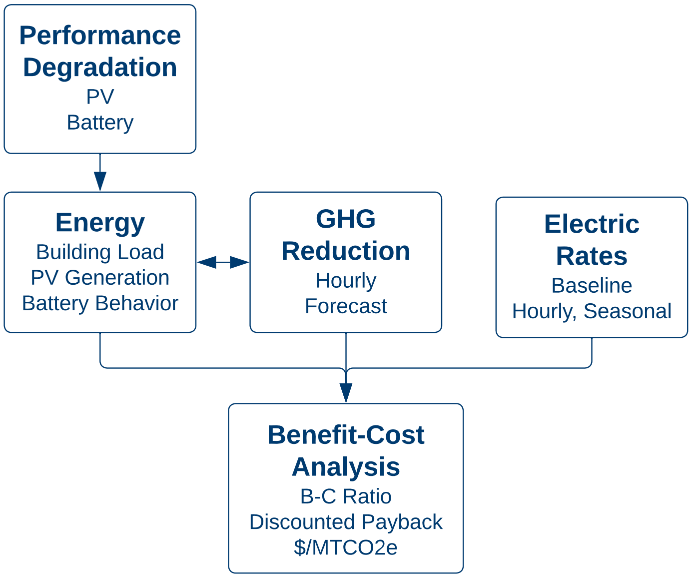
3 METHODS USED FOR MORE THAN ONE PROJECT TYPE

This section provides a summary of methods used for more than one project type, including the overall method for estimating cost and GHG impacts for PV and battery projects, electric emissions rates, and the benefit cost analysis approach used. Discussion of specific methods used to estimate GHG impacts and cost are provided in the sections below.

3.1 Summary of Method Used for Photovoltaics and Battery Project Types

Figure 1 summarizes the overall method used to estimate both GHG and cost impacts of PV and battery storage projects. The approach used here comprises five modules: performance degradation, energy, GHG reduction, electric rates, and benefit-cost analysis. We provide a summary of each below but include more detailed discussion of key factors in the sections below.

Figure 1 Method for GHG Reduction and Cost Analysis for Electric-Related Project Types



- Performance Degradation – This module estimates the performance degradation for both PV and batteries over the life of the project. For example, we assume that PV performance declines by 1.4% per year[2] and batteries by 0.01% per cycle.[3] This provides a more realistic forecast of performance over the life of the project.
- Energy – This module calculates the amount of electricity imported from the grid, PV electric generation exported to the grid, and the self-consumption portion. Key inputs for this module include hourly building energy usage patterns (i.e., load shapes), along with hourly data on PV generation and battery behavior. Building usage patterns and PV electric

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[2] PV degradation rate: NEM 2_Lookback_Study 2021, p. 63.

[3] Degradation rate provided by Unigrid.

generation are derived from the California Energy Commission's (CEC) California Building Energy Code Compliance (CBECC) model.[4]

- **GHG Reduction –** This module estimates the GHG impact of hourly building energy consumption, including that for charging batteries self-consuming PV generation or stored battery electricity, or exporting electricity to the grid. It considers outputs from the Energy module. GHG reduction estimates are calculated using two different emission rates: hourly short-run marginal emission rates (SRMER) and annual average emissions rate (AAER). SRMER values are from the CPUC Avoided Cost Calculator.[5] AAER values are derived from CEC Power Source Disclosure program data.[6] A detailed discussion of emission rates is provided in Section 3.2 below.
- **Electric Rates –** This module converts applicable rate schedules into an hourly format that considers time-of-use variations throughout the day, seasonal changes, baseline consumption impacts, and demand charges. All rates used are from San Diego Gas & Electric's (SDG&E) current electric and natural gas tariff book.[7] All PV and PV plus battery project types use the net billing tariff export rates for bundled customers included in SDG&E's original advice letter.[8]
- **Benefit-Cost Analysis** – This module uses outputs from the other modules to estimate benefit-cost ratio, discounted payback, and how cost effectively a project type can reduce a metric ton of carbon-dioxide equivalent (MT CO_2e). Methods used are consistent with those included in the SANDAG Regional Climate Action Planning (ReCAP) Technical Appendix III.[9]

3.2 Electric Emission Rates

For measures related to electricity, a key input in the analysis is the GHG emission intensity of the electricity supply. For this project, EPIC calculated GHG impacts using two different types of emission rates: annual average and hourly marginal.

3.2.1 Annual Average Emission Rates

Annual average emission rates (AAER) represent the total emissions divide by the total associated electricity. For most GHG impact calculations done for climate action plans and other analysis, an annual average value is used. Table 5 shows the amount of electricity sales in 2021 and the annual

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[4] California Energy Commission. 2022 Energy Code Compliance Software. Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency-1.

[5] 2021 CPUC Avoided Cost Calculator. Available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm.

[6] California Energy Commission. Power Content Label. Available at https://www.energy.ca.gov/programs-and-topics/programs/power-source-disclosure/power-content-label.

[7] San Diego Gas & Electric. Current and Effective Tariffs. Available at https://www.sdge.com/rates-and-regulations/current-and-effective-tariffs.

[8] San Diego Gas & Electric Advice Letter 4155-E-A (March 31, 2023). New rates were published after the initial analysis was completed for this report.

[9] San Diego Association of Governments. Regional Climate Action Planning Framework and Technical Appendices. Available at https://www.sandag.org/-/media/SANDAG/Documents/ZIP/projects-and-programs/recap-and-technical-appendices.zip.

GHG emissions intensity for retail electricity suppliers in the San Diego region.[10] The average weighted by retail sales is 472 lbs. CO2e/MWH.

Table 5 GHG Emission Intensity for Retail Electricity Suppliers in the San Diego Region

Retail Suppliers	2021 Retail Sales (MWh)	2021 Annual Greenhouse Gas Emissions Intensity (lbs CO2e/MWh)
Clean Energy Alliance - Clean Impact Plus	419,723	238
Clean Energy Alliance - Clean Impact	5,723	472
Clean Energy Alliance - Green Impact	3,376	0
San Diego Community Power - PowerOn	1,918,834	378
San Diego Community Power - Power100	129,043	0
San Diego Gas & Electric Company	11,298,590	504
San Diego Gas & Electric Company - EcoChoice	43,107	0

This value is associated with a certain percentage of renewable supply. We assume that the ratio of GHG emissions intensity and percentage renewable remains constant as suppliers reach the statutory goal of 60% renewable electric supply by 2030 and 100% zero carbon by 2045. Table 6 shows data for the year 2021 (year of Power Source Disclosure data), 2030 (interim year of renewable electricity content requirements), and 2045 (final year of requirements). For the analysis conducted in this project, we interpolated between these values to get annual average emissions intensity rates.

Table 6 Forecast of Renewable/Zero Carbon Content and Annual Average Emission Rates

Year	Renewable/ Zero Carbon Content	Annual Average Emissions Intensity (lbs CO2e/MWh)
2021	45%	472
2030	60%	340
2045	100%	-

One benefit of this approach is that average emission intensity data is released publicly every year for all retail electricity suppliers through the CEC's Power Source Disclosure program. Also, it is

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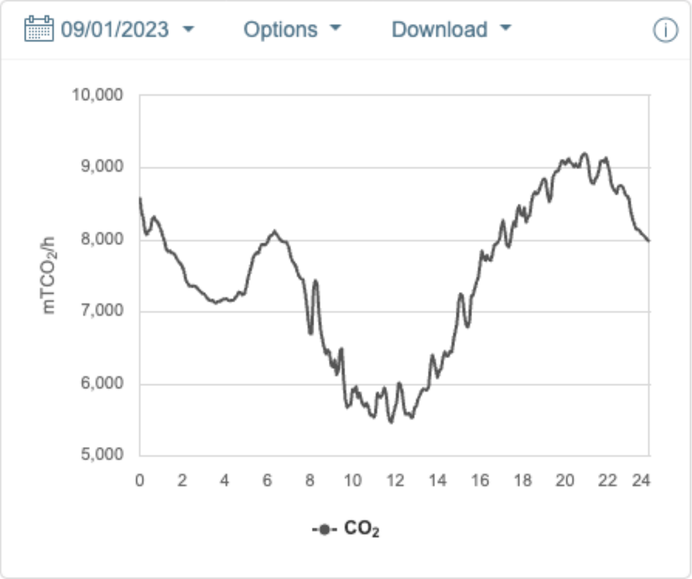
[10] Note that energy service providers that sell to customer under direct access are not listed here. Data is not available on the specific companies supplying customers or the amount supplied to customers in the San Diego region.

relatively straightforward to project. One significant limitation is that one annual value can obscure changes in emission rates during the year and across a single day. In general, emissions are lower in the middle of the day when solar production is plentiful, but higher in the evening when solar production declines and natural gas is used to serve peak electric demand. Figure 2 shows the total emission per hour in the CAISO planning area for a day in September 2023.[11] This is total emissions and not a rate (i.e., emissions per unit of electricity) as discussed in this section, but nonetheless illustrates the variation in emissions by hour. As a result, using AAER likely can over- or underestimate the GHG impacts of projects. Section 3.2.2.3 discusses this in more detail.

Figure 2 GHG Emissions in the CAISO Area – September 2023



3.2.2 Hourly Emission Rates

Hourly emission rates represent the emissions per unit of electricity for every hour of the year. There are two main types: average and marginal. Average hourly emission rates reflect the total emissions over one hour divided by the total energy consumed. This can be a useful metric to understand total emissions (i.e., GHG inventory), but hourly average emission rates do not reflect the physical changes that occur on the grid because of activities to increase, reduce, or avoid electric use. For that, hourly marginal emission rates can be more helpful. These represent the rate of emissions from the resource that was increased or decreased due to changes in consumption. In general, electricity is added to the grid based on marginal cost to operate. Because many renewable electricity resources have a very low cost to operate, they are often added first. This results in an electric resource "stack" with the lowest marginal cost resources used first and higher marginal cost resources used last. Dispatching electricity in this way helps to ensure that electricity is dispatched at the lowest cost.[12] If electricity demand increases, the highest cost resource in the stack (e.g.,

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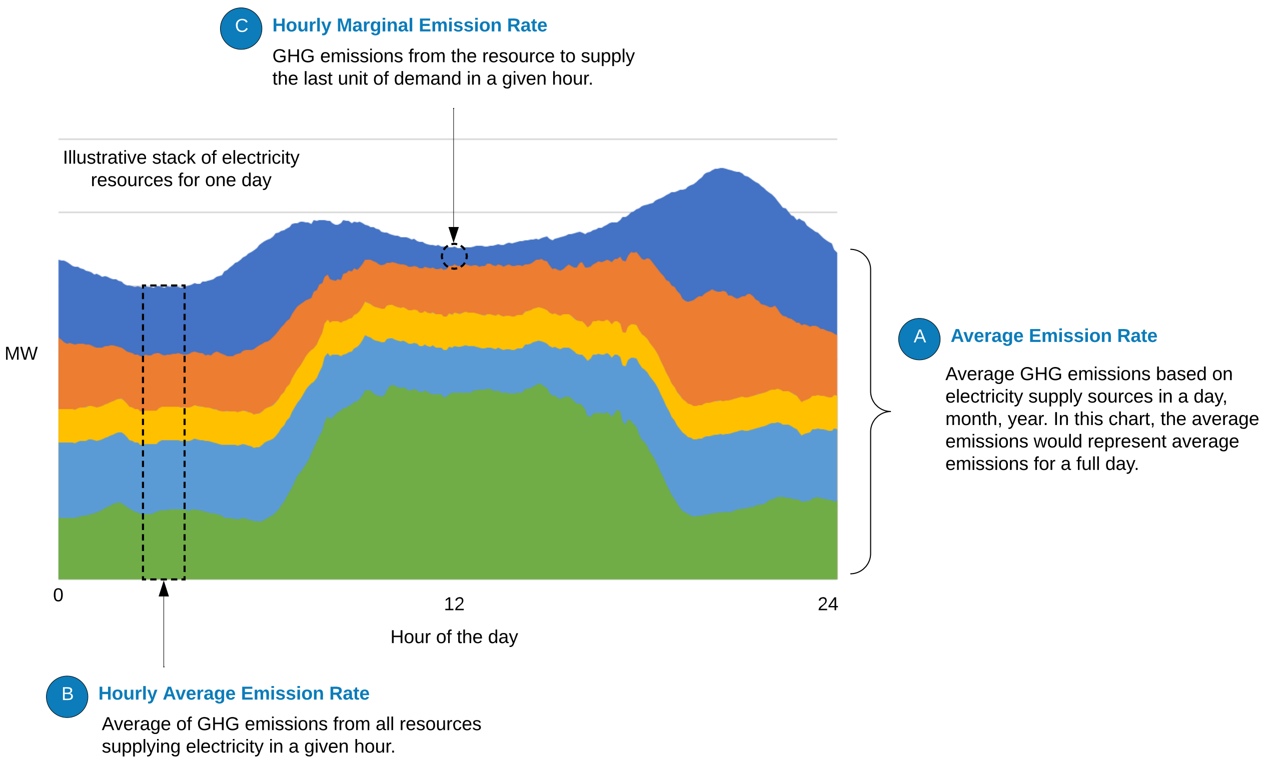
[11] California Independent System Operator. Daily Outlook – CO_2 emissions (serving ISO load). Available at https://www.caiso.com/TodaysOutlook/Pages/emissions.html#section-total-co2-trend.

[12] Resources for the Future. US Electricity Markets 101. Available at https://www.rff.org/publications/explainers/us-electricity-markets-101/.

natural gas combined cycle turbine) will be increased or another, higher cost resource (e.g., natural gas peaker plant) will be added. If demand decreases the highest cost resource will be reduced.

Figure 3 illustrates different types of electric emission rates. In this example, the average emission rate (marked as "A") represents the total emissions divided by the total electricity supplied *in one day*. As discussed above, for the analysis presented here, we used an annual average emission rate. An hourly average emissions rate (marked as "B") represents the total emissions divided by the total electricity supplies *in one hour*. Finally, an hourly marginal emission rate (marked as "C") represents emissions from the last resource used to serve demand in each hour.

Figure 3 Comparison of Electric Emission Rate Approaches



Hourly Marginal Emission Rate

GHG emissions from the resource to supply the last unit of demand in a given hour.

Average Emission Rate

Average GHG emissions based on electricity supply sources in a day, month, year. In this chart, the average emissions would represent average emissions for a full day.

Hourly Average Emission Rate

Average of GHG emissions from all resources supplying electricity in a given hour.

3.2.2.1 Short-Run Marginal Emission Rates

In addition to operating cost, each generator in the resource stack has a rate of GHG emissions, typically measured in pounds or kilograms per megawatt-hour (lbs or kg/MWh). So, if there is a decrease in electric use in each hour, the emissions impact can be estimated using the rate of the last resource dispatched. Figure 4 presents hourly emissions data from the CPUC Avoided Cost Calculator[13] for 2023 and 2045. These represent the short-run marginal emission rates (SRMER), which show the emissions that would result from an increase or decrease in energy use from the grid in 2023 and 2045. Hourly SRMER assume only limited changes to the grid due to policy and other changes like additional electricity demand from electric vehicles and heat pumps for heating water and space heating and cooling. As a result, they are more accurate in the short-term but can

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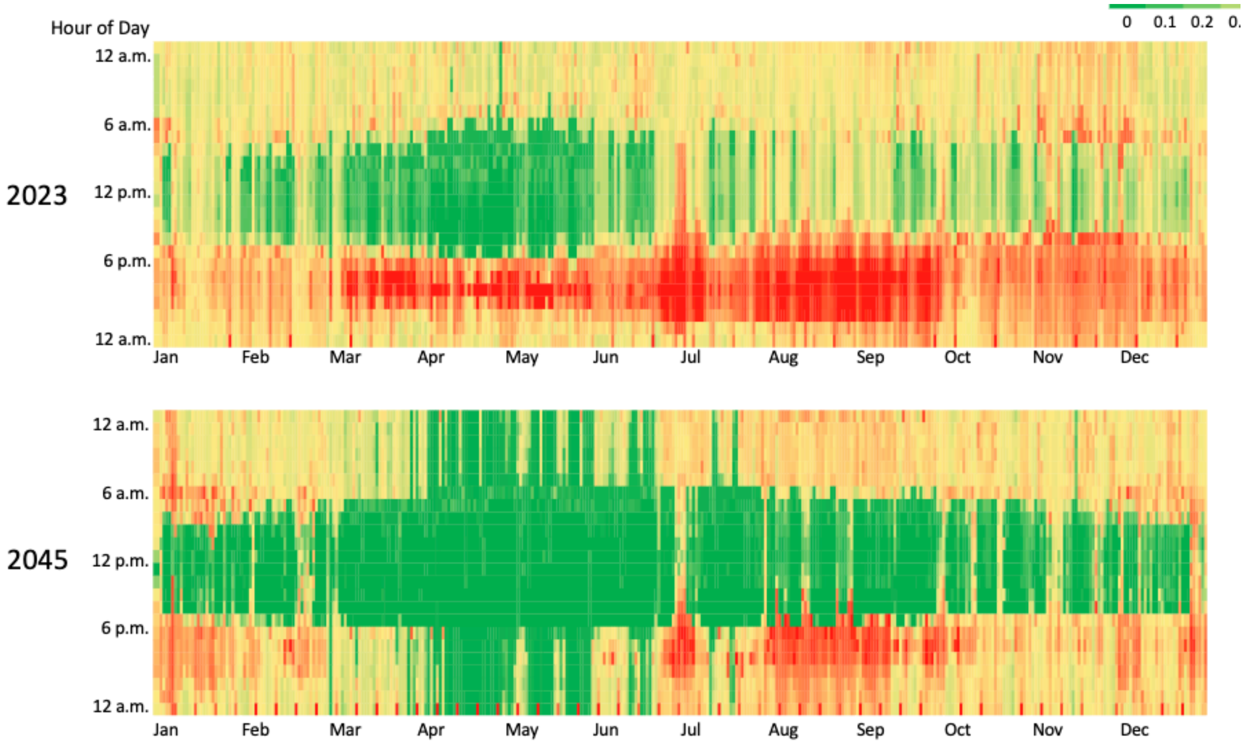
[13] 2021 CPUC Avoided Cost Calculator. Available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm.

overestimate the level of emissions from the grid over time. Nonetheless, the SRMER presented below get cleaner (green) over time, but there are still many hours of the year when marginal emissions are high (red).

Using SRMER to estimate the GHG reduction potential of policies and other actions is a generally accepted practice and is routinely used in analysis conducted for the CPUC.[14] For example, recent CEC-funded research on targeted electrification and natural gas system decommissioning by E3 used a SRMER to estimate the total resource cost (TRC) test, which is equivalent to the measure cost (i.e., participant and non-participant costs) as described in Section 3.4.3.[15] Similarly, in a recent whitepaper analyzing the electric system level impacts of voluntary carbon-free purchasing strategies, the authors used a SRMER to estimate GHG impacts.[16] See Section 5.2 for further discussion.

Figure 4 Short-Run Hourly Marginal Emissions Rates (2023) (MT CO2e/MWh)[17]



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[14] We note that long-run marginal emission rates (LRMER) are available from the National Renewable Energy Laboratory (NREL). See Cambium, available at https://www.nrel.gov/analysis/cambium.html. Future analysis could consider the effect of using LRMER to estimate GHG impacts.

[15] Energy+Environmental Economics. December 2023. Benefit-Cost Analysis of Targeted Electrification and Gas Decommissioning in California: Evaluation of 11 Candidate Sites in the San Francisco Bay Area. California Energy Commission: PIR-20-009.

[16] Xu, et al. September 2023. System-level Impacts of Voluntary Carbon-free Electricity Procurement Strategies. Working Paper.

[17] 2021 CPUC Avoided Cost Calculator. Available at https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm.

3.2.2.2 Marginal Income Tax Rate Analogy

The concept of marginal electric resources and associated emissions can be complicated. Income tax rates provide a useful analogy. In the U.S., personal income is taxed at different rates depending on the total amount of income. Table 7 presents the 2023 U.S. federal personal income tax brackets for single filers.[18]

Table 7 2023 U.S. Federal Income Tax Brackets for Single Filers

Tax Rate	Income Range for Single Filers
37%	$578,126 or more
35%	$231,251 - $578,125
32%	$182,101 - $231,250
24%	$95,376 - $182,100
22%	$44,726 - $95,375
12%	$11,001 - $44,725
0%	Up to $11,000

Each tax rate applies to a specific range of income. For example, the first $11,000 is not taxed. Income from $11,001 to $44,725 is taxes at 12%. Income from $44,726 to $95, 375 is taxes at 22%. The tax rate associated with the highest slice of income is referred to as the marginal tax rate. For example, someone earning $95,375 would have a marginal tax rate of 22%. If income increased to $100,000, the additional $4,625 would be taxed at 24% and the new marginal tax rate would be 24% (Figure 5).

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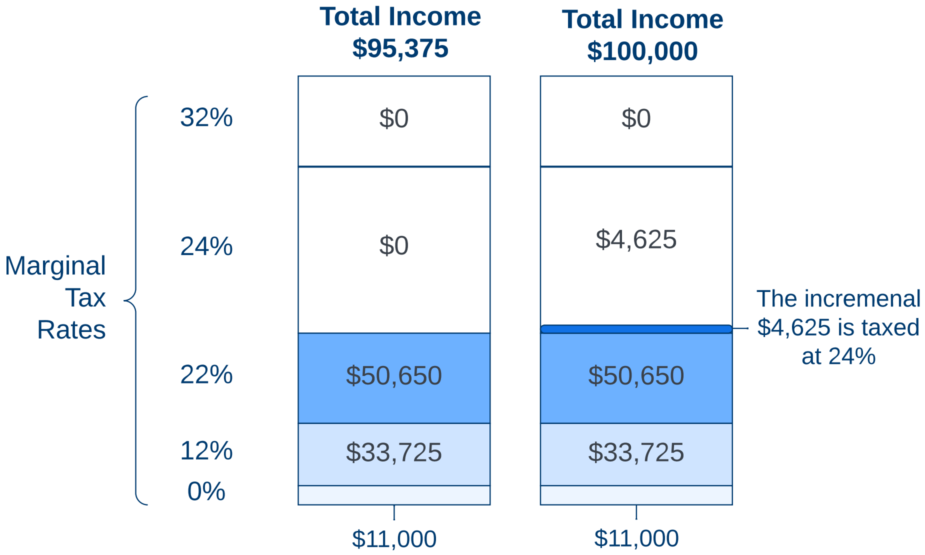
[18] https://www.irs.gov/newsroom/irs-provides-tax-inflation-adjustments-for-tax-year-2023.

Figure 5 Illustrative Example of Marginal Income Tax Rates for Single Filers



Because each slice of income is taxed at a separate rate, it is also possible to calculate the average tax rate – often referred to as the "effective" tax rate – for the total amount of income. Table 8 provides an example that compares two different incomes as described above. In Example 1, the single filer earns $95,375, the highest amount before moving into the next marginal tax rate. In this scenario, the marginal tax rate is 22% and the average tax rate is 15.9% (total tax divided by total income). In Example 2, the same single filer receives a salary increase and the added income is taxed at the 24% marginal rate. In this scenario, the marginal rate is 24% and the average is 16.3%. What is true of an increase in income is also true of a reduction in income. If the filer could reduce the total amount of additional income through deductions, they would be back to the 22% marginal rate. The tax savings from deductions would be calculated using the 24% marginal rate. It would not make sense to estimate the tax savings using the average tax rate. This is analogous to GHG emissions. To calculate total emissions, using an average emission rate is appropriate, but to estimate the impact of an increment or decrement of electricity generation, it would not make sense to use the average rate. The marginal rate would provide an estimate more consistent with the actual changes to the grid that occurred.

Table 8 Illustrative Calculation of Marginal Tax Rates

		Example 1		Example 2	
Marginal Income Tax Rate	**Income per Tax Bracket**	**Illustrative Income of $95,375**	**Estimated Tax**	**Illustrative Income of $100,000**	**Estimated Tax**
0%	11,000	11,000	-	11,000	-
12%	33,725	33,725	4,047	33,725	4,047
22%	50,650	50,650	11,143	50,650	11,143
24%	86,724	-	-	4,625	1,110
Total		**95,375**	**15,190**	**100,000**	**16,300**
Marginal Rate			*22%*		*24%*
Average Rate			*15.9%*		*16.3%*

3.2.2.3 Impact of Emissions Rates on GHG Reduction Estimates

As noted above, choice of electric emission rate likely over- or underestimates GHG impacts. Table 9 compares how using AAER and SRMER can affect GHG impact estimates. In general, because the AAER averages out the high and low emissions rates over one year, it tends to reflect lower emissions from the grid. By contrast, the SRMER varies by hour and at some points reflects higher emissions from natura gas plants and at other points reflects lower emissions due a high proportion of zero carbon resources. As a result, using AAER tends to overestimate emissions impacts for projects that replace fossil fuel technology, including replacing natural gas water heaters with electric heat pumps and replacing internal combustion engine vehicles with electric vehicles. This is because the difference between grid emissions using the AAER and emissions from natural gas consumption in the case of water heaters likely would be higher if AAER reflects lower grid emissions. Conversely, using AAER likely underestimate GHG reductions when comparing the impacts of rooftop solar, which replaces electricity from the grid with that from the solar system. So, assuming rooftop solar has no emissions, the difference between grid emissions and solar electricity would be lower if AAER underestimates grid emissions.

The opposite is true for SRMER. As these tend to overestimate the amount of emissions on the grid in the long run, they likely underestimate actions that are measured against a natural gas baseline (e.g., heat pump water heaters) and overestimate actions that are measured against grid electricity supply as the baseline (e.g., PV). As a result of this uncertainty, EPIC presents results using both annual average and hourly marginal emission rates. This is not intended to represent the potential range of reductions, but rather to show how choice of emission rate can affect results.

Table 9 Impact of Electric Emission Rate on GHG Reduction Estimate

	Fossil Fuel Baseline		**Grid Electricity Baseline**
	Replace Natural Gas Water Heater with an Electric Heat Pump	Replace Gasoline Vehicle with an Electric Vehicle	Rooftop Solar Production Reduces Electricity Use from the Grid
Annual Average Emission Rate (AAER)	Overestimate GHG Impacts		Underestimates GHG Impacts
Hourly Short-Run Marginal Emission Rate (SRMER)	Underestimates GHG impacts		Overestimates GHG Impacts

3.3 Energy Usage Patterns for Buildings and Appliances

The energy usage pattern, or "load shape," of a building or appliance is a key input to estimate cost and GHG impact of project types. For analysis completed for this report, we used the California Energy Commission's California Building Energy Code Compliance (CBECC) model to derive load shapes both for baseline buildings and appliances and technologies that will be installed (e.g., heat pump water heater). We assumed that all projects would be in Climate Zone 7, which covers the City of Oceanside.[19]

There are several factors to consider when using the CBECC model. First, the model is designed to help new building proponents evaluate and demonstrate compliance with California's new building energy standards. As a result, the model evaluates new buildings, which may be more energy efficient than older buildings built either before introduction or in the earlier years of energy codes. This could understate the energy use and therefore the cost and GHG impacts of certain electricity-related project types. This is a limitation of the analysis presented here. There are significant advantages of using the CBECC model, including relative ease of use, many different building types and sizes that can be evaluated, the ability to conduct analysis by climate zone, and the range of energy improvements that can be modeled.

3.4 Benefit-Cost Analysis Methods

The benefit-cost analysis conducted for this project seeks to answers two important questions: (1) How cost-effectively a project type can reduce one metric ton of CO_2e? and (2) What are the financial impacts on the project owners or users? In general, the methods used follow those provided in the San Diego Regional Climate Action Planning (ReCAP) Framework Technical

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[19] California Energy Commission. Climate Zone tool, maps, and information supporting the California Energy Code. Available at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and.

Appendix III.[20] The section below, which is based on that document, summarizes the methods used in this analysis. The same method was used for all GHG reduction project types.

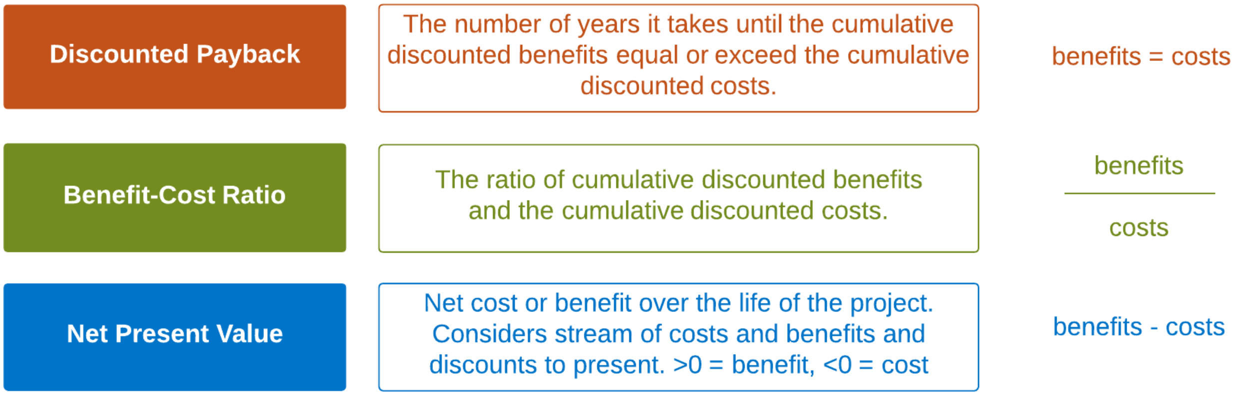
3.4.1 Cost Effectiveness

Understanding how cost effectively a project type can reduce a metric ton of CO_2e allows for comparison among measures. Results represent the net costs or benefits over the life of the project associated with a one metric ton of CO_2e reduced. Net costs and benefits are estimated using a net present value (NPV) calculation, which considers all the costs (e.g., installation, operation and maintenance, etc.) and benefits (e.g., utility bill savings) over the life of project. A positive NPV is a net benefit. This mean that benefits are greater than costs over the life of the project. Similarly, a negative number is a net cost, meaning that costs are greater than benefits over the life of the project.

3.4.2 Financial Impact to Project Owners

The financial impact to project owners is determined by several metrics (Figure 6). As mentioned above, NPV determines whether a project would result in a net cost or benefit over. This is a commonly used metric that can stand alone or be used to determine the cost or benefit associated with a metric ton of CO_2e reduced. We also use discounted payback to determine the number of years necessary for benefits to equal costs. Benefit-cost ratio (BCR) is another common metric to determine the financial potential of a project. BCR represent the ratio between cumulative discounted benefits and cumulative discounted costs. A BCR greater than 1 means that the project benefits are greater than the costs.

Figure 6 Benefit-Cost Analysis Metrics



Discounted Payback	The number of years it takes until the cumulative discounted benefits equal or exceed the cumulative discounted costs.	benefits = costs
Benefit-Cost Ratio	The ratio of cumulative discounted benefits and the cumulative discounted costs.	$\frac{\text{benefits}}{\text{costs}}$
Net Present Value	Net cost or benefit over the life of the project. Considers stream of costs and benefits and discounts to present. >0 = benefit, <0 = cost	benefits - costs

3.4.3 Perspectives

When analyzing the financial benefits and costs of GHG reduction project types, it is important to consider whose benefits and costs are being evaluated. For a typical project or program, there are multiple perspectives to consider, including the **administrator** of the program (e.g., a local government or organization), **participants** in the program (e.g., residents and businesses), and

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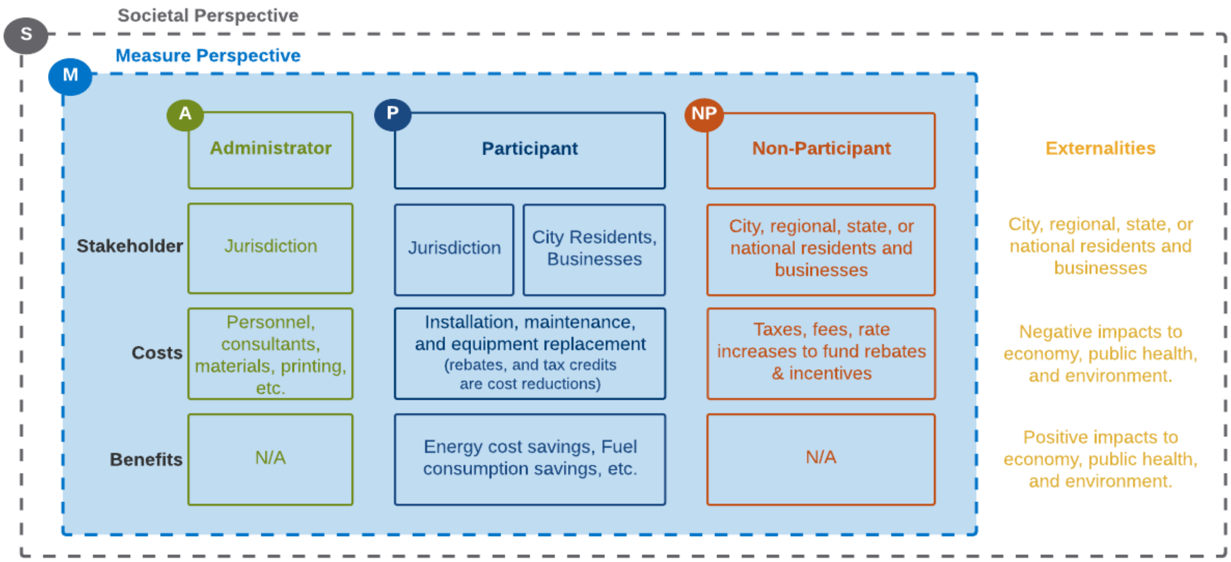
[20] San Diego Association of Governments. 2020. Regional Climate Action Planning Framework. Available at https://www.sandag.org/-/media/SANDAG/Documents/ZIP/projects-and-programs/recap-and-technical-appendices.zip.

those who pay the cost to subsidize certain activities, which we call **non-participants** (e.g., taxpayers or utility ratepayers). For example, if Preserve Calavera provided funding for a PV project, it would be considered one of the non-participants and it would be possible to determine how cost effectively the investment reduced a metric ton of CO_2e. The measure perspective, which combines these three main perspectives, allows for a more comprehensive view. Adding externalities to the measure perspective, which are not accounted for in the direct costs and benefits, provides a broader societal perspective.

For the analysis conducted in this project, we only consider the participant perspective. Figure 7 summarizes these perspectives and provides examples of who might be affected by a measure and provides examples of the respective financial benefits and costs.

Figure 7 Benefit and Cost Perspectives[21]



	Administrator	Participant	Non-Participant	Externalities
Stakeholder	Jurisdiction	Jurisdiction City Residents, Businesses	City, regional, state, or national residents and businesses	City, regional, state, or national residents and businesses
Costs	Personnel, consultants, materials, printing, etc.	Installation, maintenance, and equipment replacement (rebates, and tax credits are cost reductions)	Taxes, fees, rate increases to fund rebates & incentives	Negative impacts to economy, public health, and environment.
Benefits	N/A	Energy cost savings, Fuel consumption savings, etc.	N/A	Positive impacts to economy, public health, and environment.

3.4.4 Role of Subsides

There are numerous state and federal subsidies for the project types considered here. For example, the Inflation Reduction Act extended and expanded tax credits for a range of project types, including PV, battery storage, and heat pump technologies.[22] In addition, state programs like the Self-Generation Incentive Program (SGIP) also provide subsidies for related project types. We account for subsidies in our analysis and consider them cost reductions rather than benefits. Further discussion of the SGIP is in Section 9.3.2.1.

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[21] Ibid.

[22] U.S. Environmental Protection Agency. Summary of Inflation Reduction Act provisions related to renewable energy. Available at https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy.

4 SUMMARY OF RESULTS

This section summarizes the results from the GHG emissions reduction estimates and cost analysis completed for this project.

4.1 GHG Reduction Analysis

We conducted detailed analysis for a subset or project types that are related to electricity.

4.1.1 Electricity Related Project Types

For each project type, we estimated the GHG reduction from a representative project. The magnitude of the emission reductions is directly related to the scale of activity. For example, the building electrification project analysis assumes one representative home whereas the large high school solar PV would generate an amount of electricity many times more than required for a single home. At the same time, there are many more homes that could install electric appliance than schools that could install solar, so the total potential of project types also varies. In this way, the results in this section may not be directly comparable but provide some insight into the cost and magnitude of GHG reductions.

Table 10 summarize the GHG reduction estimates from electric-related project types using hourly SRMER and Table 11 summarizes results using an AAER. Table 11 does not include GHG reduction results for project types including battery storage, because it is not possible to estimate the impacts using an AAER. An hourly approach is needed to compare the rate of emissions when the batteries are being charged with the rate when the batteries are being discharged.

Table 10 Annual GHG Emission Reductions Using Hourly Short-Run Marginal Emission Rates

Project Type	2025	2030	2035
Residental Heat Pump Water Heater (Single Family)*	-0.3	-0.1	-0.1
Residential Electric Heat Pump HVAC (Single Family)	-0.1	-0.1	-0.1
Small Commercial Photovoltaics	8.6	6.1	4.6
Small Commercial Photovoltaics + Battery Storage	8.9	6.4	4.9
High School Photovoltaics	330	233	179
High School Photovoltaics + Battery Storage	615	444	344
Standalone Residential Energy Battery Storage (Single Family)	0.1	0.1	-0.01

*A negative value represents an increase in emissions.

Table 11 Annual GHG Emission Reductions Using Annual Average Emission Rates

Project Type	2025	2030	2035
Residental Heat Pump Water Heater (Single Family)*	0.3	0.4	0.5
Residential Electric Heat Pump HVAC (Single Family)	0.01	0.02	0.04
Small Commercial Photovoltaics	5.2	4.0	2.5
Small Commercial Photovoltaics + Battery Storage	N/A	N/A	N/A
High School Photovoltaics	198	152	95
High School Photovoltaics + Battery Storage	N/A	N/A	N/A
Standalone Residential Energy Battery Storage (Single Family)	N/A	N/A	N/A

*It is not possible to estimate the impact of battery storage using an annual average emission rate.

As described in Section 3.2.2, for project types related to electricity, we estimated GHG emissions reductions using two different electric emission rates: hourly short-run marginal and annual average. As noted in Table 9, while SRMER may better reflect actual grid emissions in the short run, our results show that using SMER likely overestimates GHG reductions from PV and underestimates GHG impacts of switching from natural gas to electric appliances *in the long-run*. Conversely, using an AAER likely overestimates GHG reductions from residential building electrification and underestimates impacts from PV. This is because short-run marginal emission rates are on average higher than annual average because they assume rates are based on the plant that would serve the next unit of electricity needed, which in many hours through 2045 are still natural gas. Table 12 compares estimated GHG impacts for each emission rate type for 2030.

Table 12 Comparison of GHG Results for 2030 Using Different Electric Emission Rates

Project Type	Short-Run Marginal Emission Rate (MT CO_2e Reduced)	Annual Average Emission Rate (MT CO_2e Reduced)
Residental Heat Pump Water Heater (Single Family)*	-0.14	0.37
Residential Electric Heat Pump HVAC (Single Family)*	-0.05	0.02
Small Commercial Photovoltaics	6.08	4.02
Small Commercial Photovoltaics + Battery Storage**	6.37	N/A
High School Photovoltaics	233	152
High School Photovoltaics + Battery Storage**	444	N/A
Standalone Residential Energy Battery Storage (Single Family)**	0.1	N/A

* A negative value represents an increase in emissions.

** It is not possible to estimate the impact of battery storage using an annual average emission rate.

4.1.2 Other Project Types

No detailed GHG analysis was completed for other project types. Section 10 provides a summary of the literature review and qualitative evaluation of these project types.

4.2 Cost Analysis

We estimated how cost effectively each project type could reduce a MT CO_2e and the financial impacts to project owners and users.

4.2.1 Electricity Related Project Types

Table 13 summarizes the results for project types that are related to electricity. It shows results for benefit-cost ratio, discounted payback, and the cost to reduce a MT of CO_2e using both electric emission rates. For residential heat pump technology, the net present value over the life of the project is negative. In this case, there are no financial benefits to installing new technology, so no BCR or payback can be calculated. This is, in part, because switching from natural gas appliances to electric heat pump technologies leads to higher energy bills.

Residential heat pump water heaters cost more than natural gas storage versions; thus, the upfront cost is higher and the ongoing cost to operate is higher. This leads to a negative net present value, and hence, a net cost of several thousand dollars per MT reduced (at least using the AAER). Alternatively, the cost to replace both a natural gas furnace and electric air conditioner with an electric heat pump HVAC system is lower. Even with a higher operating cost, the difference in upfront costs contributes to a positive net present value over the life of the project. This results in a net benefit of nearly $5,000 per MT CO_2e reduced. Table 14 summarizes the upfront and incremental costs of the project types analyzed here.

Further, because using SRMER shows a slight increase in emissions from switching to heat pump technologies, it is not possible to show cost effectiveness results (NPV/MT CO_2e) because no GHG reductions occur.

All PV project types, including those with battery storage, had a BCR higher than one, meaning benefits are higher than costs over the life of the project. They also have relatively short payback times (5–8 years) relative to the project life of 25 years. For each MT of CO2e reduced, a PV project has a net benefit over this period. By contrast, standalone battery storage projects are estimated to have BCR above one but a payback close to the project life of 15 years. Note that these results do not reflect the most December 2023 CPUC clarification of the net billing tariff regulation.

Table 13 Summary of Benefit-Cost Analysis Results

Project Type	Benefit-Cost Ratio	Discounted Payback (years)	NPV/MT CO2e Reduced (SRMER)**	NPV/MT CO2e Reduced (AAER)
Residential Heat Pump Water Heater (Single Family)*	N/A	N/A	N/A	(3,166)
Residential Electric Heat Pump HVAC (Single Family)	N/A	N/A	N/A	4,789
Small Commercial Photovoltaics	2.24	5	468	800
Small Commercial Photovoltaics + Battery Storage	1.44	7	261	474
High School Photovoltaics	1.90	6	310	540
High School Photovoltaics + Battery Storage	1.64	8	274	514
Standalone Residential Energy Battery Storage (Single Family)	1.21	10	1,230	N/A

*Total upfront cost/incremental cost compared to baseline appliance.

**These values cannot be reported for heat pumps since they increase emissions in our analysis.

Table 14 Upfront and Incremental Project Costs

Project Type	Upfront Cost before Incentives	Incremental Cost*
Residential Heat Pump Water Heater (Single Family)**	2,470	800
Residential Electric Heat Pump HVAC (Single Family)**	14,170	(3,150)
Small Commercial Photovoltaics	60,270	N/A
Small Commercial Photovoltaics + Battery Storage	92,100	N/A
High School Photovoltaics	2,105,400	N/A
High School Photovoltaics + Battery Storage	4,804,596	N/A
Standalone Residential Energy Battery Storage (Single Family)	10,000	N/A

*The incremental cost is the cost between traditional appliances and heat pump technology.

**Natural gas storage water heater, and natural gas furnace and traditional air conditioner for heating and cooling are used as baseline.

4.2.2 Other Project Types

We did not complete a detailed cost analysis for PV on multifamily, wetland restoration, or other habitat restoration. Further research would be needed.

5 OPT-UP CARE AND FERA CUSTOMERS TO 100% CARBON-FREE ELECTRICITY

5.1 Project Overview

Investor-owned utilities and community choice aggregation programs offer a range of service options that have differing levels of renewable or carbon-free electricity supply (Table 15).[23]

Table 15 Renewable and Zero Carbon Content of Retail Electric Suppliers in the San Diego Region[24]

Retail Suppliers	Eligible Renewables	Zero Carbon	Other	Total
Clean Energy Alliance - Clean Impact Plus	52.1%	22.6%	25.2%	100.0%
Clean Energy Alliance - Clean Impact	50.0%	0.0%	50.0%	100.0%
Clean Energy Alliance - Green Impact	100.0%	0.0%	0.0%	100.0%
San Diego Community Power - PowerOn	54.9%	11.8%	33.3%	100.0%
San Diego Community Power - Power100	100.0%	0.0%	0.0%	100.0%
San Diego Gas & Electric Company	44.5%	2.0%	53.5%	100.0%
San Diego Gas & Electric Company - EcoChoice	100.0%	0.0%	0.0%	100.0%

Customers receive power from the default service option and can choose to switch – or "opt -up" – a higher level of renewable or carbon-free content. In general, these cleaner service options cost more than the default. One option to use grant funding to increase carbon-free electricity supply is to pay the cost to opt-up low-income qualified electric customers. There are existing income-qualified programs, including California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs, that provide discounts on utility bills.[25] Under the CARE program, qualified customers can receive an energy bill discount of 30% or more. Eligibility for CARE is determined by either eligibility for another income-qualified program (e.g., CalFresh (Food Stamps) and SNAP, CalWORKs (TANF) or Tribal TANF, or Head Start Income Eligible (Tribal Only)) or meeting certain income eligibility thresholds (Table 16). FERA qualified customers can receive an 18% discount.

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[23] Note that energy service providers that sell to customer under direct access are not listed here. Data is not available on the specific companies supplying customers or the amount supplied to customers in the San Diego region.

[24] Eligible renewables comprise biomass and biowaste, geothermal, eligible small hydroelectric, solar, and wind. Zero carbon resources comprise large hydroelectric and nuclear. Other includes coal, natural gas, and unspecified power.

[25] https://www.sdge.com/residential/pay-bill/get-payment-bill-assistance/assistance-programs.

Table 16 CARE Program Income Guidelines[26]

Number in Household	Income Eligibility Upper Limit*
1-2	$39,440
3	$49,720
4	$60,000
5	$70,280
6	$80,560
7	$90,840
8	$101,120
Each add'l member	$10,280

*Upper limit calculation = 200% of Federal Poverty Guidelines

Because Preserve Calavera is primarily interested in projects located in the City of Oceanside, we focused on Clean Energy Alliance's (CEA). The concept of opting up CARE and FERA customers to Clean Energy Alliance's (CEA) 100% renewable electricity service option appears attractive at first glance. It appears to be simple, cost-effective, equity-focused, and have low transaction costs. However, the idea is more complicated upon further analysis. The findings from our preliminary analysis of this project type suggest that unless new carbon-free capacity is added to the grid because customers opted up, this approach may not achieve GHG emission reductions.

5.2 Methods

We did not complete a detailed GHG or cost analysis; rather, we did a mostly qualitative analysis to determine whether such a program could result in GHG reductions.

5.3 Results

5.3.1 GHG Reduction Analysis

We did not complete a detailed GHG analysis for this project type due, in part, to lack of data for electricity procurement and dispatch. Instead, we completed a more qualitative analysis to determine whether it would be possible to achieve GHG reductions by opting up CARE and FERA customers. Two key points emerged: GHG reductions likely only would occur if new renewable or carbon-free generation capacity was added, and the GHG accounting methods used to estimate impact of changing to a higher renewable content service option would affect any results.

5.3.1.1 New Generation Capacity

Based on preliminary analysis, it appears that to ensure that this action would lead to emission reductions, it would be necessary to add new renewable electricity generation. We assume that if

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[26] Effective June 1, 2023 to May 31, 2024. See https://www.sdge.com/residential/pay-bill/get-payment-bill-assistance/assistance-programs#overview.

new capacity is not built and the additional supply comes from existing plants, no additional GHG emissions reductions occur because the renewable electricity was already being produced. This logic is like additionality, a concept to determine whether an action leads to GHG reductions that would not have happened anyway and only happened because of the action under consideration.

To understand whether there is a GHG reduction, we focus on the physical reality of the electric system in the California Independent System Operator area (about 80% of California); that is, what physical changes to the grid structure and operations would occur because a portion of customers was opted up to a 100% renewable electricity service option. Depending on procurement levels, moving customers to a service option that has a higher renewable or carbon-free electricity content may not reduce GHG emissions. For example, if a retail supplier has over procured renewables, then additional renewable procurement could be allocated to the customer that opt up. Because of this uncertainty, the burden of proof is on the retail supplier. If a retail supplier could ensure that it would build or invest in new capacity to serve the additional demand for renewable electricity caused by Preserve Calavera's short-term commitment to opt-up CARE/FERA customers, this strategy could reduce emissions. Otherwise, for our purposes here, we assume that if no additional generation capacity is added, no GHG reductions occur.

Further, even if Preserve Calavera could invest in this strategy, it is not clear whether such investment would provide a strong enough financial signal to invest in new renewable electricity capacity. For example, if Preserve Calavera could support such a program for 1–3 years ($600,000 – $1.8M), the commitment may not be long enough to justify building a new plant.

5.3.1.2 GHG Accounting Methods

The GHG impact also may differ depending on the GHG accounting method used. There are three methods to account for emissions in this case: energy or volumetric matching, emissions matching, and hourly energy matching[27] (Table 17). Using the **energy matching** method, which is generally how load-serving entities in California track the percentage clean energy supplied, the percentage of carbon-free electricity is calculated by comparing the total amount purchased and the total amount of electricity supplied to customers, regardless of when it was delivered. So, for example, if a supplier have a total demand of 1,000 MWH and delivers an equal amount of carbon free electricity supply, the supplier would claim to be 100% carbon-free supply (and have zero emissions); however, there would be hours of the year when the carbon-free supply does not match up with the customer demand, which would result in net emissions. The **hourly matching** approach seeks to match carbon-free supply with demand for every hour of the year. Under this method, a supplier likely would have to over procure during certain times of the day and use energy storage to fill times when carbon-free electricity is either not producing or not producing enough to cover customer demand.[28] The **emissions matching** option is the most complicated of the three. Under this approach, emissions reductions from purchasing carbon-free electricity are used to offset emissions from consuming electricity. The emissions avoided from purchasing carbon-free electricity would be determined by the SRMER in the location of the power plant. The emissions induced by electricity consumption would be determined by the SRMER of the supplying grid. The

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[27] Xu, et al. September 2023. System-level Impacts of Voluntary Carbon-free Electricity Procurement Strategies. Working Paper.

[28] See. J. Pepper, et al. January 2023. Achieving 24/7 Renewable Energy by 2025. Peninsula Clean Energy.

relationship between these would determine the emissions impact. In this way, the GHG reductions from a smaller amount of electricity from a carbon-free supplier located in a relatively dirty grid (i.e., high SRMER) could be used to offset a larger amount of consumption in a relatively cleaner grid (i.e., low SRMER). As an example, the local emissions impacts from a wind project in an area that has a high proportion of coal-fired electricity supply could be used to offset the emissions impacts of electricity consumption in California, a relatively clean grid.

Table 17 Accounting Methods for Carbon-Free Electricity Procurement

Energy Matching	Comparing an amount of carbon-free electricity supply to total consumption, regardless of when it is generated/consumed
Hourly Matching	The amount of carbon-free electricity supply equals consumption during every hour of the year
Emissions Matching	Emission reductions from carbon-free electricity offsets the emissions from electricity consumption

A Working Paper from a team of researchers[29] estimated the GHG impacts of these three methods on corporate purchasing strategies, which is analogous to the opt-up approach. They found that "in the current U.S. policy environment, both volumetric [energy] and emissions matching procurement strategies drive little to no change in system-level CO_2 emissions compared to counterfactual scenarios where no voluntary procurement occurs." The paper further concludes that "[b]y contrast, our results indicate that temporal [hourly] matching does consistently drive reductions in system-level CO2 emissions.[30] For our purposes here, this suggests that comparing hourly demand and supply would be necessary to estimate the GHG reductions from electric purchasing strategies.

And, regardless of the methods used, as the grid gets cleaner over time, and as more hybrid plants that combine renewable generation and energy storage are added, the impact of customers opting up to cleaner service options will decline.

5.3.2 Cost Analysis

CARE/FERA customers represented about 20% of CEA total sales in 2021, which is a significant portion of customers. Based on the incremental cost to opt-up to the 100% renewable electricity service option reported in the SDG&E-CEA Joint Rate Comparisons,[31] the annual cost of moving

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[29] Researchers from Tsinghua University, Princeton University, and Binghamton University.

[30] Xu, et al. September 2023. System-level Impacts of Voluntary Carbon-free Electricity Procurement Strategies. Working Paper.

[31] SDG&E-CEA Joint Rate Comparisons for SDG&E rates effective January 1, 2023, and CEA rates as of February 1. 2023.

CARE and FERA customers to this option would be about $600,000. This initial cost analysis assumes that the cost to opt up is fixed at rates provided in the Joint Rate Comparison.

Since very few customers opt up to the 100% service option, it is not clear how the associated cost would change if 20% of sales opted up. While renewable electricity costs have declined over time, our understanding is that there is little available renewable capacity available and delays in interconnection, permitting, equipment availability are slowing the number of projects being completed. It is not clear how future costs to procure renewable electricity would affect the cost to opt up CARE and FERA customers.

5.4 Limitations and Need for Future Analysis

We acknowledge the following limitations and topics for further study.

- **No Actual Energy Usage Data** – EPIC does not have access to CEA's actual energy usage. Using historic load shape data to do a more detailed analysis, would improve the resolution and applicability of the results provided here.

- **No Actual Supply Contracts and Dispatch Data** – EPIC does not have access to CEA supply contracts or dispatch patterns of those resources. Findings presented here are based on a general understanding of electricity procurement and GHG emissions attribution accounting.

- **GHG Analysis of Supply Portfolio** – We did not estimate the GHG impacts of moving customers from one service option to another. To understand the GHG impact of customers opting up, a more detailed analysis of a retail electric supplier's portfolio would be necessary. For each electricity service option, it would be necessary to estimate the hourly load shape of the electricity usage for the entire customer base, estimate the hourly dispatch of contracted resources as reported as part of the CEC Power Source Disclosure program (or using data from the retail electricity supplier), and determining the hourly match between the customer usage and generation. Comparing the GHG emissions from the default service option to one with a higher renewable electricity or carbon-free content would yield the GHG impacts.

6 HEAT PUMPS IN SINGLE FAMILY BUILDINGS

Building electrification generally refers to replacing fossil fuel combustion appliances used for water heating, space heating and cooling, cooking, and clothes drying with heat pump or electric alternatives. We did not include onsite generation from rooftop PV in our analysis nor did we analyze a whole home electrification scenario. Sections 7, 8, 10.1 summarize results for solar PV projects.

6.1 Project Overview

For this project type, we estimated the energy, cost, and GHG emission impacts of installing electric heat pumps for water heating and space heating and cooling. Specifically, we estimate the impacts of replacing a natural gas storage water heater with an electric heat pump and replacing a mixed fuel space heating and cooling system (i.e., natural gas furnace for heating and an electric air conditioner for cooling) with an electric heat pump heating and cooling system. Additional analysis would be needed to estimate the impacts of induction cooktops and heat pump clothes dryers. We focused on water heating and space heating and cooling in part because the San Diego Regional Decarbonization Framework Technical Report highlighted that water heating and space heating and cooling are the primary targets for early electrification efforts.[32]

6.2 Methods

We used building and appliance energy load shapes from the CEC CBECC model for a representative single-family home in climate zone 7, which includes all of Oceanside. Like our other analysis related to electricity, we used both an annual average and hourly approach for electricity GHG emission rates. We use hourly analysis to determine consumption and cost impacts.

For the cost analysis, we also included the impact of financial incentives, like the federal tax credits for heat pumps and other appliances, and used common rates (e.g., TOU-DR1 for electric).

6.2.1 Key Assumptions

Table 18 summarizes the key assumptions used in the analysis for electric heat pump technology.

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[32] McCord, Gordon C., et al. San Diego Regional Decarbonization Framework: Technical Report. County of San Diego, California. 2022. See Section 4. Available at https://www.sandiegocounty.gov/content/sdc/sustainability/regional-decarbonization/reports.html.

Table 18 Key Assumptions for Heat Pump Project Analysis

INPUTS	USED IN ANALYSIS	REFERENCE
Model		CEC CBECC Model 2022
Building load shape	CBECC Model	
Building size	2,100 SqFt	
Building type	Single-family	
New construction vs. existing building	New construction load shape	
GHG Emissions		
	Hourly SRMER	CPUC Avoided Cost Calculator 2022
	Annual average	EPIC 2023
Rate Structure		
Residential Time-of-use Plans	TOU-DR1	SDG&E Schedule TOU-DR1, 2023
BCA		
Heat pump space heating/cooling	$14,170	Electrify San José, 2022
Heat pump water heater	$2,470	Electrify San José, 2023
Incentives	Federal Tax Credit	EPA Website
Discount rate	5%	N/A
Appliances		CEC CBECC Model 2022
Heat pump space heating/cooling system	Type: PkgHeatPump	
	Efficiency metric: HSPF2/SEER2/EER2	
	Performance: HSPF2-7.5; EER2-11.7	
Conventional gas heating system	Type: PkgGasFurnace	
	AFUE: 81%	
Conventional cooling system	Type: PkgAirCond	
	Efficiency metric: SEER2-14.3/EER2-11.7	
	Refrigerant type: R410A	
Heat pump water heater	Model UEF 2 (50 gal)	
Gas water heater	UEF 0.63 (50 gal), Model WHAM (0.641858)	

6.3 Results

6.3.1 GHG Reduction Analysis

Based on analysis for this project, GHG impacts of replacing natural gas technologies with heat pump alternatives could modestly increase or decrease emissions, depending on the electric emission rate used. Table 19 shows GHG emissions reduction estimates for both residential heat pump water heaters and heating and cooling (HVAC) systems.

Table 19 GHG Reductions Using Hourly Short-Run Marginal Emission Rates (MT CO2e)

Project Type	2025	2030	2035
Residential Heat Pump Water Heater (Single Family)*	-0.3	-0.1	-0.1
Residential Electric Heat Pump HVAC (Single Family)*	-0.1	-0.1	-0.1

*A negative value represents an increase in emissions.

Table 20 presents results from analysis using the annual average emission rates. In this case, there is a modest reduction in emissions, particularly from HVAC systems.

Table 20 GHG Reductions Using Annual Average Emission Rates (MT CO_2e)

Project Type	2025	2030	2035
Residential Heat Pump Water Heater (Single Family)	0.3	0.4	0.5
Residential Electric Heat Pump HVAC (Single Family)	0.01	0.02	0.04

The sections below discuss some factors that contributed to these results.

6.3.1.1 Load Shape and Hourly Emissions

The electric usage patterns of many of the appliances evaluated for this project type generally coincide with the times when emissions rates are high. Figure 8 shows total emissions by hour in the CAISO territory in metric tons per hour.[33] Figure 9 shows the total annual energy use by hour for a heat pump water heater. The highest electricity usage for a heat pump water heater according to the CEC CBECC model occurs from 4:00 a.m. –8:00 a.m., which coincides with emissions levels of about 8,000 MT CO_2/h. There is also another spike in usage in the evening, which matches the highest level of emissions around 12,000 mt/h. Note that we used a different source in our analysis for electric emissions but show this for illustrative purposes. The energy usage pattern is similar for heat pump HVAC (heating and cooling). These results are for single-family homes in climate zone 7; results may differ for analysis using different climate zones and building types.

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[33] Note this is not an emissions rate per unit of energy and only shows the CO_2 emissions. Emissions rates described in Section 3.2 are MT CO_2e/MWh.

Figure 8 GHG Emissions in CAISO Territory

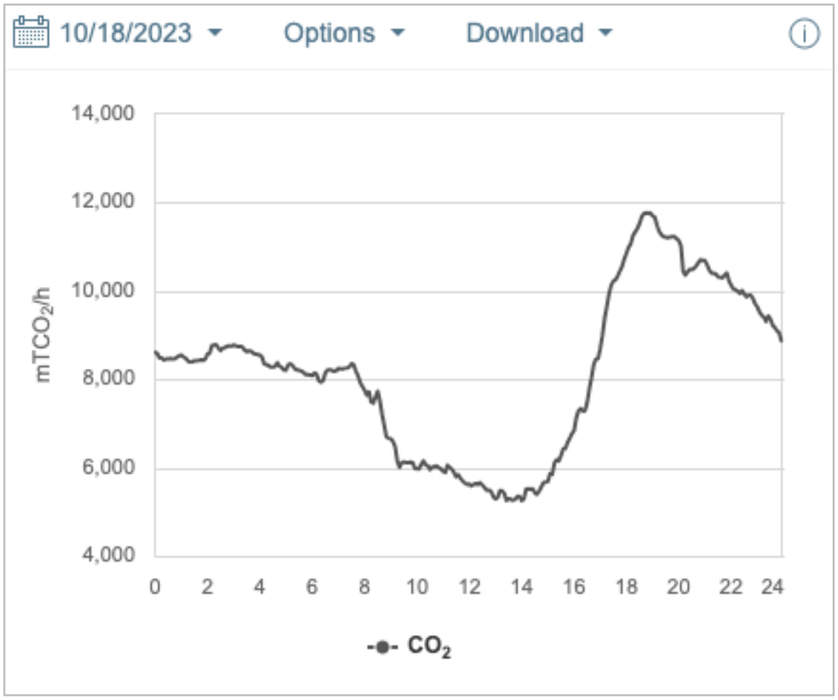
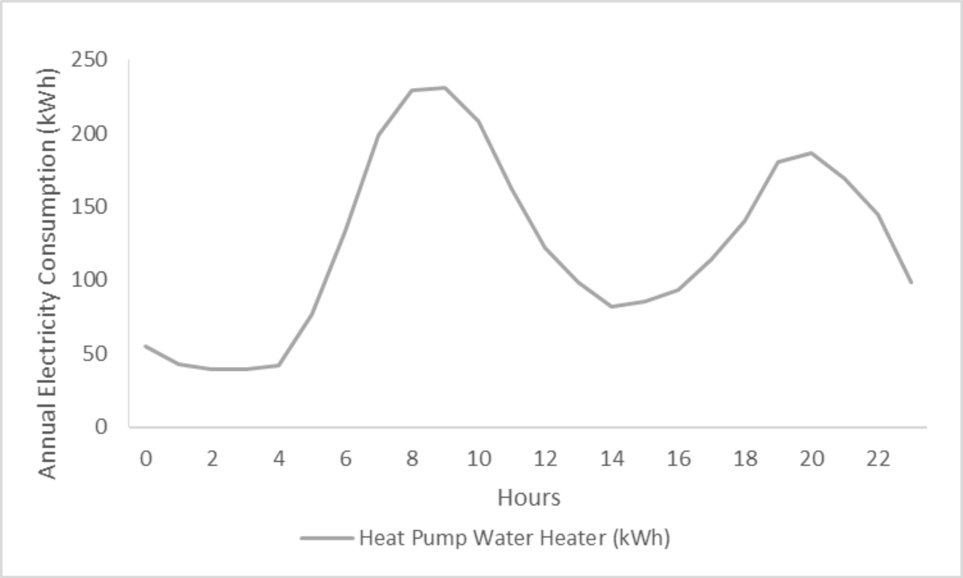


Figure 9 Load Shape of a Heat Pump Water Heater in a Single-Family Residential Building



6.3.2 Cost Analysis

Electric heat pump HVAC (heating and cooling) was the only option that appears to be cost effective in our initial findings (Figure 10). It had a benefit-cost ratio (BCR) greater than 1, meaning benefits were greater than costs over its lifetime. All other appliances we looked at were not cost effective (BCR <1). In general, the alternative heat pump and electric equipment is more expensive and costs more to operate, since electricity rates are high, particularly in the evening. The TOU-DR1 summer peak rate is about $0.80/kWh. Switching to electric versions increases electricity bills, so unless the equipment costs less than that being replaced, it will not be cost effective. Also, we did not include the cost of panel upgrades, assuming instead that an electric panel upgrade would only be needed for a whole house electrification scenario (not analyzed here). If any of the separate appliances needed a panel upgrade, cost effectiveness would be negatively affected.

Figure 10 Results of Cost Analysis for Heat Pumps in Single-Family Buildings

Project Type	Benefit-Cost Ratio	Discounted Payback (years)	CO2e Reduced (SRMER)*	NPV/MT CO2e Reduced (AAER)
Residential Heat Pump Water Heater (Single Family)	N/A	N/A	N/A	(3,166)
Residential Electric Heat Pump HVAC (Single Family)	N/A	N/A	N/A	4,789

*These values cannot be reported for heat pumps since they increase emissions in our analysis.

6.4 Limitations and Need for Future Analysis

We acknowledge the following limitations and topics for further study.

- **Load Shapes Are from a New Building Model** – Building and appliance load shapes are taken from the California Energy Commission's California Building Energy Code Compliance model, which is intended to analyze new buildings. Because new buildings are likely more efficient than older ones, the results presented here could underestimate the GHG reductions from heating and cooling. Older homes may not be as well insulated as newer homes, or they may not have any insulation. Future analysis could consider using load shapes for existing buildings.

- **Analysis Does Not Include Heat Pump Clothes Dryers and Induction Cooktops** – Future analysis could include other appliances like heat pump clothes dryers and induction cooktops. This would allow comparison to additional appliances and provide an estimate for a whole house electrification scenario.

- **Analysis of Total Fossil Fuel Replacement** – While heat pump technologies may not be cost effective at this time according to the parameters of our analysis, there is some evidence that, in certain cases, considering both building and transportation energy, electrification can have a net cost reduction.[34] Considering this was outside the scope of the analysis here but future analysis could estimate the GHG and cost impacts of replacing all fossil fuel consumption associated with a range of residential household types, and varying building type and income level. Similarly, we did not analyze the impacts of whole home electrification. This is also a potential topic of future study.

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[34] California Public Utilities Commission. 2021. Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates and Equity Issues Pursuant to P.U. Code Section 913.1. See Section 3.6. Available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf.

- **Impact of Methane and Refrigeration Leaks** – This analysis focuses on the change in natural gas and electricity consumption from switching to heat pump technology for water heating and space heating and cooling. It does not consider the impact of upstream methane leaks in the natural gas system, nor does it consider the GHG impact of potential refrigeration leaks from heat pump appliances and equipment.[35]

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[35] For an example of analysis that included methane and refrigerant leakage, see Energy and Environmental Economics (E3), December 2023. Benefit-Cost Analysis of Targeted Electrification and Gas Decommissioning in California: Evaluation of 11 Candidate Sites in the San Francisco Bay Area (California Energy Commission: PIR-20-009).

7 PHOTOVOLTAICS ON A HIGH SCHOOL

7.1 Project Overview

This project type would install both solar PV only and PV with battery storage on a high school. When storage is included, the analysis assumes the system owner would maximize bill savings.

7.2 Methods

The following summarizes the main assumptions, data, and methods used to estimate cost and GHG impacts of this project type.

- **Building Electricity Usage Data** – For this analysis, EPIC used actual hourly electricity usage data for a high school.
- **PV System Size** – We considered a range of PV system sizes, from meeting 20% up to 110% of the total annual building energy consumption.
- **Battery Behavior Modeling** – We developed a comprehensive model to simulate the behavior of the battery system. The model is based on hourly energy use patterns, PV generation profiles, and storage capacity. It forecasts how the battery will discharge during peak demand periods and charge during periods of surplus PV generation.
- **Rate Structures** – The high school we modeled take electric service on the AL-TOU rate structure. We modeled the cost impact of installing PV using the DG-R rate structure, which is more advantageous for customers with solar PV due to lower demand charges and higher volumetric rates. SDG&E Net billing tariff (NBT) export rates for bundled customers were used to determine the value of electricity exported to the grid. Note that SDCP recently adopted the same base NBT export rates as SDG&E but will have adders to improve the payback.[36] Also, the CPUC recently clarified the method for estimating the amount of export credits under NBT and modified the Virtual Net Energy Metering (VNEM) tariff (Section 7.2.1.1).[37] Results here do not reflect these recent changes.
- **Cost-Effectiveness Estimates** – EPIC integrated building energy consumption with PV and storage, GHG emissions, and electric rate structures to calculate the financial impact to the school – including benefit-cost ratio and payback, and cost to reduce a metric ton of carbon dioxide equivalent (MT CO2e).
- **Sensitivity Analysis** – We identified the most cost-effective option of PV only by evaluating different-sized systems and maximizing self-consumption during evening hours for PV with battery.
- **System Performance Degradation –** Our analysis considers the annual degradation of system performance. The PV system experiences about 30% production degradation over its 25-year lifespan.

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[36] Adoption is summarized on PDF p. 8 of the November meeting agenda at https://sdcommunitypower.org/wp-content/uploads/2020/12/00.-Agenda-Packet-11.16.23-BOD-3.pdf. The original proposal is summarized starting on PDF p. 151 of the October 26, 2023 agenda at https://sdcommunitypower.org/wp-content/uploads/2020/12/00.-Agenda-Packet-11.16.23-BOD-3.pdf.

[37] California Public Utilities Commission. December 2023. Resolution E-5301. Establishment of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company Net Billing Tariffs as Directed by Decision 22-12-056.

7.2.1 Key Assumptions

Table 21 summarizes key assumptions used for PV on High Schools.

Table 21 Key Assumptions for PV Only and PV with Battery Storage Analysis

INPUTS	USED IN ANALYSIS	REFERENCE
Model		
Building load shape	15-minute increment energy use data	SDG&E Green Button 2022-2023
PV system size (PV-only)	638 kW	CEC CBECC Model 2022
PV system size (PV + Battery)	1,155 kW	CEC CBECC Model 2022
Battery capacity (PV + Battery)	936 kWh	CEC CBECC Model 2022
Climate zone	CZ07	
Simulation goal	PV-only: achieve a high benefit-cost ratio across different PV sizes PV & battery: offset evening consumption	
GHG Emissions		
	Hourly SRMER	CPUC Avoided Cost Calculator 2022
	Annual average	EPIC 2023
Rate Structure		
Commercial/Industrial rates	DG-R (Distributed Generation Renewable)	SDG&E Schedule DG-R, 2023
	AL-TOU (General Service - Time Metered)	SDG&E Schedule AL-TOU, 2023
	Net Billing Tariff (NBT) export rates	SDG&E Advice Letter 4155-E-A
BCA		
PV installation cost	$3,300/kW	LBNL, Tracking the Sun, 2022
Battery installation cost	$1,061/kWh	LBNL, Tracking the Sun, 2022
Incentives	Self-Generation Incentive Program (SGIP)	Self-Generation Incentive Program
	The investment tax credit (ITC)	Federal Solar Tax Credits for Businesses
Operation and maintainance cost	Inverter replacement $300/kW	Verdant, NEM 2.0 Lookback Study, 2021
Discount rate	5%	N/A

7.2.1.1 Virtual Net Energy Metering Reforms Applicable to Schools

The CPUC issued a reformed Decision that changed the compensation for VNEM to follow the net billing tariff (NBT) adopted in late 2022 to favor onsite consumption and use of batteries that load shift. The analysis conducted for this report assumed the NBT structure is required for projects that do not use the VNEM tariff. As a result, the results of our analysis are consistent with these latest changes to VNEM.

Based on the recent CPUC Decision, nonresidential customers — such as schools — will now follow a new net billing Aggregation Subtariff that only allows credits based on avoided cost calculator export value of exported electricity with no netting against imported electricity. The CPUC ordered SDG&E to implement the Aggregation Subtariff no later than March 31, 2025, with the previous VEMA available on an interim basis until the new Aggregation Subtariff is adopted and a 90-day sunset period from the 11/16/23 date of the decision for current customers to enroll in the original VEMA tariff ends.

The CPUC determined that the NBT should be applied in the aggregation factual situation for nonresidential customers with the following elements: an ACC Plus as a nine-year glide path (which excludes an adder for SDG&E service territory), no netting, net surplus compensation (as calculated under the net billing tariff), and continuance of the credit and debit approach used in the current NEMA subtariff.

Besides the annul true-up to determine whether net surplus compensation is owed under the existing NEMA subtariff, the new Aggregation subtariff will have no netting. All generation sent to the grid will receive Avoided Cost Calculator-based retail export compensation and all consumption will be charged at the applicable consumption retail rate. However, the absence of netting will not prevent self-consumption at the generating account, i.e., the meter located on the same property as the customer-generator. Additionally, the Commission allowed for one set of differences from the net billing tariff specific to aggregation: the credit and debit provisions, crediting methodology, and annual true-up will remain the same as the current NEMA subtariff, but the allocation of credits and debits will be provided in dollars (i.e., bill credits) rather than in kilowatt-hours.

The current NEMA subtariff will remain intact with no changes for currently enrolled customers until the end of their current legacy period, including if energy storage systems are added by existing enrolled customers. There is a 90-day sunset period from the 11/16/23 decision date before the interim period begins that will result in all new aggregation customers interconnecting after the sunset period to be placed on the new Aggregation subtariff. SDG&E is mandated to implement an Aggregation successor subtariff by March 31, 2025.

7.3 Results

7.3.1 GHG Reduction Analysis

As noted above, using hourly SRMER will overestimate GHG reductions from PV projects and using an AAER likely underestimates GHG impacts. In general, adding battery storage to PV projects results in higher GHG reductions. Table 22 and Table 23 summarize results. It is not possible to estimate GHG impacts from projects with battery storage, since GHG reductions results form the difference in emission rate when charging and discharging. This is not possible using an AAER; therefore, we do not report any results for combined PV and battery storage in Table 23.

Table 22 GHG Reductions Using Hourly Short-Run Marginal Emission Rates (MT CO_2e)

Project Type	2025	2030	2035
High School Photovoltaics	330	233	179
High School Photovoltaics + Battery Storage	615	444	344

Table 23 GHG Reductions Using Annual Average Emission Rates (MT CO_2e)

Project Type	2025	2030	2035
High School Photovoltaics	198	152	95
High School Photovoltaics + Battery Storage*	N/A	N/A	N/A

*It is not possible to estimate the impact of battery storage using an annual average emission rate.

7.3.2 Cost Analysis

In general, installing solar PV on a High School can be cost-effective with the Federal Solar Tax Credits (ITC) and incentives for battery storage. Table 24 summarizes the cost analysis results for PV with and without storage. Both types have a BCR greater than one, which means benefits are greater than costs over the life of the project. Similarly, payback ranges from 6 to 8 years. Nonetheless, high upfront cost remains a potential barrier for large PV projects. The upfront cost of the PV system analyzed here, excluding ITC and Self-Generation Incentive Program (SGIP), would be roughly $2 million, while for PV with battery storage, it's approximately $5 million. Over the life of the project, both system types have a net benefit from about $270 to $310 for every metric ton of GHG reduction.

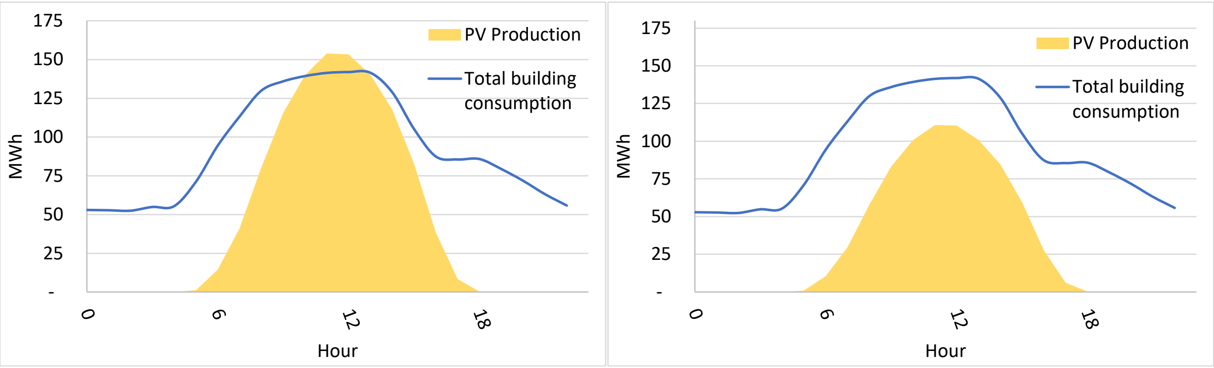
Table 24 BCA Results for Photovoltaics on a High School

Project Type	Benefit-Cost Ratio	Discounted Payback (years)	NPV/MT CO2e Reduced (SRMER)	NPV/MT CO2e Reduced (AAER)*
High School Photovoltaics	1.90	6	310	540
High School Photovoltaics + Battery Storage	1.64	8	274	N/A

*It is not possible to estimate the impact of battery storage using an annual average emission rate.

For the PV only scenario, we found that a 638 kW PV system, which would cover about 50% of total consumption in year 1, would be cost-effective over the life of the project. As system size increases past this point, however, projects become less cost-effective because after meeting the school's demand, the excessive PV generation is exported to the grid and compensated at relatively low export rates.

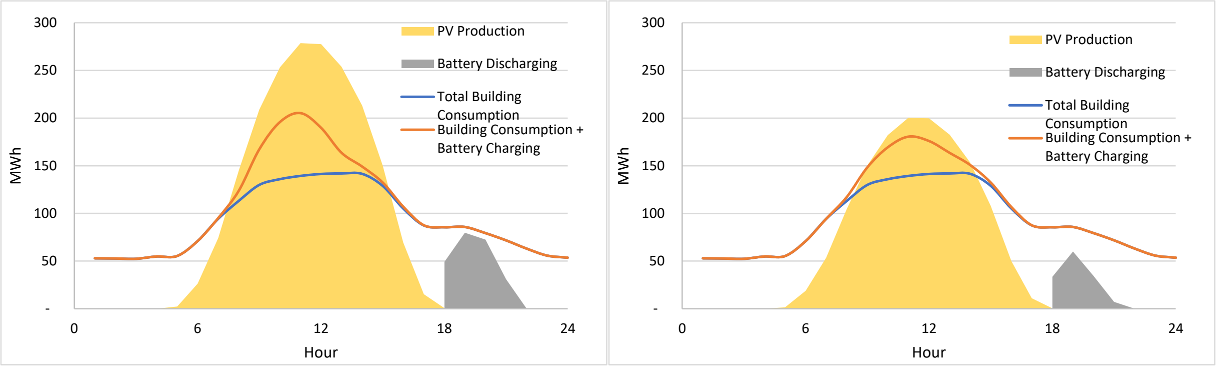
Figure 11 (a) PV generation in the first year and (b) PV generation in year 25 after system degradation



(a) (b)

Figure 2 illustrates PV and storage discharging patterns in the first year and 25 years, accounting for system degradation in both PV and the battery. The PV system degrades by 30% over 25 years, and the battery experiences more than 11% degradation over its 13-year lifespan. When considering the combined degradation of both PV and storage, the battery's discharging capacity is reduced by 50% from year 1 through the project life of 25 years.

Figure 12 (a) PV with storage in year one and (b) PV with storage in year 25 after degradation



(a) (b)

7.4 Limitations and Need for Future Analysis

We acknowledge the following limitations and topics for further study.

- **Additional Project Sizing Scenarios** – Our initial analysis suggests that adding storage solely for offsetting evening consumption may reduce the overall cost-effectiveness of the system. Further study is needed to determine the cost-effectiveness of larger solar and battery systems that can export additional electricity during peak hours after serving the school's energy needs. This would allow the school to take advantage of higher export rates during the evening.

- **Updated Analysis to Reflect Recent Changes to Net Billing Tariff** – As noted above, the CPUC recently adopted changes to the way solar projects are compensated for the electricity exported to the grid. These changes differentiate between credits for delivery costs and energy commodity costs. Credits can only offset costs in the same category; that is, credits for delivery costs can only offset bill charges for delivery and credits associated with commodity costs can only offset bill charges for energy commodity procurement. It is expected that these changes would decrease the value of exported electricity, therefore making projects less cost effective. Additional analysis would be needed to verify this hypothesis.

8 PHOTOVOLTAICS ON SMALL COMMERCIAL BUILDINGS

8.1 Project Overview

Preserve Calavera wanted to explore options for installing solar on non-profit buildings. As a proxy, we used small commercial buildings from the CBECC model for this analysis.

8.2 Methods

The general approach to assess both GHG impacts and benefit-cost analysis (BCA) for PV or PV with battery storage in small commercial buildings mirrors that employed for Solar PV on high schools in Section 7. We used the default energy consumption data for the small office building configuration in the CBECC model. The model generated hourly data on energy use, PV generation, and battery utilization for the initial year. Subsequently, we applied degradation factors for PV and battery to project the impact on hourly usage data for the following 24 years.

We assume the baseline (before PV) small commercial building owner uses the AL-TOU rate structure and switches to the DG-R rate structure once PV is installed for the same reasons as noted above. The NBT export rates used to determine the value of electricity exported to the grid do not reflect the most recent changes adopted by the CPUC.[38]

We integrated the energy consumption with PV and storage, GHG emissions, and electric rate structures to calculate the impact — including benefit-cost ratio and payback, and cost to reduce a metric ton of carbon dioxide equivalent (MT CO2e).

Figure 13 illustrates the average daily electricity consumption of a small office building during the summer, overlapping with the corresponding PV generation and battery performance. PV generation starting from 6 a.m. to 7 p.m., covers Off-Peak and part of the Peak period in early evening hours, aligning with the day's lowest marginal emission rate.

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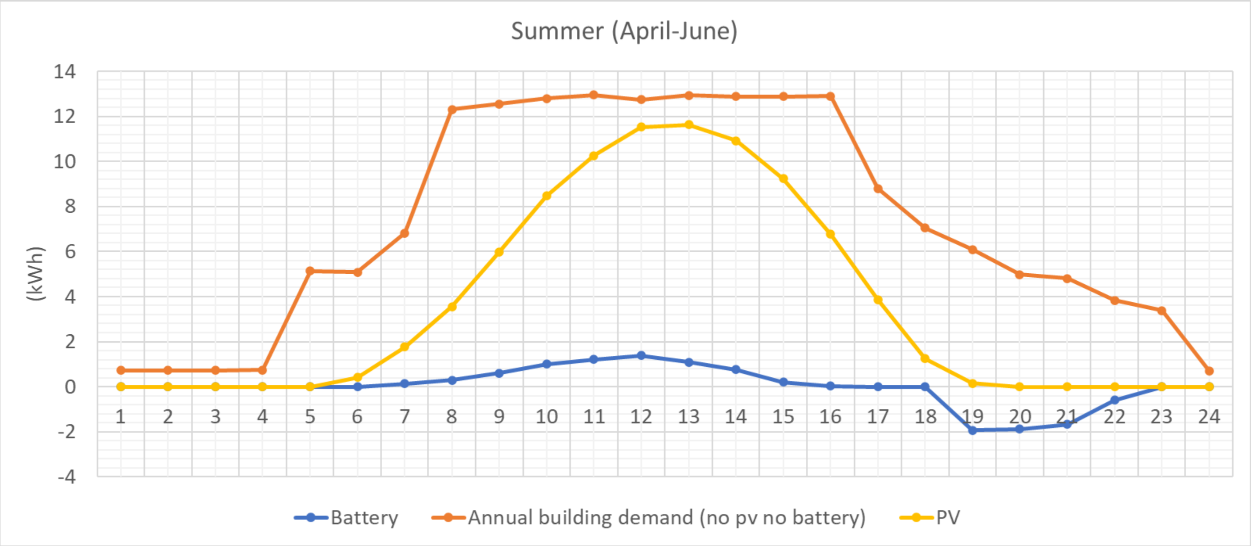
[38] *Ibid.*

Figure 13 Building Electricity Usage Compared with PV Generation and Battery Performance



8.2.1 Key Assumptions

Table 25 summarizes the key assumptions used for the PV on small commercial buildings analysis.

Table 25 Key Assumptions for PV on Small Commercial Buildings

INPUTS	USED IN ANALYSIS	REFERENCE
Model		CEC CBECC Model 2022
Building load shape	CBECC Model	
Building size	1 story/ 5,502 SqFt	
PV system size (PV-only)	25 kW	
PV system size (PV + Battery)	25 kW	
Battery capacity (PV + Battery)	30 kWh	
Climate zone	CZ07	
Simulation goal	Default settings for Small Office from CBECC model	
GHG emissions		
	Hourly SRMER	CPUC Avoided Cost Calculator 2022
	Annual average	EPIC 2023
Rate structure		
Commercial/Industrial rates	DG-R (Distributed Generation Renewable)	SDG&E Schedule DG-R, 2023
	AL-TOU (General Service - Time Metered)	SDG&E Schedule AL-TOU, 2023
	Net Billing Tariff (NBT) export rates	SDG&E Advice Letter 4155-E-A
BCA		
PV installation cost	$3,300/kW	LBNL, Tracking the Sun, 2022
Battery installation cost	$1,061/kWh	LBNL, Tracking the Sun, 2022
Incentives	Self-Generation Incentive Program (SGIP)	Self-Generation Incentive Program
	The investment tax credit (ITC)	Federal Solar Tax Credits for Businesses
Operation and maintainance cost	Inverter replacement $300/kW	Verdant, NEM 2.0 Lookback Study, 2021
Discount rate	5%	N/A

8.3 Results

8.3.1 GHG Reduction Analysis

As noted above, using an hourly SRMER could overestimate GHG reductions from PV projects. In general, adding battery storage to PV projects results in higher GHG reductions. It is also important to recognize that using an AAER likely underestimates the short-term GHG impacts of the PV project. Table 26 and Table 27 summarize GHG impacts.

Table 26 GHG Reductions Using Hourly Short-Run Marginal Emission Rates (MT CO_2e)

Project Type	2025	2030	2035
Small Commercial Photovoltaics	8.60	6.10	4.6
Small Commercial Photovoltaics + Storage	8.90	6.40	4.9

Table 27 GHG Reductions Using Annual Average Emission Rates (MT CO_2e)

Project Type	2025	2030	2035
Small Commercial Photovoltaics	5.20	4.00	2.5
Small Commercial Photovoltaics + Storage*	N/A	N/A	N/A

*It is not possible to estimate the impact of battery storage using an annual average emission rate.

8.3.2 Cost Analysis

In general, installing solar PV on a small commercial building can be cost-effective with the ITC and incentives for battery storage. Table 28 summarizes the cost analysis results for two system types: PV only and PV with storage. Both types have a BCR greater than one, which means benefits are greater than costs over the life of the project. The payback ranges from 5 years to 7 years. Nonetheless, high upfront cost remains a potential barrier for large PV projects. The upfront cost of the PV system analyzed here, excluding ITC, would be roughly $60,000, while for PV with storage, it's approximately $92,000. Over the life of the project, both system types have a net benefit from about $250 to $800 for every metric ton of GHG reduction using annual average emission rates.

Table 28 BCA Results for Photovoltaics on a Small Commercial Building

Project Type	Benefit-Cost Ratio	Discounted Payback (years)	NPV/MT CO2e Reduced (SRMER)	NPV/MT CO2e Reduced (AAER)*
Small Commercial Photovoltaics	2.24	5	468	800
Small Commercial Photovoltaics + Storage	1.44	7	261	N/A

*It is not possible to estimate the impact of battery storage using an annual average emission rate.

8.4 Limitations and Need for Future Analysis

In addition to updating the analysis to reflect recent changes to the net billing tariff noted above, several other factors affect the results of GHG impacts and benefit-cost analysis for PV or PV with storage in small commercial buildings. These considerations highlight areas for exploration and refinement in future studies.

- Ownership of the Small Commercial Buildings – The ownership structure of both the building and the PV system significantly influences the benefits and costs incurred by participants. In scenarios where participants own both the building and the PV system, they may experience direct financial benefits, such as reduced energy costs and potential credit generation from excess electricity production. However, the initial investment and maintenance costs become the responsibility of the participants. On the other hand, if the building or PV system is owned by a third party, participants might benefit from a more straightforward arrangement, potentially involving lower upfront costs and outsourced maintenance responsibilities. However, the financial gains for participants may be indirect, as they could be in the form of lease payments or other negotiated agreements. Understanding the ownership dynamics is crucial for accurately assessing the economic implications for participants, encompassing both the advantages and costs associated with the building and PV system.

- **Building Energy Load Shapes** – For a small commercial building, a favorable energy load shape aligns with the peak sunlight hours, allowing the PV system to generate electricity during periods of high demand. This enhances the system's ability to offset grid electricity usage, leading to higher cost savings and potentially reducing demand charges. Conversely, if the building's energy load is misaligned with the solar generation profile, the cost-effectiveness of the PV system may be reduced. In such cases, the system may generate surplus electricity during periods of low demand or experience inadequate generation during peak demand, leading to suboptimal savings and longer payback periods. In this analysis, the default load shape from the CBECC model was used without considering its inherent uncertainty. Future studies should incorporate uncertainty, and for more precise results, using actual energy consumption data specific to a project would be beneficial.

- **PV System Size and Battery Behavior** – The size of the PV system and battery behavior significantly impact both GHG reductions and bill savings. A larger PV system contributes to greater GHG reductions, while an appropriately sized battery with efficient charge and discharge patterns optimizes bill savings. Conversely, undersized PV systems or inefficient battery behavior may compromise environmental and economic benefits. Future studies should consider these factors for maximizing the effectiveness of renewable energy integration in a small commercial building.

9 STANDALONE BATTERY STORAGE IN SINGLE-FAMILY RESIDENTIAL BUILDINGS

9.1 Project Overview

For this project type, EPIC analyzed the cost and GHG impacts of installing a standalone battery storage system in a single-family residential building in climate zone 7 (coastal).

9.2 Methods

For this project type, we used an hourly analysis using a SRMER. It is not possible to analyze cost or GHG impacts using AAER because cost and GHG reductions result from charging up the battery when rates and emission rates are lower and using the stored electricity to serve building load in the evening when rates and emission rates are higher.

9.2.1 Key Assumptions

Table 29 summarizes the inputs used in the analysis. The energy use load shape for a typical single-family building was generated by the CEC's CBECC model.

Table 29 Inputs Used for Standalone Battery Storage Analysis

INPUTS	USED IN ANALYSIS	REFERENCE
Rate Structure		
Time-of-use plans	TOU-DR1	SDG&E Schedule TOU-DR1, 2023
CARE	Not considered	
Building Load Shape		CEC CBECC Model 2022
Building size	2,100 ft2	
Building type- MF building vs. SF house	Single-family	
All electric vs. mixed-fuel	Mixed-fuel	
New construction vs. existing building	New construction load shape	
Battery Performance and Cost		
Estimated performance	Uncertainty not considered	
Installation and maintenance cost	Included a sensitivity analysis	
Incentives	Investment Tax Credit (ITC),	Federal Solar Tax Credits for Businesses
	Self-Generation Incentive Program (SGIP)	Self-Generation Incentive Program
Model		
Climate zone	CZ 7 (Coastal)	
Discount rate	5%	
Simulation goal	Cost reduction	

Table 30 summarizing the assumptions used for battery performance. We assumed a 10 kWh battery with a maximum charging rate of 5 kW and a maximum discharging rate of 20 kW.

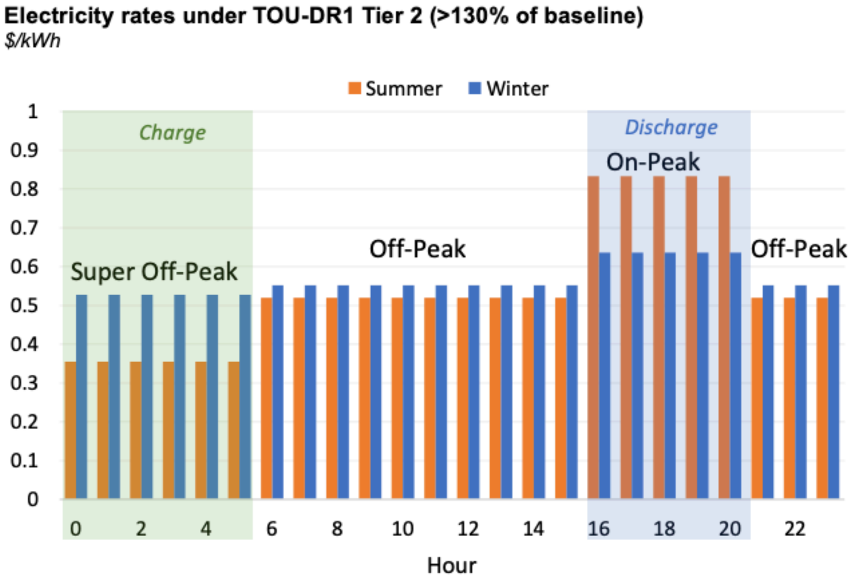
Table 30 Battery Parameters Used in Analysis

Battery Parameters	Unit	Li-ion
Max Charging Rate	kW	5
Normal Charging Rate	kW	5
Max Discharging Rate	kW	20
Normal Discharging Rate	kW	5
Battery Capacity	kWh	10
Charging Efficiency	-	0.96
Total Charging Capacity	kWh	10
Discharging Efficiency	-	0.96
Total Discharging Capacity	kWh	10
Efficiency Decay Rate (charge and discharge)	/cycle	0.0001
Capacity Decay Rate	/cycle	0.0001
Installation Cost	$/kWh	1,000
Operation and Maintenance Cost	$/kWh/ lifespan	200
Lifespan	years	15

9.2.1.1 Charging and Discharging Behavior

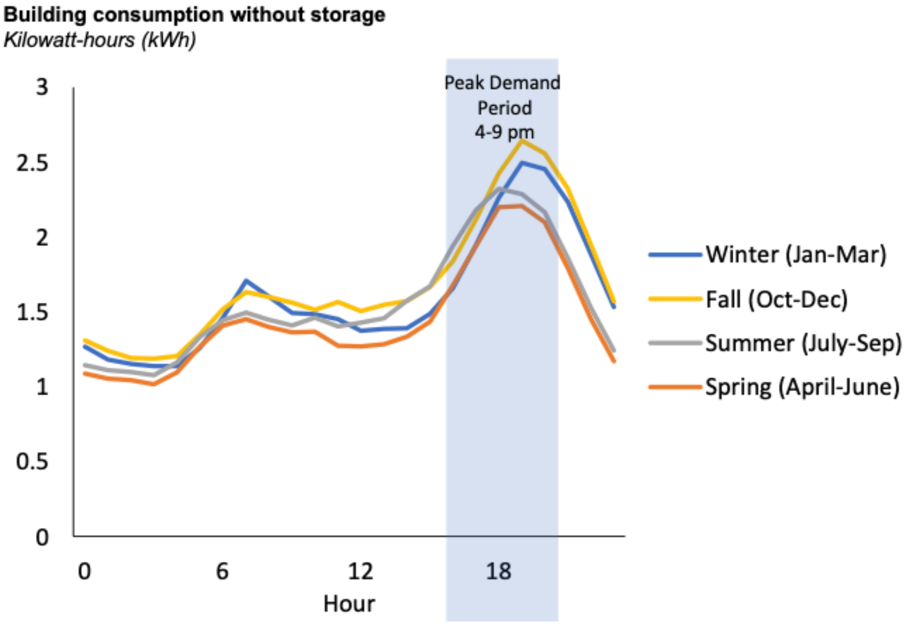
Battery behavior is determined by two factors: electric rates and building load shape. Figure 14 shows the electricity rates under SDG&E's TOU-DR1 rate schedule. Since charging when rates are lowest and consuming energy from the battery when rates are highest is one goal of this project type, Figure 14 shows that the project should charge should occur during super off-peak hours (0–5) and discharge during peak hours (16–20). In this project example, we assume that electricity cannot be exported to the grid, so all battery electricity is consumed by the buildings (i.e., self-consumed). As such, recent changes to net billing tariff would not affect the results for this project type.

Figure 14 Electricity Rates Under TOU-DR1 Tier 2 and Battery Behavior



To validate assumed battery charge and discharge behavior for the specific building, we evaluated the building's load shape across for seasons (Figure 15). These load shapes are from the 2022 CBECC model for a single-family residential building using both electricity and natural gas appliances (i.e., mixed fuel). Peak period consumption between 4:00 p.m. and 9:00 p.m. typically falls within the range of 9.5-10.7 kWh. This suggests that a battery with a discharge capacity of 10 kWh would be a suitable choice for this building and that discharging during these hours would have the largest impact on electricity costs.

Figure 15 Building Load and Determining Discharge Period

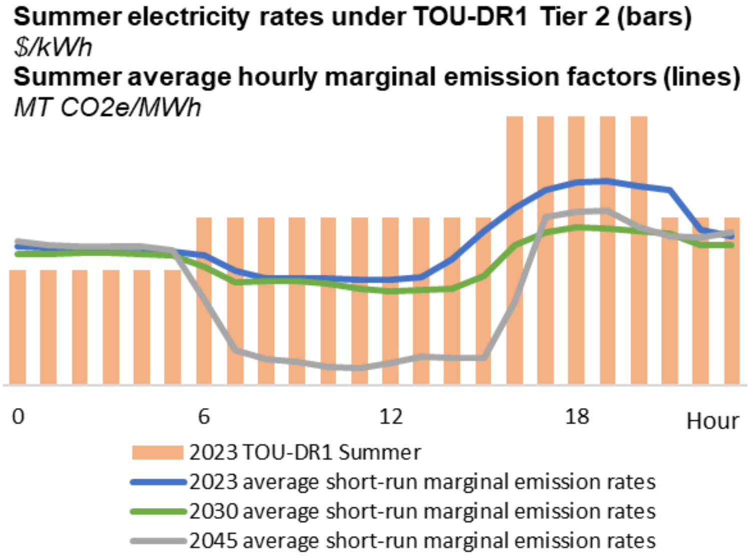


9.3 Results

9.3.1 GHG Impact

Because the hourly emission rate is roughly correlated to the hourly electric rate structure, there is an emissions reduction benefit from buying at time of low retail rates and charging up the battery and then discharging when the retail rates are highest. Figure 16 demonstrates this but also shows that during summer months the differential between retail rates from hours 0–5 and 4–9 is greater than the differential in emissions during this same period. Adding 10 kWh of storage to a typical single-family residential building would reduce GHG emissions by about 1.2 metric tons of CO_2 equivalent emissions over the 15-year battery lifespan. By comparison, replacing a gasoline internal combustion engine vehicle to an electric vehicle would reduce this amount of GHG emissions in about one year.

Figure 16 Correlation between Retail Electric Rates and Hourly Emission Rates



9.3.2 Cost Analysis

Costs to install and operate and maintain (O&M) batteries are key inputs to the cost analysis. We assumed that the installed cost was $1,000/kWh and that maintenance would cost $200/kWh during its lifespan (Table 30 above). To provide a range of results, we used costs above and below these values. Table 31 and Table 32 summarize the benefit-cost ratio results with and without current incentives. Considering current incentives, almost all cost combinations would be cost effective in our analysis (Table 31). If no incentives were available, only the lowest installation costs would yield a cost-effective project (Table 32).

Table 31 Benefit Cost Ratio for Standalone Battery Project - With Incentives

		Installation Cost ($/kWh)						
		$ 700	$ 800	$ 900	$ 1,000	$ 1,100	$ 1,200	$ 1,300
	$100	1.96	1.70	1.50	1.34	1.21	1.11	1.02
O&M	$150	1.81	1.59	1.41	1.27	1.16	1.06	0.98
($/kWh)	$200	1.69	1.49	1.34	1.21	1.10	1.02	0.94
	$250	1.58	1.41	1.27	1.15	1.06	0.98	0.91

Table 32 Benefit Cost Ratio for Standalone Battery Project - Without Incentives

		Installation Cost ($/kWh)						
		$ 700	$ 800	$ 900	$ 1,000	$ 1,100	$ 1,200	$ 1,300
	$100	1.16	1.03	0.92	0.83	0.76	0.70	0.65
O&M	$150	1.11	0.98	0.89	0.81	0.74	0.68	0.64
($/kWh)	$200	1.06	0.95	0.86	0.78	0.72	0.67	0.62
	$250	1.02	0.91	0.83	0.76	0.70	0.65	0.60

Table 33 and Table 34 provide similar results for discounted payback. With incentives, the payback ranges from 5 to 15 years, depending on installation and O&M costs. Without incentives the payback ranges from 12-14 years but only for the lowest installation costs. Because costs would be greater than benefits for most of the installation and O&M cost combinations, the project would never pay for itself in these cases (indicated by N/A).

Table 33 Discounted Payback for Storage-Alone Battery Project (years) – With Incentives

		Installation Cost ($/kWh)						
		$ 700	$ 800	$ 900	$ 1,000	$ 1,100	$ 1,200	$ 1,300
	$100	5	7	8	9	11	12	14
O&M	$150	6	7	8	10	11	13	N/A
($/kWh)	$200	6	7	9	10	12	14	N/A
	$250	6	8	9	11	13	15	N/A

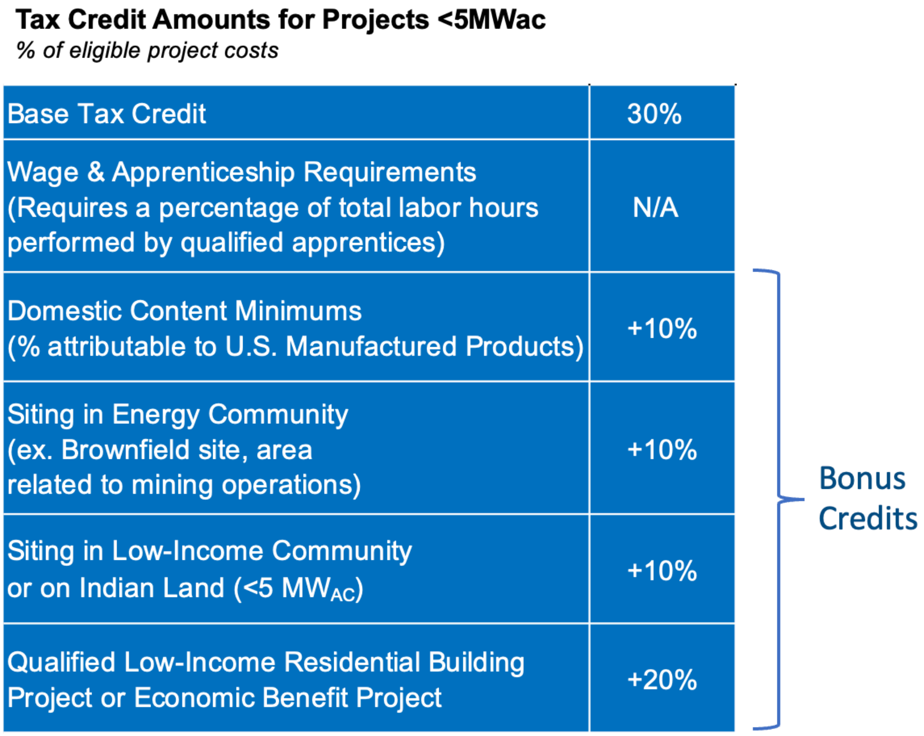
Table 34 Discounted Payback for Storage-Alone Battery Project (years) – Without Incentives

		Installation Cost ($/kWh)						
		$ 700	$ 800	$ 900	$ 1,000	$ 1,100	$ 1,200	$ 1,300
	$100	12	14	N/A	N/A	N/A	N/A	N/A
O&M	$150	12	N/A	N/A	N/A	N/A	N/A	N/A
($/kWh)	$200	13	N/A	N/A	N/A	N/A	N/A	N/A
	$250	14	N/A	N/A	N/A	N/A	N/A	N/A

9.3.2.1 Role of Financial Incentives

The Federal Investment Tax Credit (ITC) was extended as part of the Inflation Reduction Act.[39] Standalone battery storage systems with a capacity greater than 5 kWh are now eligible for the ITC. The base ITC credit is 30% of eligible project costs and opportunities exist to receive bonus credits for domestic content, project location, and project type (Figure 17).

Figure 17 Federal Investment Tax Credit Tiers



Tax Credit Amounts for Projects <5MWac
% of eligible project costs

Base Tax Credit	30%
Wage & Apprenticeship Requirements (Requires a percentage of total labor hours performed by qualified apprentices)	N/A
Domestic Content Minimums (% attributable to U.S. Manufactured Products)	+10%
Siting in Energy Community (ex. Brownfield site, area related to mining operations)	+10%
Siting in Low-Income Community or on Indian Land (<5 MW_{AC})	+10%
Qualified Low-Income Residential Building Project or Economic Benefit Project	+20%

Source: U.S. EPA

In addition to the ITC, certain battery storage projects are eligible for incentives from California's Self-Generation Incentive Program (SGIP). There are two important aspects to the SGIP funds. First, the CPUC has focused the incentive of SGIP per Public Utilities Code Section 379.6-379.10 to fund incentives for the general market for small residential storage with higher incentives for customers that qualify under equity and equity resilience eligibility. The statutory authorization and program design for these incentives require the funding and regulation of funded resources to decrease GHG emission and other criteria air pollution for air quality improvements, provide other value such as peak load shift, and creates specific allocations for critical load and facilities in high fire risk areas. SGIP is authorized until the end of 2025, at which point any remains funds from ratepayers will be returned to ratepayers and taxpayers funds will return to the general fund unless SGIP is authorized after 2025. Presently, small residential storage is in the last CPUC authorized Step 7 of funding at

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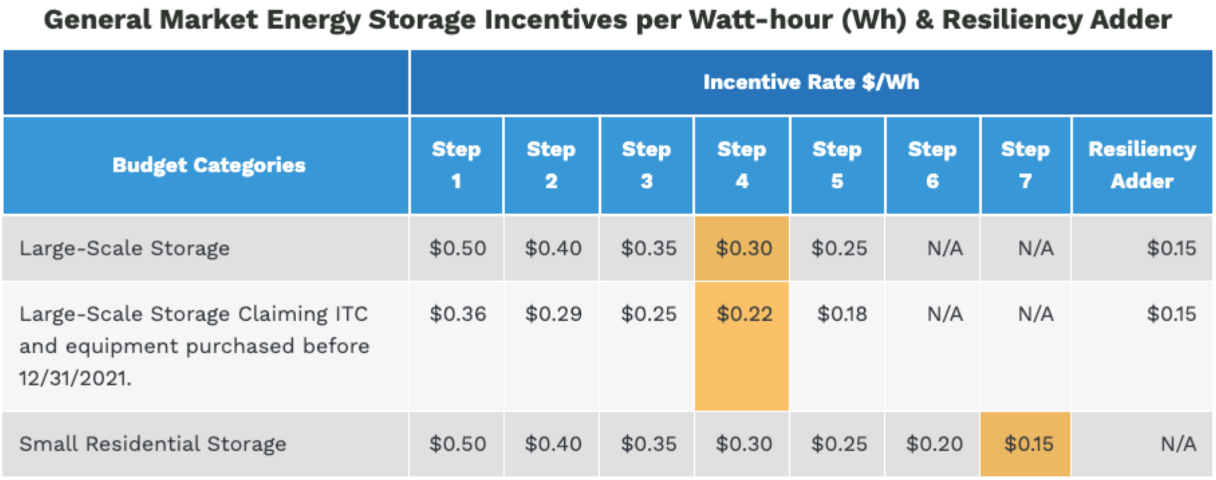
[39] U.S. Environmental Protection Agency. Summary of Inflation Reduction Act provisions related to renewable energy. Available at https://www.epa.gov/green-power-markets/summary-inflation-reduction-act-provisions-related-renewable-energy.

the lowest incentive rate per watt-hour and large-scale solar is in Step 4 as shown below. Figure 18 summarizes the general market SGIP incentives and Figure 19 summarizes equity-related incentives.

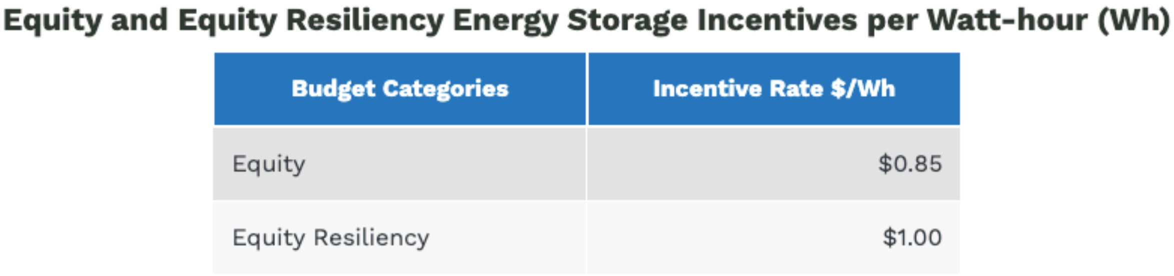
Figure 18 Self-Generation Incentive Program General Market Energy Storage Incentives



General Market Energy Storage Incentives per Watt-hour (Wh) & Resiliency Adder

	Incentive Rate $/Wh							
Budget Categories	**Step 1**	**Step 2**	**Step 3**	**Step 4**	**Step 5**	**Step 6**	**Step 7**	**Resiliency Adder**
Large-Scale Storage	$0.50	$0.40	$0.35	$0.30	$0.25	N/A	N/A	$0.15
Large-Scale Storage Claiming ITC and equipment purchased before 12/31/2021.	$0.36	$0.29	$0.25	$0.22	$0.18	N/A	N/A	$0.15
Small Residential Storage	$0.50	$0.40	$0.35	$0.30	$0.25	$0.20	$0.15	N/A

Figure 19 Self-Generation Incentive Program Equity and Equity Resiliency Energy Storage Incentives



Equity and Equity Resiliency Energy Storage Incentives per Watt-hour (Wh)

Budget Categories	**Incentive Rate $/Wh**
Equity	$0.85
Equity Resiliency	$1.00

Second, AB 123 (2023) amended the statutory authorization for the SGIP funding under Public Utilities Code Section 379.10 to further define the AB 209 (2022) amendments that direct general fund taxpayer allocations from the state budget (e.g., funds not collected from ratepayers for general market incentives) to only low-income customers for the installation of eligible PV + Battery or battery only distributed resources. AB 101 Budget Act of 2023 allocated $280 million[40] for fiscal year 2023–2024 to this funding type to decrease ratepayers cost for SGIP funding. It is projected that $125 million will be allocated for 2024–2025 and $225 million for 2025–2026.[41] It is unclear whether this funding for the program is fully implemented but it should be part of the program in

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[40] See also General Government 2023-2024 State Budget – 1, 8660 Public Utilities Commission, Detailed Budget Adjustment, Workload Budget Amendments, Workload Budget Change Proposals: General Fund Solution: Energy Package – Residential Solar and Storage, at p. 3: https://ebudget.ca.gov/2023-24/pdf/Enacted/GovernorsBudget/8000/8660.pdf.

[41] See AB 209 Discussion SGIP Program, June 28, 2023, at p. 47: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/self-generation-incentive-program/2023-sgip-2nd-quarterly-workshop.pdf.

the near-term as AB 1254 (2023) was an urgency statute that become law after Governor Newsom's signature in June 2023.

9.4 Limitations and Need for Future Analysis

There are several limitations to the analysis of standalone battery storage conducted for this project and areas for future analysis.

- **Short-Run Marginal Emission Rate Overestimate GHG Impacts** – It is not possible to use an annual average emission rate to estimate the GHG impacts of standalone battery storage systems, therefore, we only provide results using an hourly short-run marginal emission rate. As noted above (Section 3.2), these can overestimate the rate of emissions on the grid. In this case, using these rates would overestimate GHG reductions, which are already modest.

- **Additional Scenarios** – There are many factors to consider when evaluating the impacts of battery storage (Table 30). The results presented here represents a limited combination of these factors. Analyzing additional combinations of factors would expand the range of results. Future analysis could include additional climate zones, other rate structures, etc.

- **Impact of Combining Solar with Battery Storage** – While we evaluated the combination of solar and battery storage for other building types (Sections 7 and 8), we did not evaluate this combination on single-family residential buildings. Additional analysis would help to determine whether results for single family residential projects are like those for schools and small commercial buildings.

10 OTHER PROJECT TYPES

We did not complete a GHG reduction and cost analysis for several project types. This section provides a summary of findings from a literature review and qualitative evaluation.

10.1 Photovoltaics on Low-Rise Multifamily Buildings

Most residential PV installations are on single-family buildings. Installing PV on low-rise multifamily buildings can help to provide renters and owners of multifamily units access to solar electricity. However, there are several challenges inherent in multifamily projects compared to single-family project. The first is related to the ownership of the buildings. Policies and programs related to energy use in buildings that lease or rent units often face the "split incentive" dilemma. Building owners often do not pay utility bills and have no incentive to address building energy, while renters pay the utility bills and have an incentive to improve energy use but do not own the building or the main energy-consuming appliances and equipment.

A related challenge is that much of the energy use in the building is associated with tenant units. While there is some level of energy use from common area loads (e.g., exterior lighting), they are relatively small compared to the aggregate energy use of tenants. If a building owner installed a system only to serve common area energy use, the system would be relatively small and tenants would not directly benefit. This problem is partially solved by Virtual Net Energy Metering (VNEM), an electricity rate structure that allows a building owner to size a PV system based on the entire load of the building, including tenant loads. This allows for a much larger PV system and a process for the building owner to share the energy cost savings with tenants.

The amount of cost savings passed along to tenants varies by project, so it can be difficult to develop a reasonable estimate. Ivy Energy is a company that has developed software to track energy use at each unit to help allocated the cost savings from the PV system.[42] Further, VNEM was recently modified, which will change the financial impact of installing PV on multifamily buildings. More information on these changes is presented below. Additional research would be needed to estimate the impact of these factors on the GHG and cost estimates completed for high schools and small commercial buildings.

10.1.1 Virtual Net Metering Reforms

The CPUC issued a reformed Decision that changed the compensation for VNEM to follow the net billing tariff (NBT) adopted in late 2022 to favor onsite consumption and use of batteries that move building energy use from one time to another.[43] The applicable parts of the decision are divided below to reflect the primary difference in application of the CPUC Decision to residential multi-family that will now follow a successor virtual net billing tariff (VNBT) implemented by SDG&E no later than March 31, 2025 with the previous VNEM available on an interim basis until the VNBT is adopted and a 90-day sunset period from the 11/16/23 date of the decision for current customers to enroll in the original VNEM tariff ends.

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[42] See https://www.ivy-energy.com/.

[43] Available at https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M520/K845/520845431.PDF.

Notably, existing low-income multifamily VNEM tariffs related to the CPUC's Solar On Multifamily Affordable Housing (SOMAH) Program and Multifamily Affordable Solar Housing (MASH) Program are maintained and slightly modified to improve customer experience and encourage storage. The CPUC also issued a FAQ regarding this Decision.[44]

The CPUC largely adopted the net billing tariff that changed the export value for single-family residential solar energy exports based on the time-dependent value from the Avoided Cost Calculator. Importantly, residential benefitting account holders under NVBT still receive an onsite netting where the generation produced onsite is netted against onsite consumption from the grid. This allows both residential customers to net their portion of generation against their energy imports (kWh) on a 15-minute interval unit-level basis to accommodate self-consumption and to receive a bill credit ($) for any net generation compensation. Additionally, the VNBT excludes use of the bill credit for non-bypassable or fixed charges contained in a customer's applicable rate.

The CPUC found that there is no reason to create a glidepath adder for SDG&E service territory given the high rates that provide a payback period of less than 9-years. The CPUC created a 9-year adder for residential export compensation in PG&E and SCE territory that is available to customers in the first five years of the VNBT and steps down incrementally overtime as a glidepath for the transition from NVEM.

The existing VNEM tariff will remain available with no changes for enrolled customers until the end of their legacy period, including if existing VNEM customers install energy storage. For VNEM customers enrolled after April 15, 2023, D.22-12-056 decreased the legacy period of the existing VNEM tariff from 20 to nine years. This decision establishes a Sunset Period of 90 days for the current VNEM tariff for prospective customers.

10.2 Wetland Restoration

Preserve Calavera initially selected wetland restoration as a potential project type but subsequently removed it from considerations. Nonetheless, the following general information provides some context and means of comparison to the other project types analyzed in the sections above.

While other project types evaluated here (e.g., heat pumps and PV) can reduce the amount of emissions that would be added to the atmosphere, projects like wetland restoration can potentially remove carbon from the atmosphere and store it (i.e., sequestration). Wetlands can sequester carbon, but they also can emit methane, a more powerful GHG than carbon. To assess the GHG impacts of wetlands, it is necessary to assess net emissions; that is, the amount of carbon removed and stored, and methane emitted. Not all wetland types sequester carbon; some are net emitters. Saline wetlands, with soil pore water salinity surpassing 18 psu (particle salinity units) exhibit limited methane production.[45] Conversely, in wetlands where soil pore water salinity falls below 18 psu, there is a variable methane emission pattern that may be substantial enough to offset the benefits of carbon sequestration.

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[44] See https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/net-energy-metering-nem/nemrevisit/vnem-pd-fact-sheet-update-111323.pdf.

[45] Callaway, J. C., Borgnis, E. L., Turner, R. E., & Milan, C. S. (2012). Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands. Estuaries and Coasts, 35(5), 1163–1181.

Table 35 summarizes sequestration rates for different wetland types.[46] A positive emission rate indicates a net increase of atmospheric GHG levels, and a negative number indicates a net removal of carbon from the atmosphere. Brackish tidal wetlands have the highest potential for net GHG sequestration with rate of about -3.3 MT CO2e/acre/year. Freshwater tidelands also show a modest sequestration potential on the low end of the estimated range. Drained wetlands for agriculture use also have modest potential to sequester at the low end of the range but also has significant potential to result in net emissions, though converting wetlands to agricultural lands may run counter to the conservation goals of Preserve Calavera.

Table 35 Wetland Carbon Sequestration Rates

Wetland Type	Net Emission Factor (MT CO_2e/acre/yr)	Range Net Emission Factor (MT CO_2e/acre/yr)	
Brackish tidal wetland	-3.30	-3.70	-2.90
Brackish –managed seasonal wetlands, Suisun Marsh, organic or highly organic mineral soils	4.00	2.00	5.20
Freshwater tidal wetlands	0.33	-0.81	2.20
Delta seasonal wetlands, organic and highly organic mineral soils	3.60	1.70	5.50
Drained wetlands used for agriculture	9.60	-2.50	23.20
Rewetted or restored wetlands (impounded marshes)	1.35	0.42	2.28

The rates included in Table 35 represent the amount of net carbon sequestration per acre. To assess the potential of wetland restoration as a GHG reduction measure, it would be necessary to first determine the amount of GHG sequestration (or emissions) prior to restoration, then the amount of GHG sequestration (or emissions) after the restoration. The difference between these two represents the GHG impact attributable to the restoration project. Further, the total potential to sequester carbon from wetland restoration would depend on the total acres that could be restored.

10.3 Other Habitat Restoration

Similar to wetland restoration, restoring other types of habitats can remove carbon from the atmosphere and store it. A report by the Institute for Ecological Monitoring and Management at San Diego State University compiled research findings on carbon sequestration rates for a range of vegetation types. Figure 20 summarizes carbon sequestration rates for a range of vegetation types in the San Diego region from the study.[47] Values shown here are the midpoints of ranges provided.

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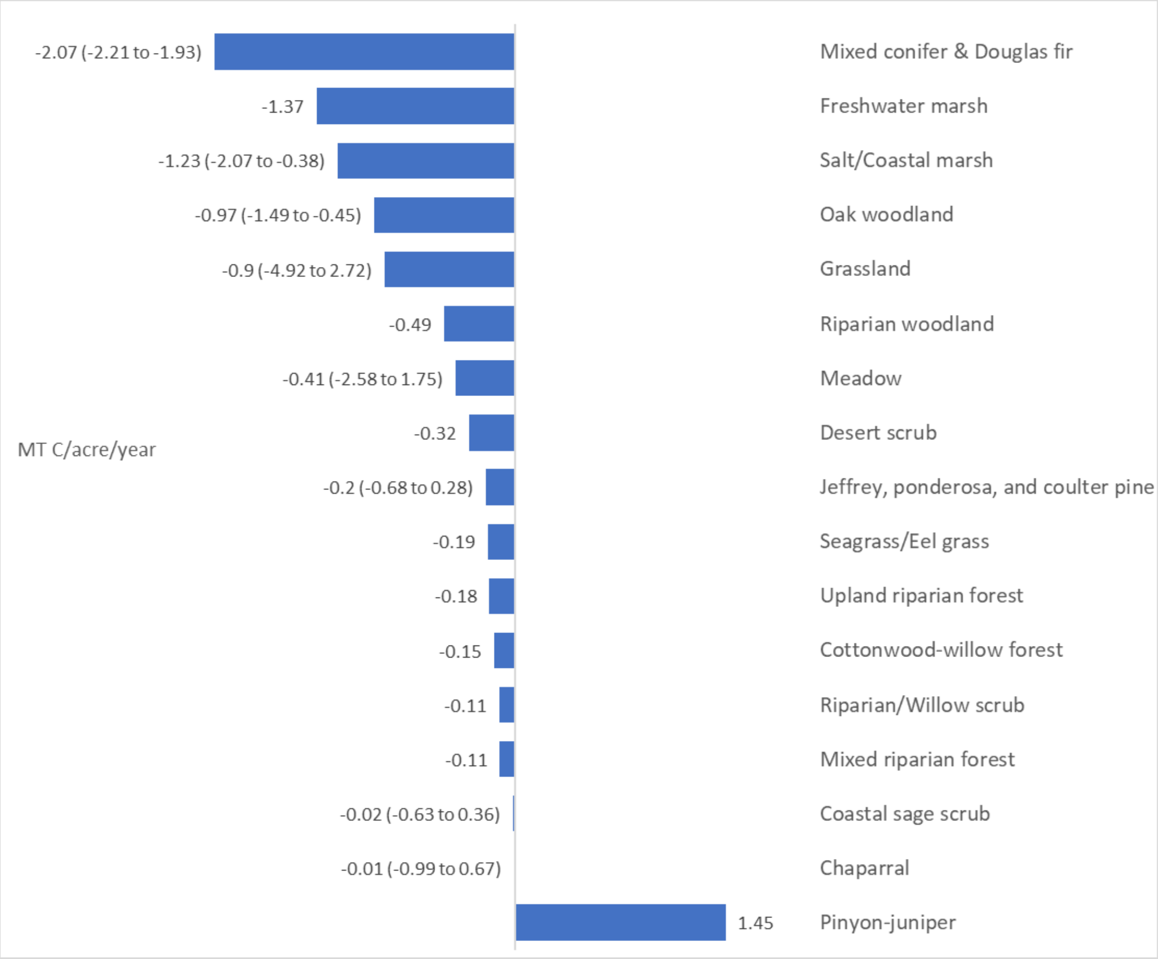
[46] California Air Resources Board. (2022). Scoping Plan November 2022, APPENDIX I – Natural and Working Lands Technical Support Document.

[47] Jennings, M., Barnett P., Foote, D. (2021). Carbon Valuation in San Diego's Natural Landscapes. Institute for Ecological Monitoring and Management, San Diego State University.

Mixed conifer and Douglas fir forests have the highest rate of sequestration at about 2 metric tons of carbon per acre per year (MT C/acre/yr.). Oak woodlands and grasslands sequester carbon at a rate about 1 MT C/acre/yr. Most of the remaining vegetation types have a rate less than 0.5 MT C/acre/yr. and several types have the potential to be net emitters (e.g., coastal sage scrub, chaparral, and pinyon juniper).

Also, like wetland restoration, to determine the net GHG reduction potential, it is necessary to compare the baseline condition before restoration with the condition after restoration. The difference would be the GHG impact.

Figure 20 Carbon Sequestration Rates for Vegetation Types in the San Diego Region[48]



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[48] Values in the report show net sequestration rates as a positive value and net emissions rates a negative value. To be consistent with Table 35, we changed the sign to show a net sequestration value as a negative value and net emission as positive value.

11 MONITORING PROJECT IMPACT

In general, funders want to know if their investments had the expected impacts. There is no single correct way to monitor project impact and examples exist from energy efficiency and state funding programs. For example, the Strategic Growth Council Transformative Climate Communities Program requires applicants to submit estimates of GHG reductions as part of the proposal and report ongoing performance during the project implementation. Another more complicated example is the energy efficiency program evaluation process to determine the effectiveness of electric and natural gas customer-funded efficiency programs. The CPUC has requirements to evaluation programs to determine whether they reduce energy in a cost-effective manner. As a result, hundreds of millions of dollars are spent to analyze and report on program effectiveness.

This section provides a brief background on evaluation, monitoring, and verification (EM&V), summarizes some of the key factors to consider when monitoring project impact, and possible options for Preserve Calavera to consider.

11.1 What is Evaluation, Monitoring, and Verification?

While not entirely analogous to our needs here, there is a concept in the energy field called EM&V. In the context of ratepayer funded energy programs, EM&V is used ensure that these programs are leading to the benefits claimed, results of these programs are validated using a process of evaluation, monitoring, and verification (EM&V). This process is important when using public funds to determine whether funds are being used efficiently and effectively. This can be a complex, time consuming, and costly process.

11.1.1 Methods

According to the U.S. Environmental Protection Agency's Guidebook for Energy Efficiency Evaluation, Measurement, and Verification, there are three broad EM&V methods for quantifying energy reductions: 1) deemed savings for specific measures, 2) direct measurement and verification (M&V) applied to individual projects or measures, and 3) comparison group methods rely on analysis of consumption data for an affected group of premises compared to another group.[49]

- **Deemed Savings** – This is an EM&V method that applies estimates of average annual impact of a single unit of an installed measure. For example, one efficient refrigerator. Deemed savings methods can include, **deemed savings values**, which are pre-specified estimates of average annual savings for a project or measure; or **deemed formulas**, which are-specified formulas for quantifying savings, using some deemed parameters and some inputs that are specific to each project or measure. **Deemed savings** generally refers to energy savings but could be applied to any project or measure to determine GHG reductions.

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[49] U.S. Environmental Protection Agency. June 2019. Guidebook for Energy Efficiency Evaluation, Measurement, and Verification A Resource for State, Local, and Tribal Air & Energy Officials. Available at https://www.epa.gov/sites/default/files/2019-06/documents/guidebook_for_energy_efficiency_evaluation_measurement_verification.pdf. Note that Section 11.1 is adapted from this Guidebook.

- **Direct Monitoring and Verification** – As its name implies, direct M&V is a set of methods to obtain measurements from an individual project or measure installation site as a basis for quantifying savings. Data could be gathered directly from equipment or from utility bills. In general, this method is more time-consuming and expensive, but, since it considers actual energy usage, can yield more accurate results.
- **Comparison Group** – This method is applied to measure the effect of an activity on a group of consumers. This approach is applied most to evaluation of publicly funded programs, like customer-funded energy programs. Given the scope of activity expected to result from Preserve Calavera funding, this likely is not an appropriate method to monitor project outcomes.

In addition to these approaches, another possible method to monitor project performance and program effectiveness is to conduce a qualitative survey to gather feedback from participants. Survey questions could include topics such as: operational status of technology, satisfaction with performance, satisfaction of program process, etc. It is also possible to gather feedback on perceived energy and bill savings, but these data may not be reliable.

11.2 Considerations for Monitoring GHG Reduction Projects

11.2.1 Goals

Preserve Calavera's overall goal for this project is to reduce GHG emissions. Once a project has been funded and implemented, it can be helpful to understand the level of GHG emission reductions that resulted from related funding. In this case there are several reasons to monitor project performance: (1) to determine whether and the extent to which the project reduced GHG emissions, (2) to determine whether any changes are needed to improve the process and lead to more GHG reductions, and (3) to determine whether the project addressed other goals besides GHG reductions, including promoting equity, public health benefits, resilience (e.g., reducing the urban heat island effect), enhancing habitat for wildlife, and promoting other community benefits.

11.2.2 Cost and Time Required

One important consideration is the cost and time required for funding recipients to monitory project impact. As an example of a more complicated approach, as mentioned earlier, the Strategic Growth Council Transformative Climate Communities Program requires reporting at several phases of the project. The program requires that 3% of the budget be set aside for a pre-qualified third-party Evaluation Partner, and that an additional 2–3% of the budget be used by the project staff "to gather data and report to the Evaluation Partner and participate in evaluation activities such as focus groups, surveys, and interviews."[50] Figure 21 summarizing the reporting requirements for the TCC Program.

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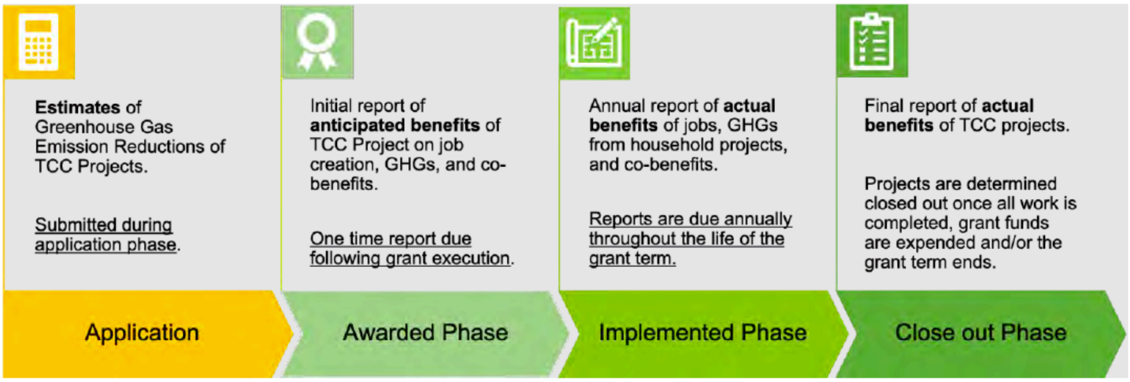
[50] California Strategic Growth Council. February 2023. Transformative Climate Communities Program Round 5 Final Program Guidelines FY 2022–2023. See p. 46. Available at https://sgc.ca.gov/programs/tcc/docs/20230308-TCC_R5_Guidelines.pdf.

Figure 21 Strategic Growth Council Reporting Requirements[51]



Estimates of Greenhouse Gas Emission Reductions of TCC Projects.

Submitted during application phase.

Initial report of **anticipated benefits** of TCC Project on job creation, GHGs, and co-benefits.

One time report due following grant execution.

Annual report of **actual benefits** of jobs, GHGs from household projects, and co-benefits.

Reports are due annually throughout the life of the grant term.

Final report of **actual benefits** of TCC projects.

Projects are determined closed out once all work is completed, grant funds are expended and/or the grant term ends.

11.2.3 Limited Actions for Non-Performing Projects

Depending on the format of the funding provided, there may be little recourse for projects that do not perform as expected. This may not be one of the overall goals for monitoring, but it should be considered. There are funding schemes that provide a portion of funding upfront to help fund action and then another portion when the project proponents demonstrate performance. For example, the Self-Generation Incentive Program discussed above provides a portion up front and then pays the remaining funds based on GHG performance. While this approach can help to encourage desired performance, it also can require significant cost and staffing to implement.

11.2.4 Persistence of Technological vs. Behavior Change

The certainty that a project will achieve the expected outcomes also can depend on the type of activity that is being funded. For example, the likelihood that a PV project will be installed and operate as intended would appear to be relatively high. If the project owner installed the system and it stopped working, they would not receive the associated utility bill cost savings. It would be reasonable to assume that they would repair the system and keep in working condition to maximize benefits.

Further, once a technology intervention is completed it will continue to provide potential benefits if it is operational. As an example, once a resident replaces an old refrigerator with a more efficient one, they don't have to do anything differently. Once the technology is in place and operating is saves energy compared to the older version or a less efficiency new version. In this way, technological changes can be persistent.

On the other hand, if an intervention relies on behavior changes, like how a particular appliance is operated, it can be less persistent. A simple example to illustrate technology versus behavior change is lighting. It is possible to save energy by diligently turning off unused lights. Energy savings possible but relies on lights getting turned off. If you buy an efficient light bulb, it saves energy compared to an inefficient bulb every time you turn it on. It is true that behavior change can help to save even more, but the base savings achieved by the technological change is persistent.

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[51] *Ibid.* at p. 48.

11.2.5 Complexity of Pre- and Post-Project Data Analysis

Given the availability of electric meter data, it is possible to compare consumption data for a baseline year before the intervention was completed with a year after the intervention to determine any changes. This is possible with the use of Green Button, a way for customers to easily give access to energy consumption data to a third party.[52]

Comparing year over year energy consumption data is not always straightforward. There are many factors consider, including weather, building occupancy, and structural changes to building. It can be difficult to attributed changes in energy usage to specific intervention. For example, if a homeowner installed a new efficient refrigerator, which saved energy, but that same year had a hot summer and air conditioner usage increased, any savings from the new refrigerator may be cancelled out by running the air conditioner more. There are ways to correct for weather changes to estimate the impact of interventions on energy consumption.

11.2.6 Consideration of Co-Benefits

While GHG reductions is an important goal, there are other potential benefits that may result from projects. A range of co-benefits can be considered along with GHG and cost impact. For example, while wetland and other habitat restoration may not have the highest GHG impact, these project types can enhance resilience and create habitat for wildlife. Other project types not assessed here can also provide co-benefits. For example, planting trees can create shade to address the urban heat island effect and beautify communities.

11.3 EM&V Resources

In addition to the sources referenced above, the following resources provide further information on EM&V.

- **CPUC E&V Resources** – The CPUC has numerous resources available, including frameworks, protocols, and manuals for conducting EM&V for energy efficiency programs.[53]
- **CALifornia Measurement Advisory Council (CALMAC) Database** – CALMAC maintains a comprehensive database of EM&V and related reports and resources.[54]
- **Equity Considerations** – The Northeast Energy Efficiency Partnerships has published a report entitled, Centering Equity with Metrics: How to Incorporate Equity and Justice in Evaluation, Measurement, and Verification.[55] It discusses "ways that policy makers and program administrators can identify, embed, and evaluate progress towards energy equity in energy efficiency programs through the evaluation, measurement, and verification process."

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[52] https://www.sdge.com/green-button.

[53] https://www.epa.gov/sites/default/files/2019-06/documents/guidebook_for_energy_efficiency_evaluation_measurement_verification.pdf.

[54] https://www.calmac.org/search.asp.

[55] https://neep.org/sites/default/files/media-files/full_report_equity_metrics.pdf.