DOCKETED

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Project Title:	2022 Energy Code Pre-Rulemaking
TN #:	235906
Document Title:	Presentation-December 8, 2020 Energy Code on Pre-Rule Making Workshop
Description:	Staff Presentation on Heatpump Baselines and PV/Battery Storage Requirements for HRMF and Selected Nonresidential Buildings, Highrise Multifamily (HRMF) Heatpump Baseline and Cost Effectiveness, Nonresidential Heat pump Baselines, HRMF and Nonresidential PV and Battery Storage, HRMF and Nonresidential PV/Storage Proposed Draft Language and 2022 Central Heatpump Water Heating Update. By Payam Bozorgchami on December 8, 2020 Energy Code on Pre-Rule Making Workshop
Filer:	Tajanee Ford-Whelan
Organization:	Efficiency Division
Submitter Role:	Commission Staff
Submission Date:	12/10/2020 12:37:42 PM
Docketed Date:	12/10/2020

2022 Pre-Rulemaking for Building Energy Efficiency Standards

Payam Bozorgchami, P.E.

December 8, 2020

Start Time: 9:00 AM

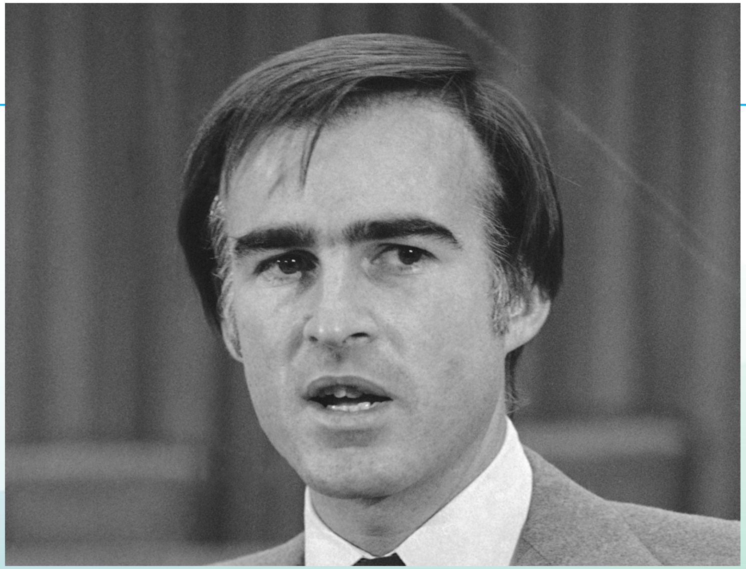
What We Will Covering Today

- **How Title 24, Part 6 is Developed**
- **Mazi Shirakh, P.E.**
  - Heatpump Baselines and PV/Battery Storage Requirements for HRMF and Selected Nonresidential Buildings
- **NORESCO**
  - Highrise Multifamily (HRMF) Heatpump Baseline and Cost Effectiveness
  - Nonresidential Heatpump Baselines
- **Danny Tam**
  - 2022 Central Heatpump Water Heating Update
- **E3**
  - HRMF and Nonresidential PV and Battery Storage
- **Mazi Shirakh, P.E.**
  - HRMF and Nonresidential PV/Storage Proposed Draft Language
- **Cleanup Language**
  - **Bill Pennington**
    - Section 10-115, Community Solar
  - **Mazi Shirakh, P.E.**
    - Other Cleanup
      - ✓ Section 150.1(c)14 Exceptions
      - ✓ New Exception to Section 150.1(c)14
      - ✓ JA11 and JA12
- **Open for Comments**

Authority & Process

•**Public Resources Code (PRC 25402):** Reduction of wasteful, uneconomic, inefficient, or unnecessary consumption of energy

- (a)(1) Prescribe, by regulation, lighting, insulation, climate control system, and other building design and construction standards that increase the efficiency in the use of energy and water…
- Warren Alquist Act Signed into law in 1974 by Governor Ronald Reagan and launched by Governor Jerry Brown in 1975 which mandates updates Building Efficiency Standards and requires the building departments to enforce them through the permit process.



Goals of the California Energy Code

1. Increase building energy efficiency cost-effectively
2. Contribute to the state's GHG reduction goals
3. Enable pathways for all-electric buildings
4. Reduce residential building impacts on the electricity grid
5. Promote demand flexibility and self-utilization of PV generation
6. Provide tools for local government reach codes

Process Used to Updated Energy Codes

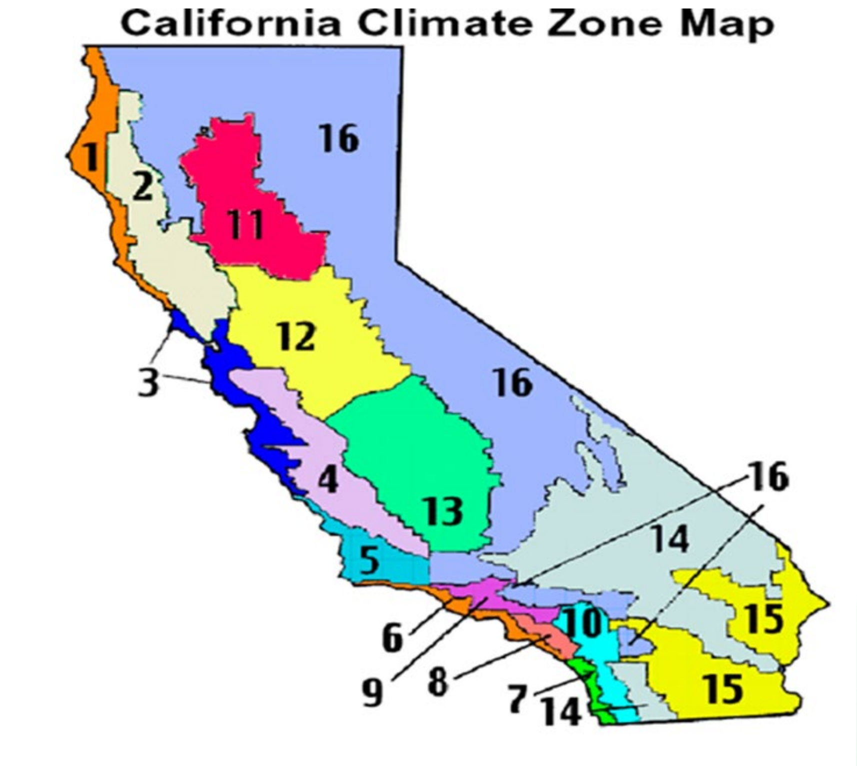
CEC staff, with input from utility partners and industry stakeholders, develop the triennial standards update

Opportunities for participation

- Utility-Sponsored Stakeholder Meetings
- CEC-Sponsored Workshops

Standards must be cost-effective

- Life-Cycle Costing Methodology
- Time Dependent Valuation (TDV)



2022 Standards Process

2022 STANDARDS UPDATE SCHEDULE	
DATE	**MILESTONES**
November 2018 - November 2019	Updated Weather Files
November 2018-December 2019	Metric Development
November 2018-July 2019	Measures Identified and approval
August 2019 to October 2020	Stakeholder meeting/workshop & final staff workshop
August 2020-October 2020	CASE Reports submitted to the CEC
February 2021	45-day Language Hearings
July 2021	Adoption of 2022 Standards at a Business Meeting
July 2021 to November 2021	Staff work on Software, Compliance Manuals, Electronic Documents Available to Industry
December of 2021	Approval of the Manuals
January 2022	Software, Compliance Manuals, Electronic Documents Available to Industry
January 1, 2023	Effective Date

Tentative Pre-Rulemaking Schedule

- **September 1**
  - Energy Savings and Process Improvements for Alterations and Additions
    - Roof deck insulation for low-slope roofs
    - Prescriptive attic insulation for alterations
    - Prescriptive duct sealing
    - Electric resistance water heating
    - Electric resistance space heating
    - 40-ft trigger for prescriptive duct requirements
    - Cool roof for steep-slope roofs
    - Cool roof for low-slope roof
- **September 9**
  - Nonresidential Grid Integration
  - Controlled Receptacle, CEA Proposal
- **September 10**
  - Verification Testing
- **September 22**
  - Outdoor lighting
  - Daylighting
- **September 23**
  - Computer Room Efficiencies
  - Pipe Sizing and Leak Testing for Compressed Air Systems
  - Refrigeration System Operation
- **September 30**
  - Indoor Air Quality Roundtable discussion with the outside world

Tentative Pre-Rulemaking Schedule (Cont.)

- **October 6 and December 8**
  - Solar Photo Voltaic and HeatPump Baseline
  - Multifamily All Electric
- **October 7**
  - Nonresidential Indoor Lighting
  - Air Distribution
  - Nonresidential HVAC Controls
- **October 13**
  - Multifamily Domestic Hot Water
  - Multifamily Restructuring
- **October 20**
  - Nonresidential High Performance Envelope
- **October 27**
  - Control Environmental Horticulture
  - New Construction Steam Trap
- **November 3 (Commissioner roundtable discussion on September 30 on IAQ)**
  - Indoor Air Quality Roundtable discussion with the outside world
  - Nonresidential Reduced Infiltration
- **December 2**
  - Alternate Compliance Method Approval Manual
  - Economizer Provisions
  - Nonresidential Data Registry Provisions
  - Restructuring of Multifamily Buildings

Key Web-Links

2022 Title 24 Utility-Sponsored Stakeholder
http://title24stakeholders.com/

Building Energy Efficiency Program
http://www.energy.ca.gov/title24/

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

NOTE: For this workshop comments To Be Submitted By December 24, 2020

Building Standards Staff Contact Information – Energy Commission

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Comments For Todays Workshop

Due Date: December 24, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

Questions ?

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Thank You!

2022 Building Energy Efficiency Standards Overview

December 8, 2020 Staff Workshop

Heatpump Baselines and PV Requirements

Mazi Shirakh, PE: Building Decarbonization Lead

2022 T24 Standards Building Decarbonization Team

Mazi Shirakh, PE
Building Decarbonization Lead

Bill Pennington
Senior Technical and Program Advisor

Danny Tam
Mechanical Engineer

Payam Bozorgchami, PE
Project Manager, Building Energy Efficiency Standards

Will Vicent
Office Manager, Building Standards Office

Consulting Team:

Energy + Environmental Economics (E3)
NORESCO
TRC

Heatpump Baseline and PV/Storage Workshops

Two workshops, twice the fun:

Two workshops dedicated to heatpump baselines and nonresidential PV and battery storage requirements:

October 6, 2020 presented:

- High level overview of the proposed requirements for heatpump baseline scenarios and PV and storage requirements; only included “TDV” and not “Source Energy” baseline options
- Draft language was not presented
- Sought public input for concepts presented

December 8, 2020

- Draft language and detailed analysis will be presented
- After seeking further public comments, will become the basis for 45-day language

2022 T24 Standards Goals

Heatpump Baselines For:

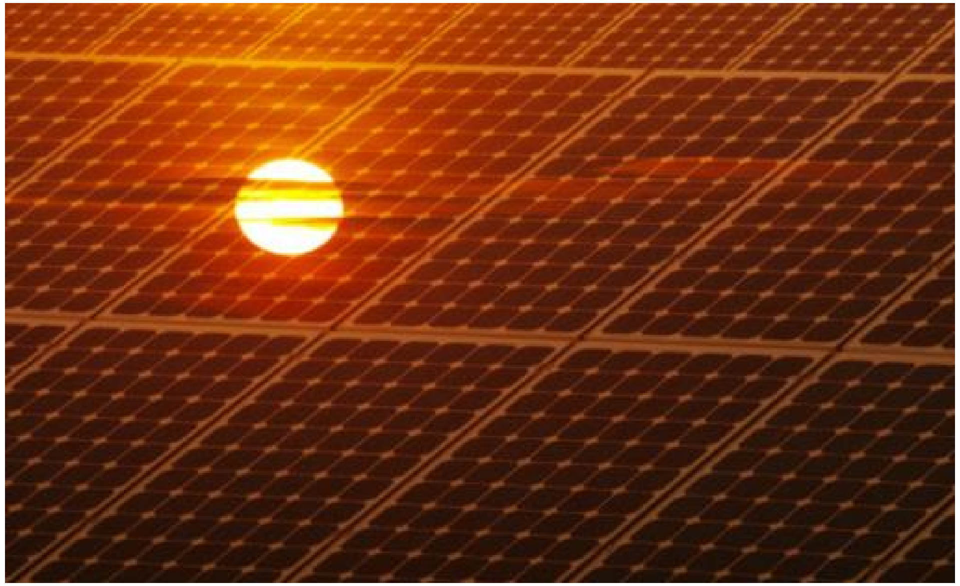
1. Highrise Multifamily (HRMF)
2. Selected Nonresidential Occupancies

PV and Battery Storage Requirements For:

1. HRMF
2. Selected Nonresidential Occupancies

2022 T24 Standards Occupancies

New Heatpump Baselines and PV Requirements for:



1. HRMF
2. Office (small)
3. Retail (small, medium, and large)
4. Educational facilities
5. Warehouses
6. Mixed occupancy building where one or more of these types-of-uses makeup at least 80 percent of the floor areas of the building

Heatpump Baselines

Heatpump for space heating in baseline for:

- HRMF and selected nonresidential occupancies
- Establish appropriate Source Energy and TDV baselines
- Must be feasible and cost effective

Creating feasible and cost-effective heatpump baselines is challenging for larger buildings currently relying on central boiler systems

PV & Battery Storage Requirements

PV and Possibly Battery Storage Requirements for HRMF and Selected Nonresidential Occupancies with access to VNEM:

1. Considering NEM2 and alternative NEM tariffs with hourly exports compensated at avoided cost
2. Emphasize maximizing self-utilization of PV generation and minimizing exports thru:
   i. "Right sizing" the PV system to avoid large exports
   ii. Pairing with battery storage, EV charging, and other load-shifting strategies to limit hourly exports to less than 10% of annual generation
3. Possible credit for standalone battery storage systems

Availability of suitable rooftop areas for PV installation may be a limiting factor

Battery Storage Ready Proposed Requirements

New residential mandatory battery storage ready requirements:

1. Panel requirements to accommodate electric end-uses, PV, EVs, and future battery storage installation

2. Identification and isolation of emergency circuits, and

3. Compatibility with both battery storage systems, bidectional Evs, and backup generators to help with PSPS events

Will reduce the future battery storage installations by $2,000 or more

Questions ?

Title 24 2022 ACM: Heat Pump Baseline Analysis – Nonresidential and High-Rise Residential Buildings

December 8, 2020

Roger Hedrick, Nikhil Kapur,
Eric Shadd, Rahul Athalye

NORESCO

OBJECTIVES

- Identify heat pump based HVAC systems for consideration as 2022 ACM Baselines
- Evaluate performance relative to current ACM baseline
  - All current standard designs use gas heat
  - Initial expectation was that TDV will increase when switching to electric heat
- Identify systems that have lower TDV consumption, but result in a minimal increase in stringency
  - A new baseline with higher TDV consumption would decrease stringency for projects with electric heat
  - Systems with large differences from the baseline in TDV consumption are excluded from the results that will follow

APPROACH

- Use CEC prototypes
  - 10 Story, Mixed-Use Apartment
  - Retail – Small, Medium and Large
  - Office – Small, Medium and Large
  - Small Restaurant
  - Small School
  - Warehouse
- Service and Domestic Hot Water Systems – Electric Only
- Cooling parameters match standard design
  - Federal standards may impact this if changes made in CBECC-Com
- Fan parameters also match standard design
- For similar system types, impacts are due to heating type only.

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HIGH-RISE BASELINE SYSTEM OPTIONS

	Current Baseline	Systems Analyzed
Highrise Residential Dwelling Units*	Single Zone Air Conditioner with Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump w/ Gas Supplemental Heat ▪ Variable Refrigerant Flow ▪ Water Source Heat Pump w/ Elec. Boiler
DHW	Central Gas Water Heating	▪ Central Gas ▪ Central Heat Pump
Ventilation	Balanced Ventilation	Balanced Ventilation

*HVAC systems for nonresidential spaces were modeled to match the baseline for all options

ALTERNATIVE SYSTEM OPTIONS

	Current Baseline	Systems Analyzed
Small Retail	Single Zone and Single Zone Variable Air Volume (VAV) – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat
Medium Retail	Single Zone and Single Zone VAV – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat
Large Retail	Single Zone VAV – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat

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ALTERNATIVE SYSTEM OPTIONS

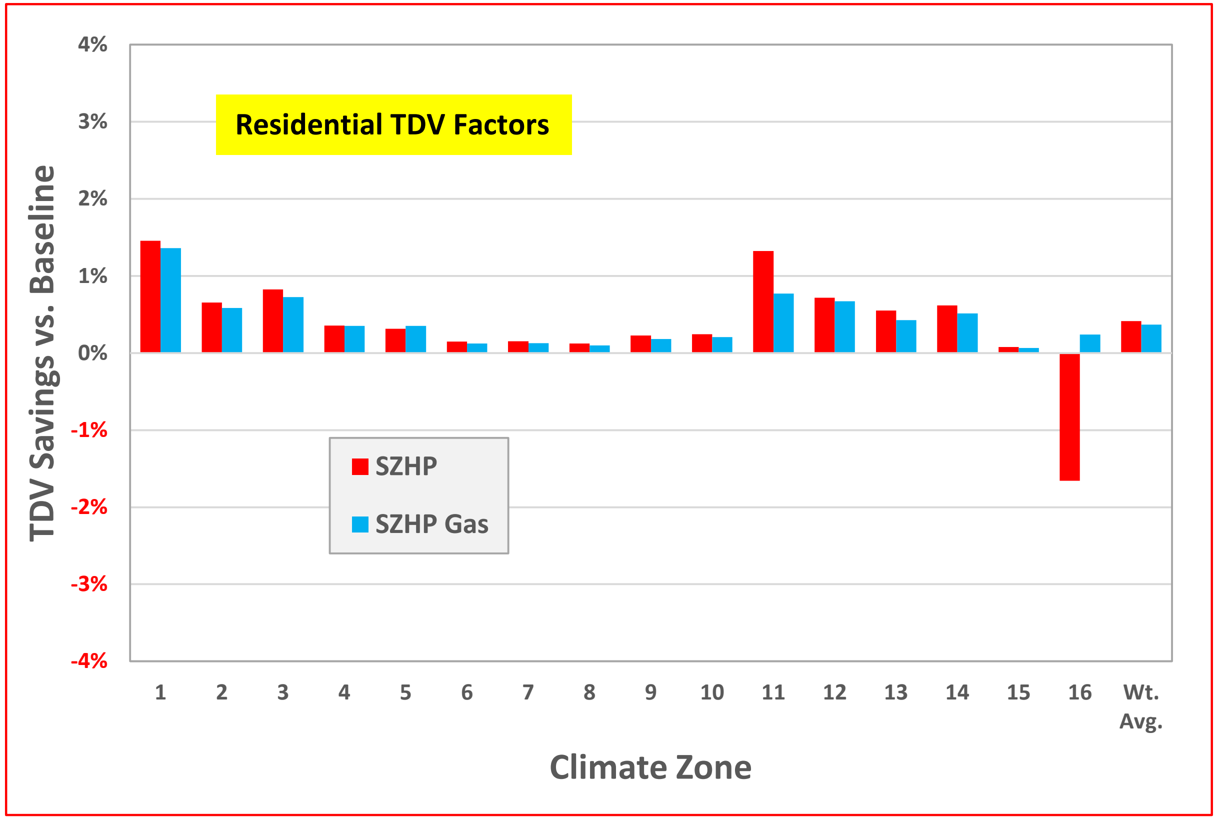
	Current Baseline	Systems Analyzed
Small Office	Single Zone Rooftop – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Supplemental Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat ▪ Variable Refrigerant Flow + DOAS
Medium Office	Packaged Variable Air Volume – Hot Water Heat with Gas Boiler	▪ Packaged VAV – Electric Resistance Reheat ▪ Packaged VAV – Electric Reheat & Parallel Fan Boxes ▪ Packaged VAV w/ Heat Pump Boiler ▪ Variable Refrigerant Flow + DOAS ▪ Water Source Heat Pump w/ Elec. Boiler + DOAS
Large Office	Built-Up Variable Air Volume – Hot Water Heat with Gas Boiler	▪ Variable Air Volume (VAV) w/ Elec. Reheat ▪ VAV w/ Electric Reheat & Parallel Fan Boxes ▪ VAV w/ Heat Pump Boiler ▪ Water Source Heat Pump w/ Elec. Boiler + DOAS

ALTERNATIVE SYSTEM OPTIONS

	Current Baseline	Systems Analyzed
Restaurant (Small)	Single Zone and Single Zone VAV – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat
School (Small)	Single Zone and Single Zone VAV – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat ▪ Packaged VAV – Electric Resistance Reheat ▪ Packaged VAV – Electric Reheat & Parallel Fan Boxes ▪ Variable Refrigerant Flow ▪ Water Source Heat Pump w/ Elec. Boiler + DOAS
Warehouse	Single Zone VAZ (Office), Heating Ventilating System (Storage) – Gas Furnace Heat	▪ Single Zone Heat Pump ▪ Single Zone Heat Pump with Gas Sup. Heat ▪ Single Zone VAV Heat Pump ▪ Single Zone VAV Heat Pump with Gas Sup. Heat

HIGH RISE MULTIFAMILY – TDV RESULTS

- Baseline is single zone air conditioners (SZAC) with gas furnace heat
- Heat pump heat gives small reductions in TDV except in CZ16
- Changing supplemental heat to gas gives TDV savings in all climate zones



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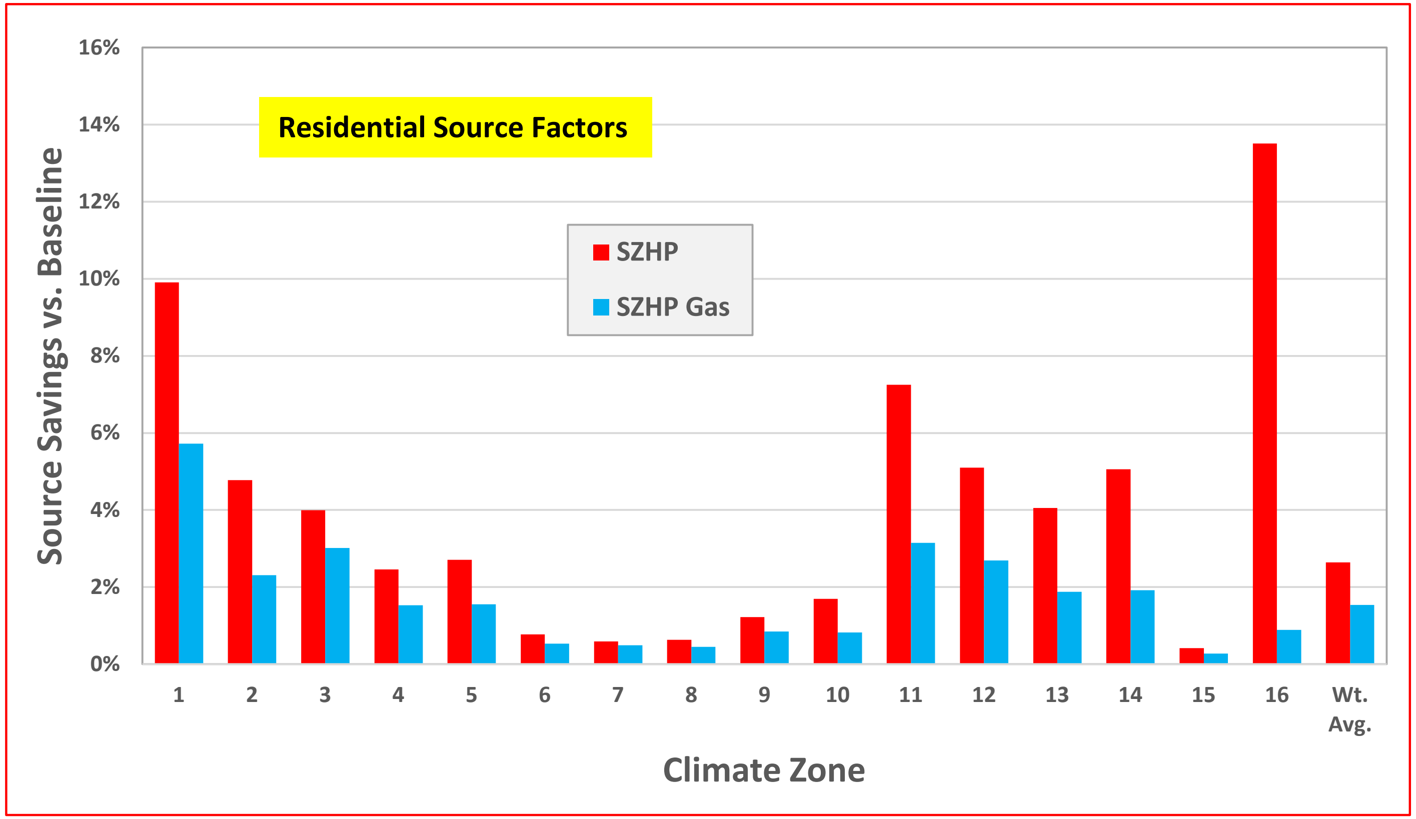
HIGH RISE MULTIFAMILY – SOURCE ENERGY RESULTS

- Source energy savings for all options
- Source energy savings means increased stringency for gas heat design choices
- Use of gas supplemental heat reduces the source energy stringency



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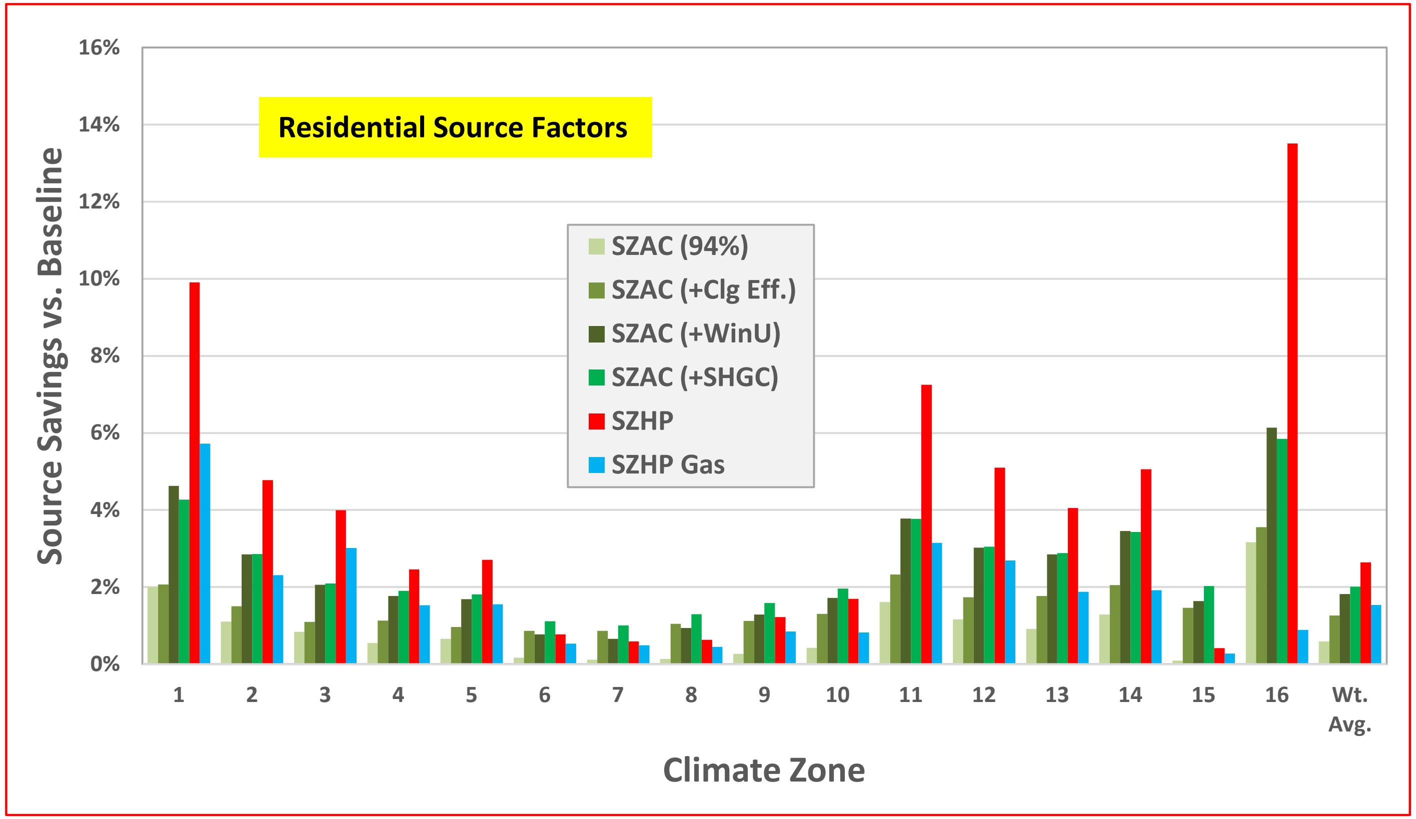
HIGH RISE MULTIFAMILY – SOURCE ENERGY RESULTS

- Will source stringency be prohibitive to gas heat?
- Added simple efficiency measures to gas furnace design
- Gas heat designs will require aggressive efficiency measures to comply in cool climate zones
- Gas supplemental heat sets more achievable targets



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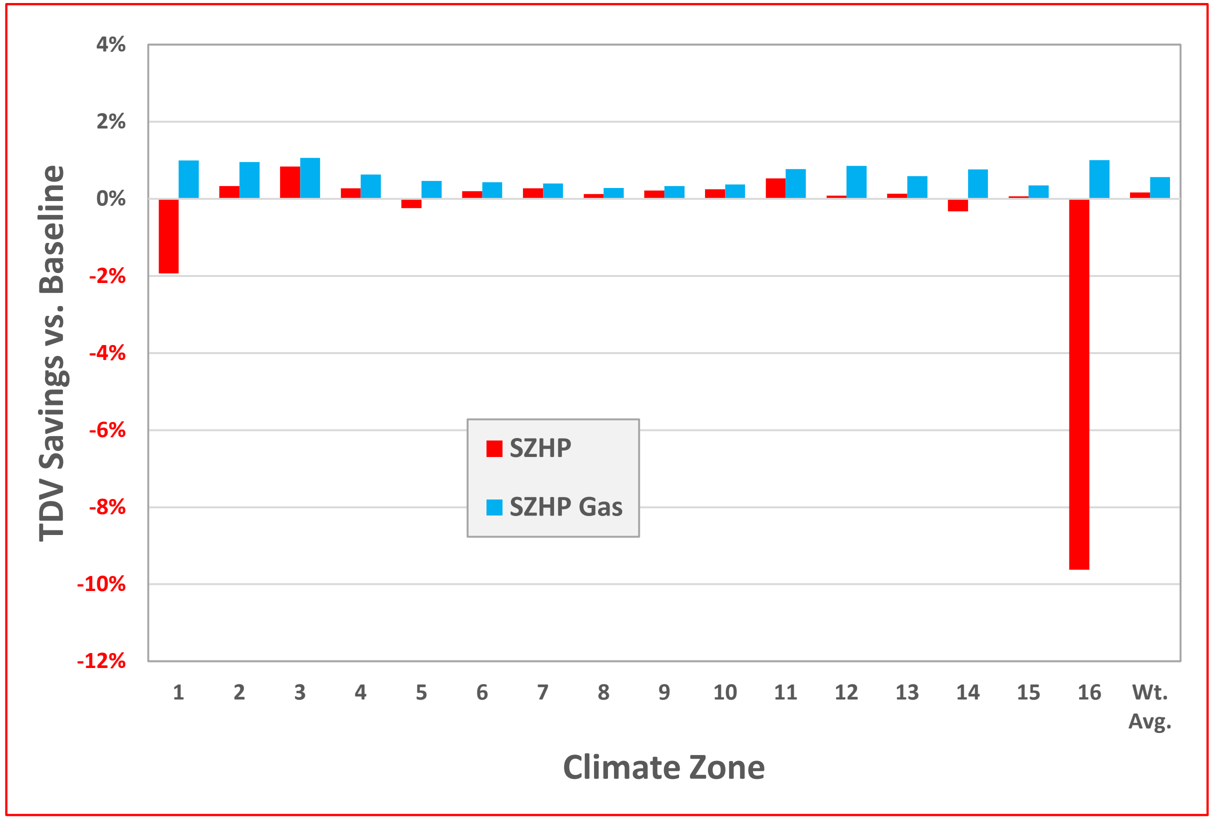
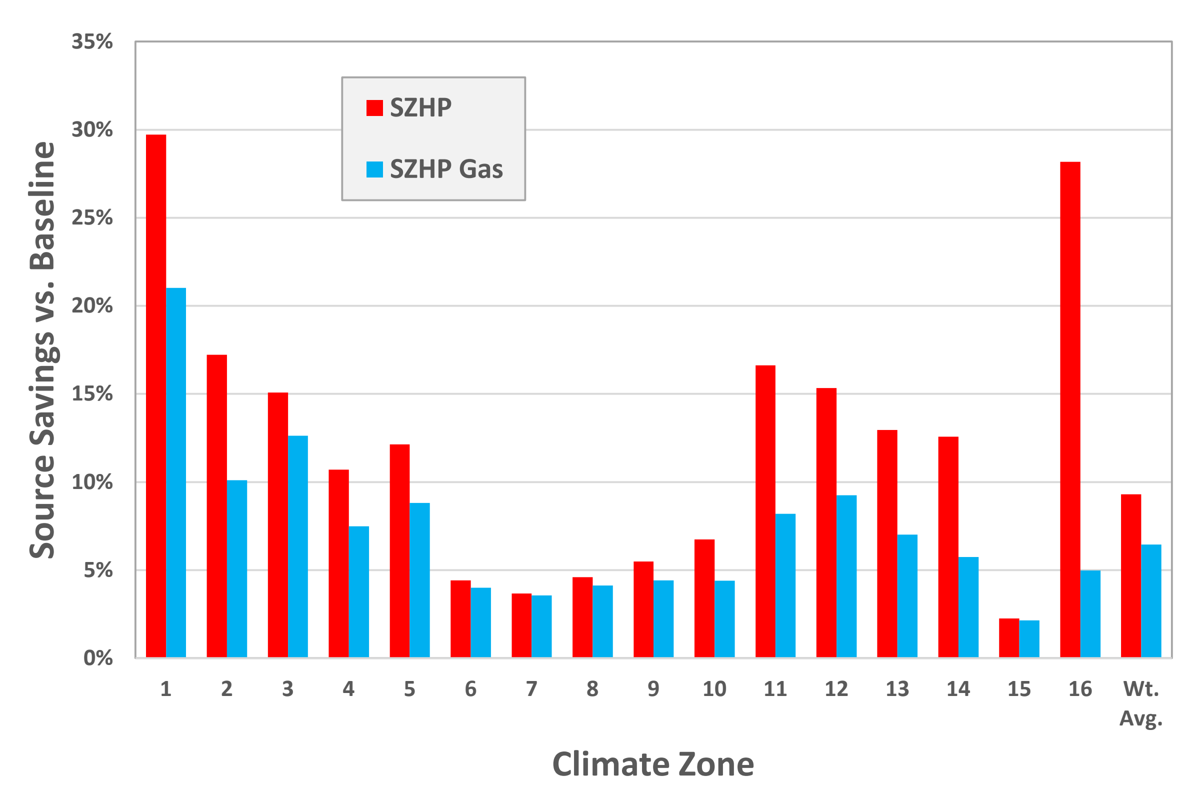
SMALL RETAIL – TDV RESULTS

- Baseline is a mix of single zone air conditioners (SZAC) and single zone VAV air conditioners (SZVAVAC), all with gas furnace heat
- Changing furnace to heat pump heat - small reduction in TDV except in CZ1, 5, 14 and 16
- Changing supplemental heat to gas gives TDV savings in all CZ



SMALL RETAIL – SOURCE ENERGY RESULTS

- Source energy savings in all Climate Zones for all options
- Increase in stringency with SZHP very significant, particularly in cool climate zones
- Use of gas supplemental heat mitigates the increased stringency



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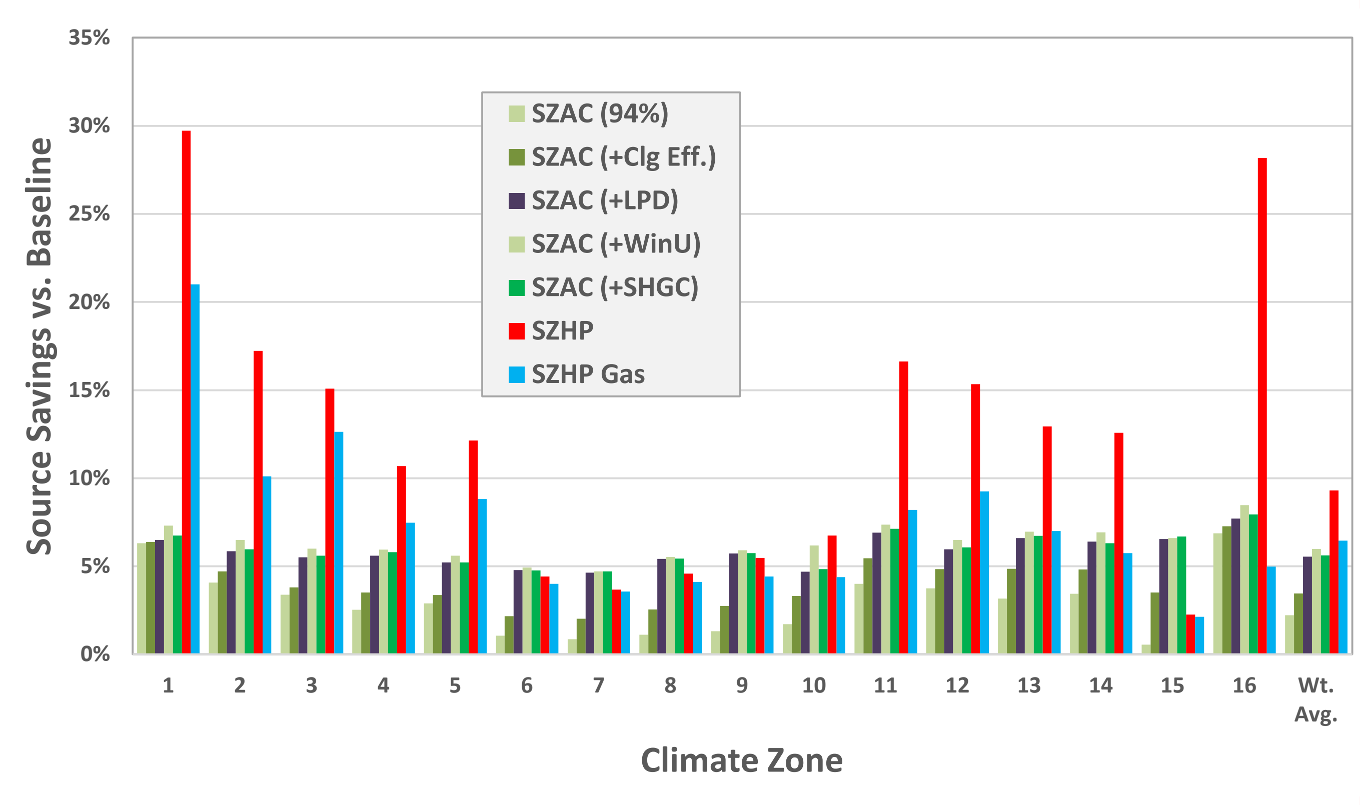
SMALL RETAIL – SOURCE ENERGY RESULTS

- Will source stringency be prohibitive for gas heat?
- Added simple efficiency measures to furnace system
- Gas supplemental heat sets achievable target in most climate zones
- VAV or DOAS may be needed in CZ1



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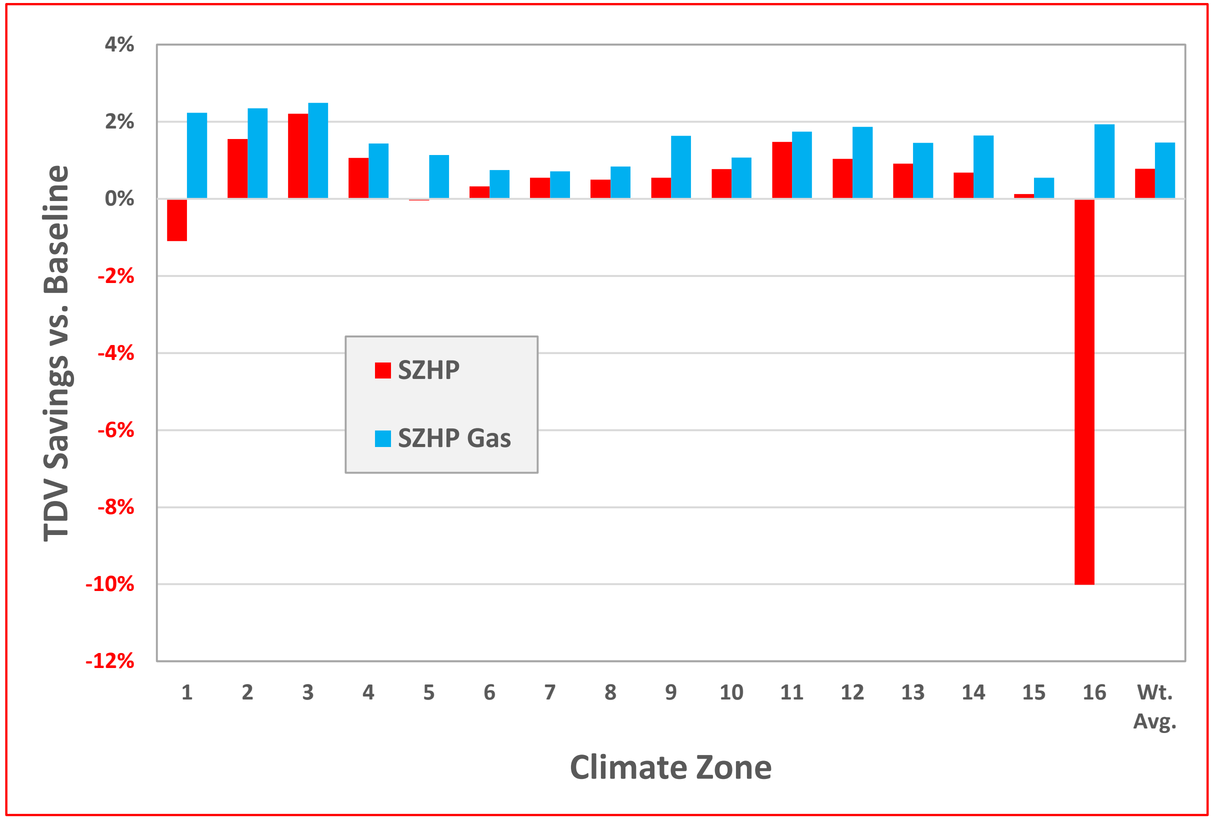
MEDIUM RETAIL – TDV RESULTS

- Baseline is a mix of SZAC and SZVAVAC, all with gas furnace heat
- Changing furnace to heat pump heat - small reduction in TDV except in CZ1, 5 and 16
- Changing supplemental heat to gas gives TDV savings in all CZ



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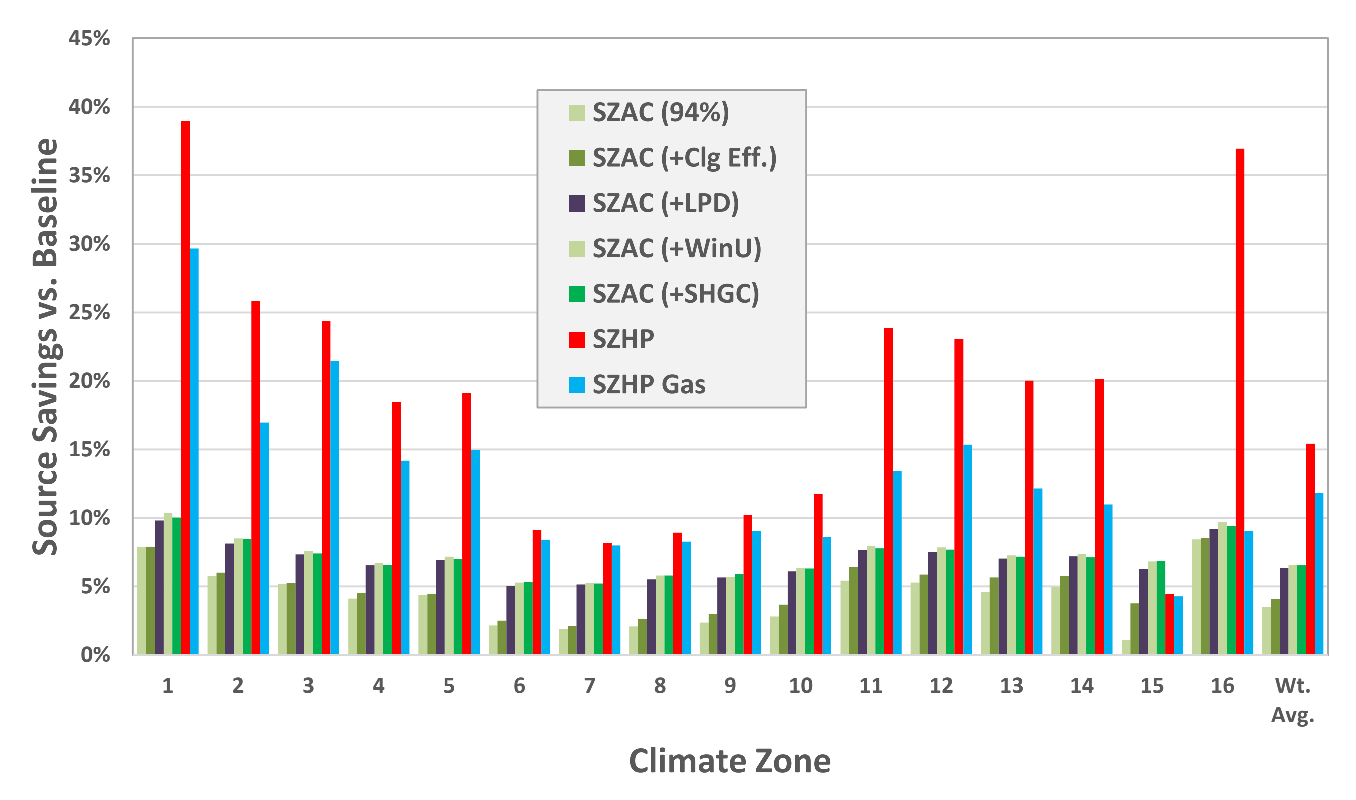
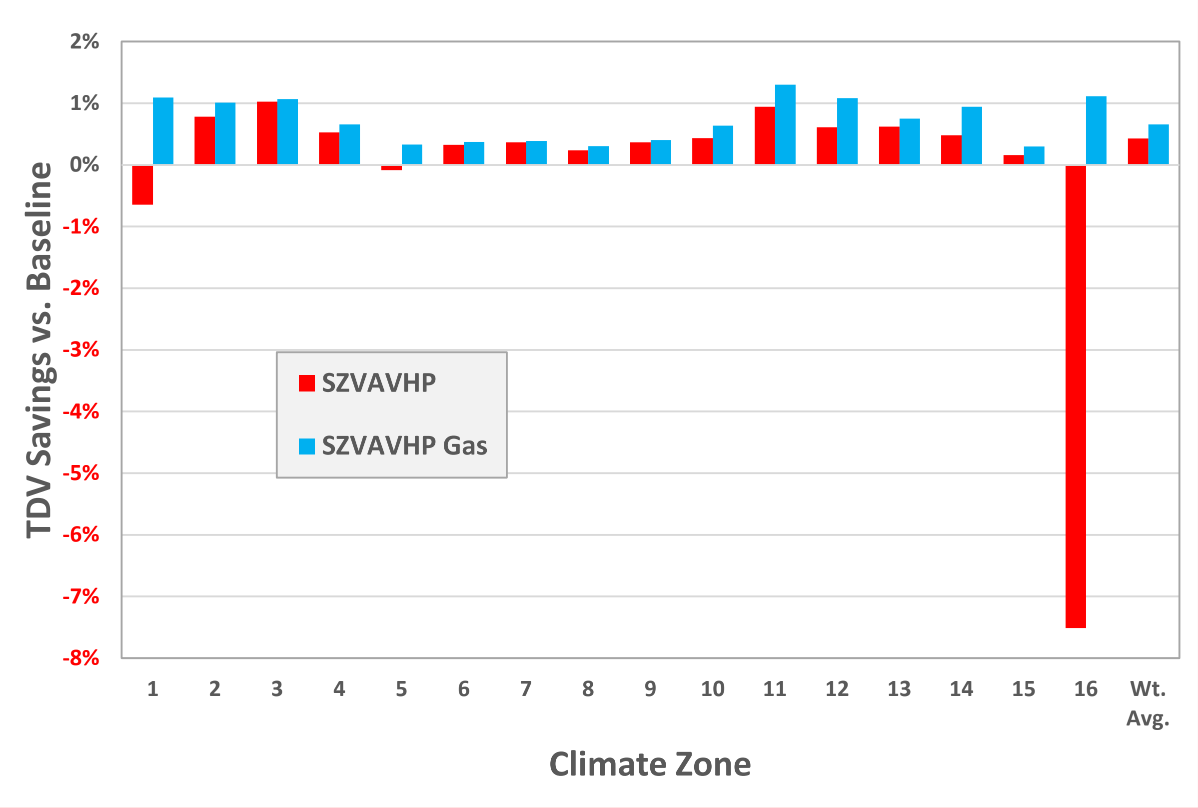
MEDIUM RETAIL – SOURCE ENERGY RESULTS

- Source stringency slightly higher than in Small Retail
- Gas supplemental heat sets challenging target in most heating climate zones
- VAV or DOAS would meet these targets



LARGE RETAIL – TDV RESULTS

- Baseline is SZVAVAC with gas furnace heat
- Changing furnace to heat pump heat - small reduction in TDV except in CZ1, 5 and 16
- Changing supplemental heat to gas gives TDV savings in all CZ



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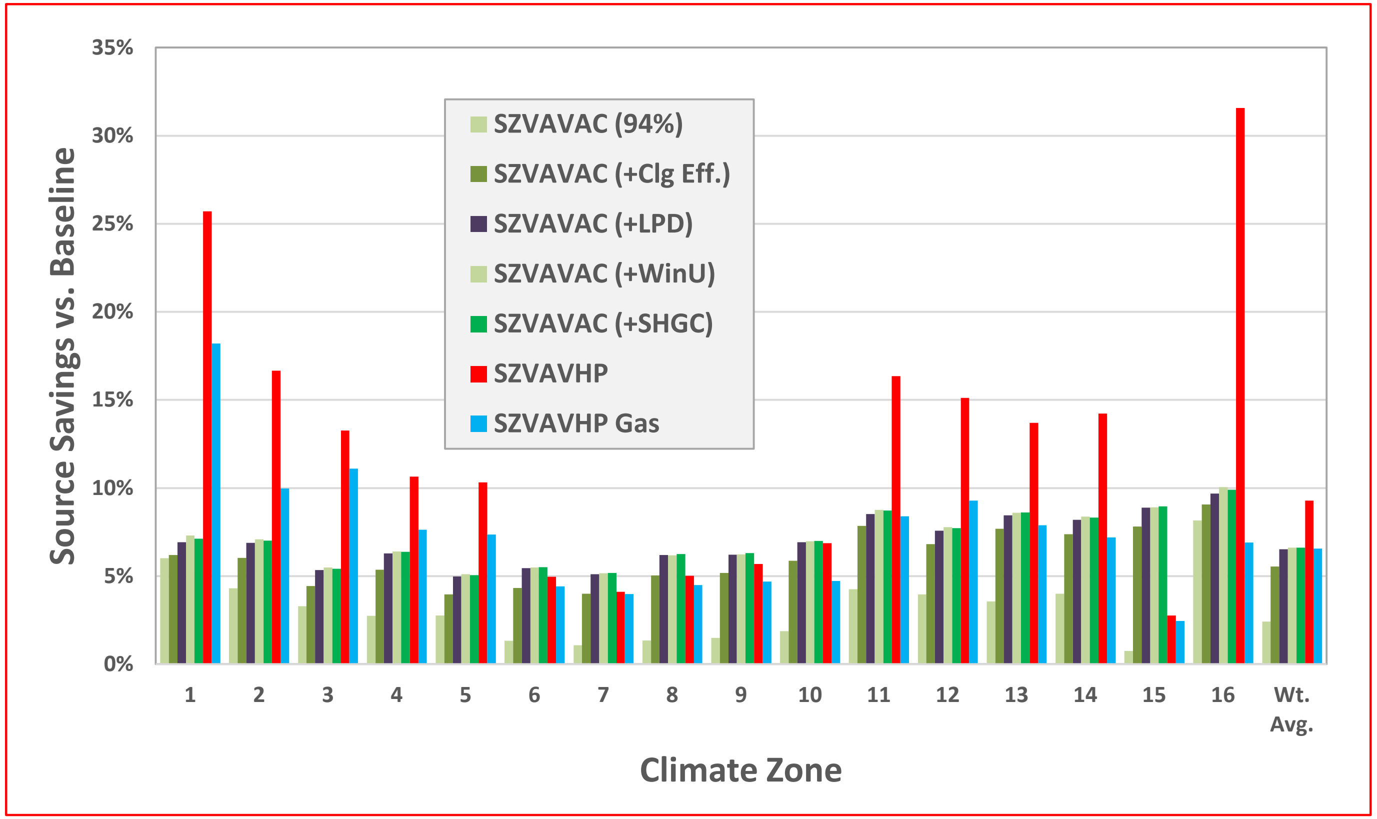
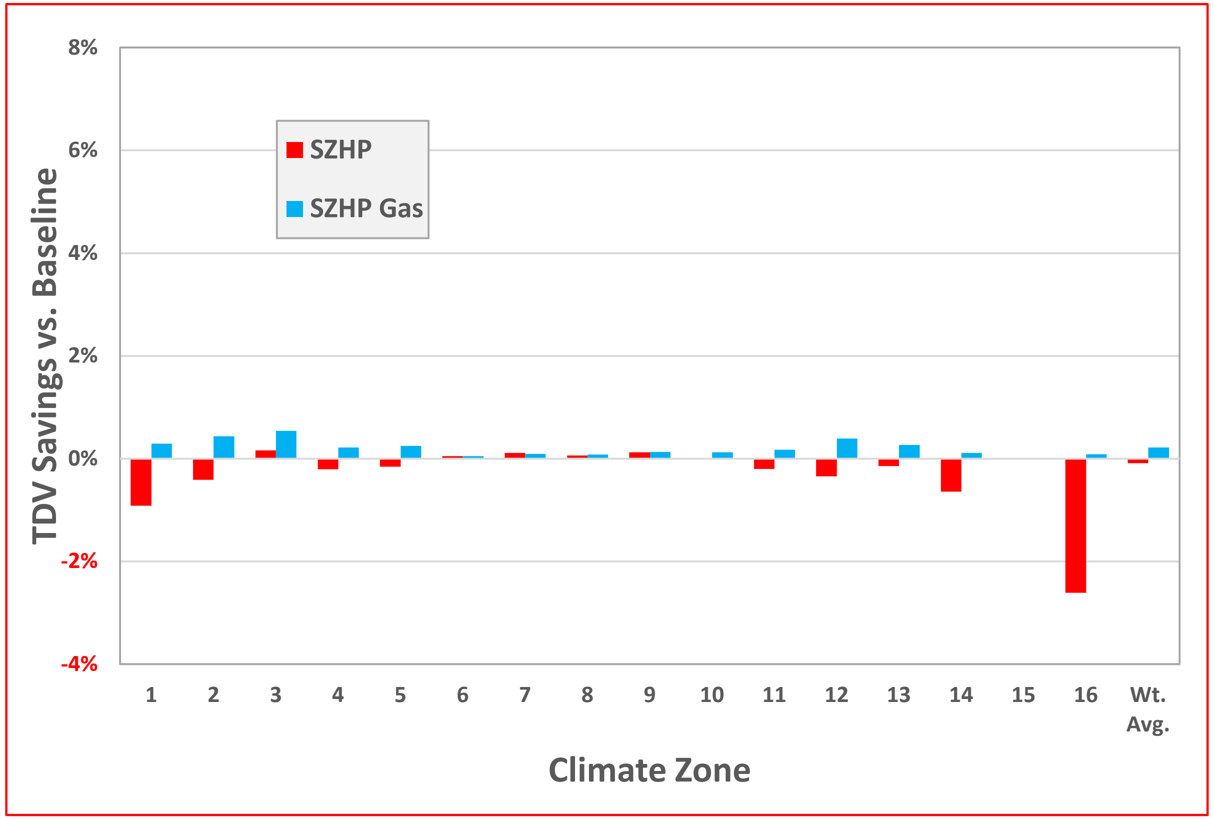
LARGE RETAIL – SOURCE ENERGY RESULTS

- Source stringency similar to Small Retail
- Gas supplemental heat sets achievable target in most climate zones



SMALL OFFICE – TDV RESULTS

- Baseline is SZAC with gas furnace heat
- Changing furnace to heat pump heat - small increases in TDV in CZ2, 4, 5, 11, 12, 13, and 14
- Significant TDV increases in CZ1 and 16
- Changing supplemental heat to gas gives TDV savings in all CZ



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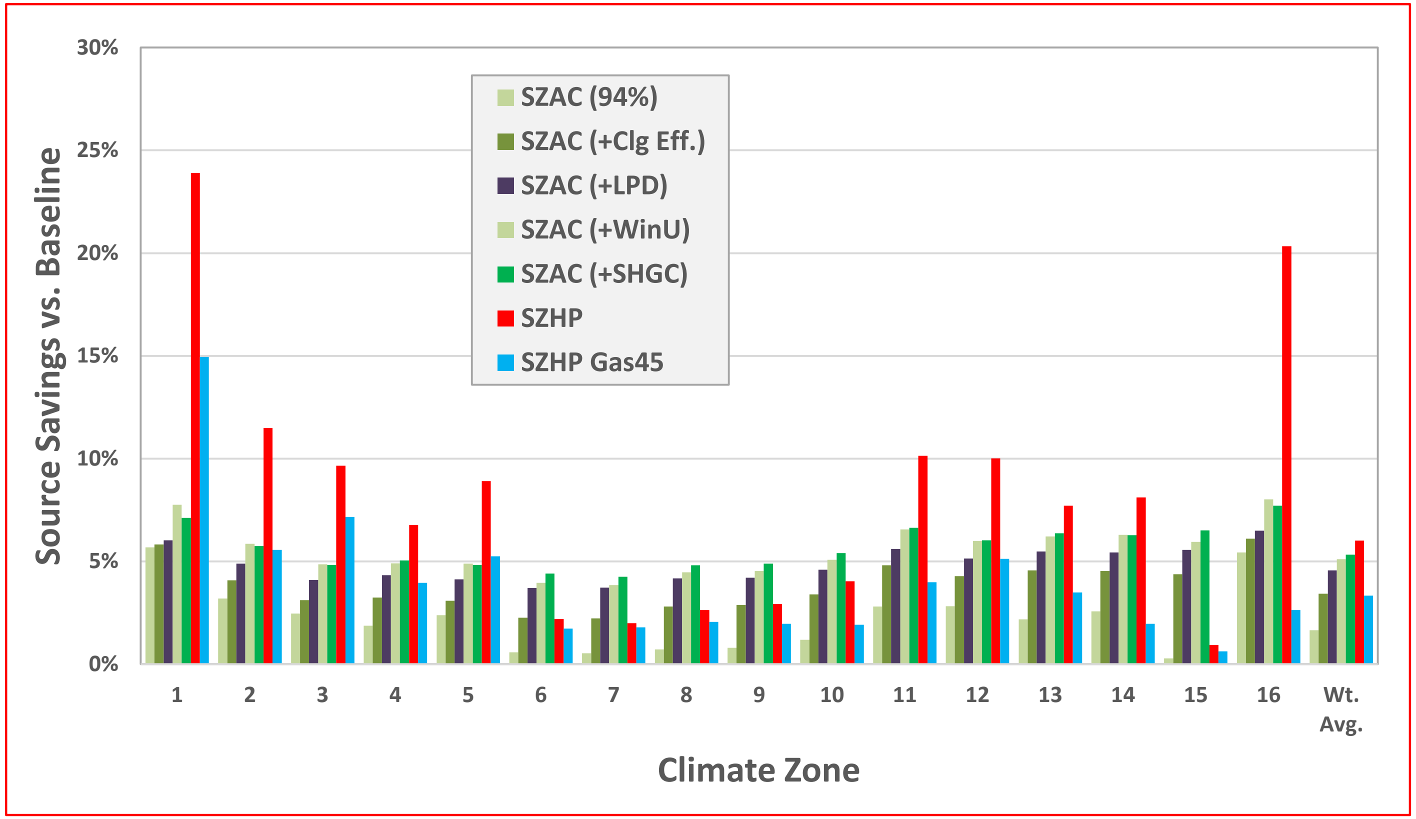
SMALL OFFICE – SOURCE ENERGY RESULTS

- Source stringency less than in Retail
- Gas supplemental heat sets achievable target in all climate zones except possibly CZ1
- VAV or DOAS would easily meet these targets



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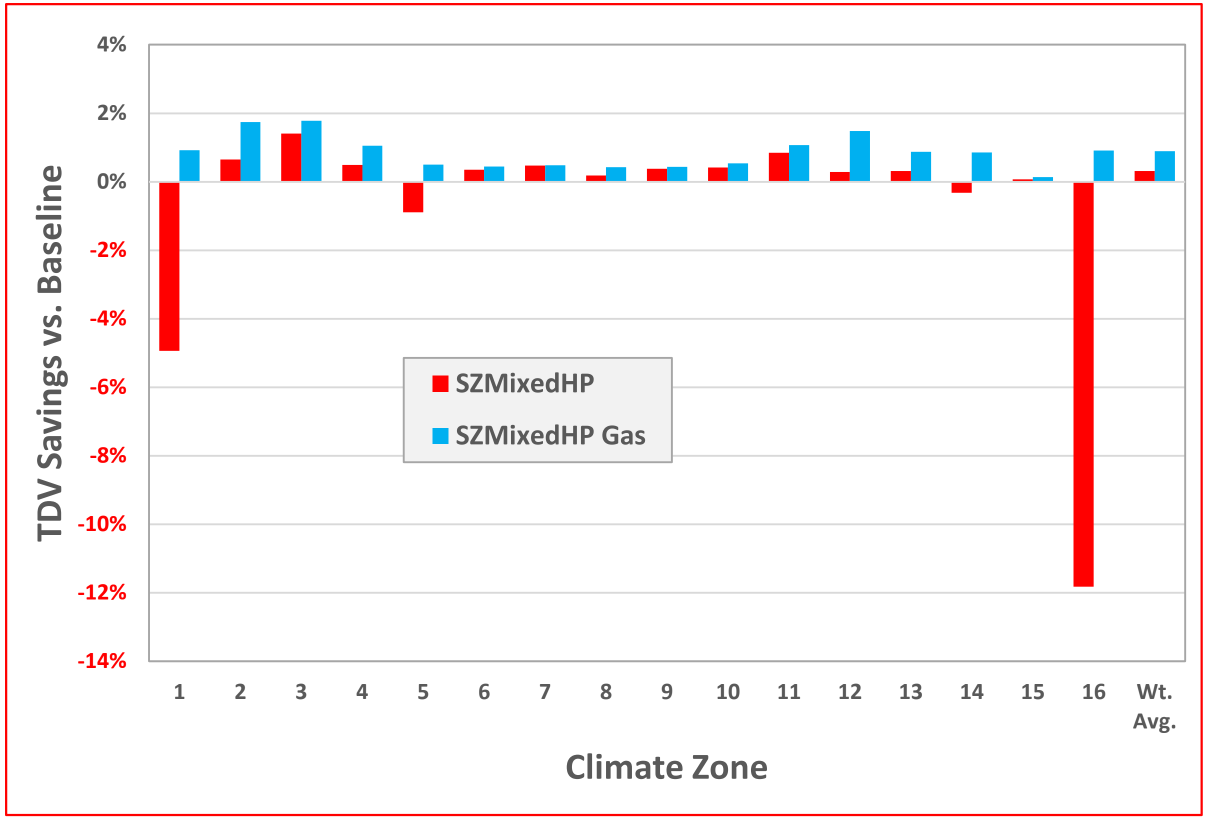
SMALL SCHOOL – TDV RESULTS

- Baseline is a mix of SZAC and SZVAVAC, all with gas furnace heat.
- Changing furnace to heat pump heat - small reduction in TDV except in CZ1, 5, 14 and 16
- Changing supplemental heat to gas provides TDV savings in all climate zones



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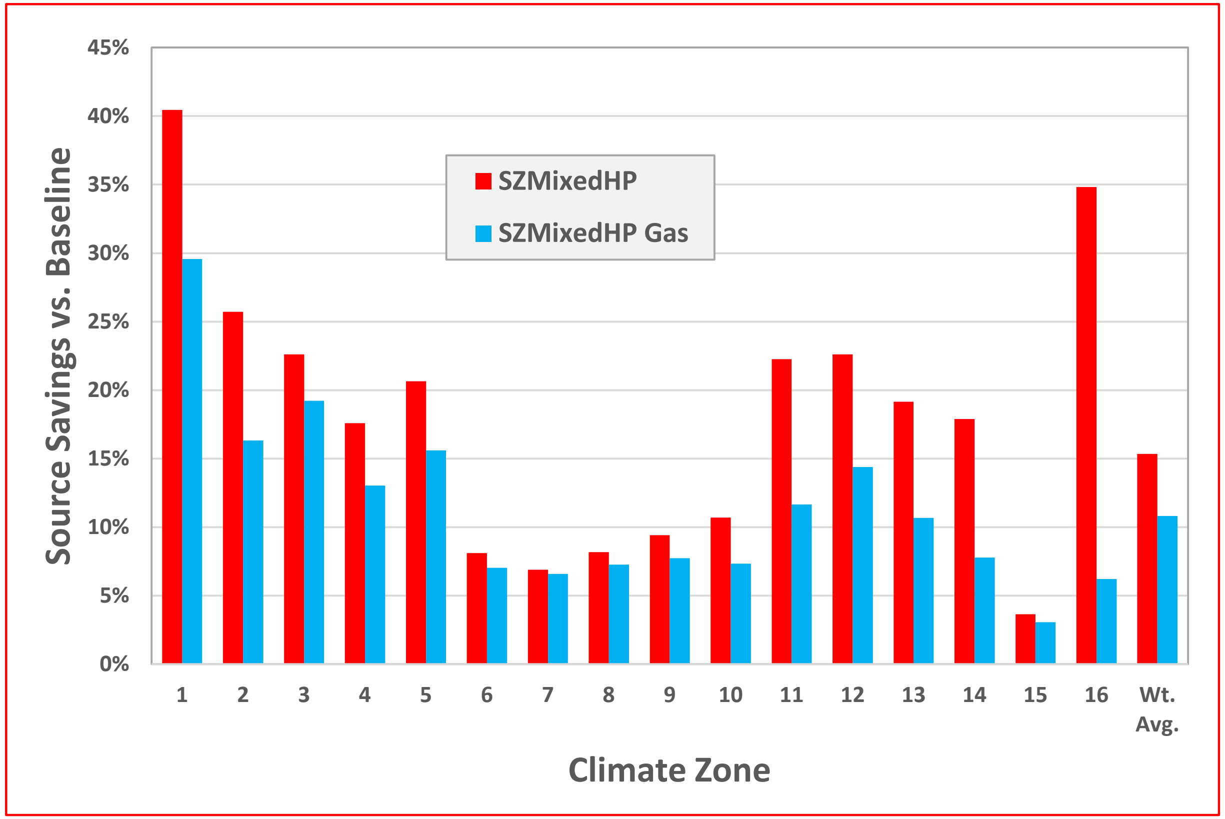
SMALL SCHOOL – SOURCE ENERGY RESULTS

- Significant increase in source stringency
- Gas supplemental heat mitigates the increased stringency in source energy



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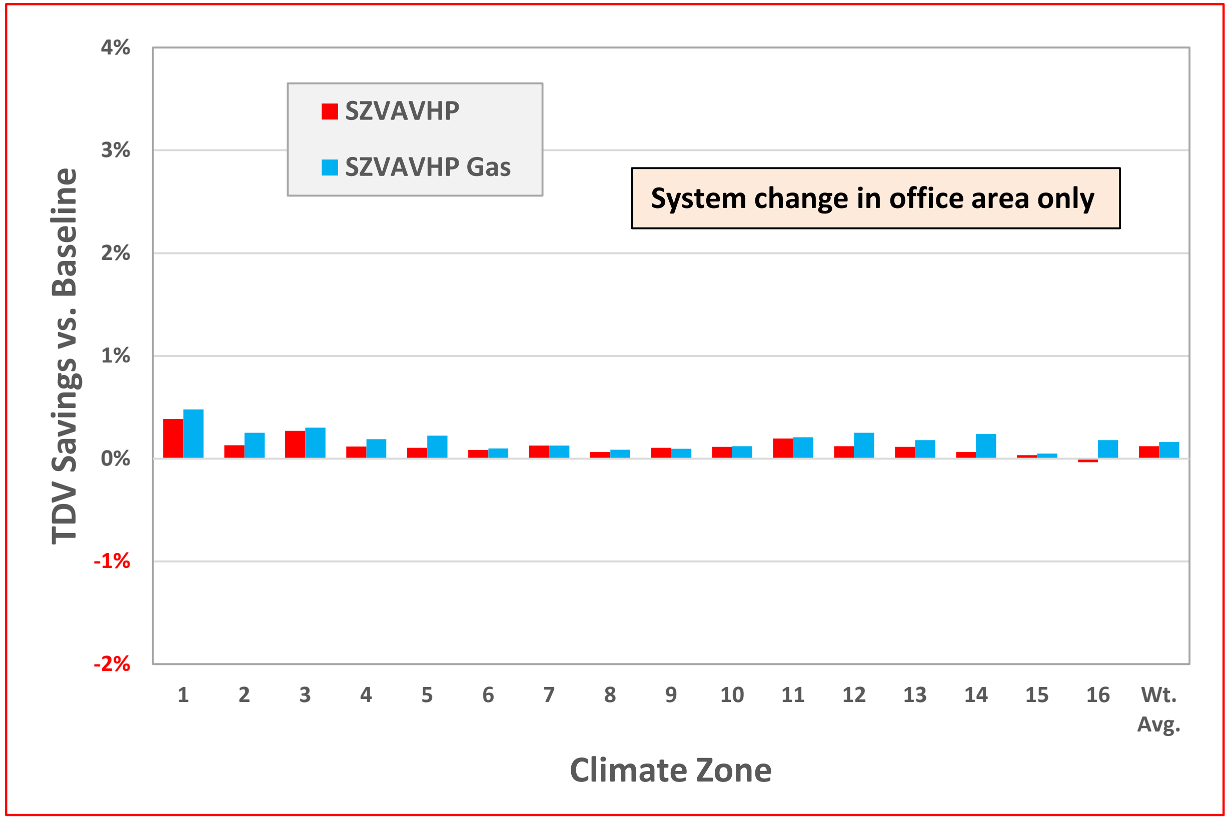
WAREHOUSE – TDV RESULTS

- Baseline is a SZVAVAC for the office and heating/ventilating units serving storage areas, all with gas furnace heat.
- No direct electric heat alternative to the H/V units
- Heat pump for the office shows small TDV savings except in CZ16
- Change to gas supplemental heat reduces TDV in all climate zones



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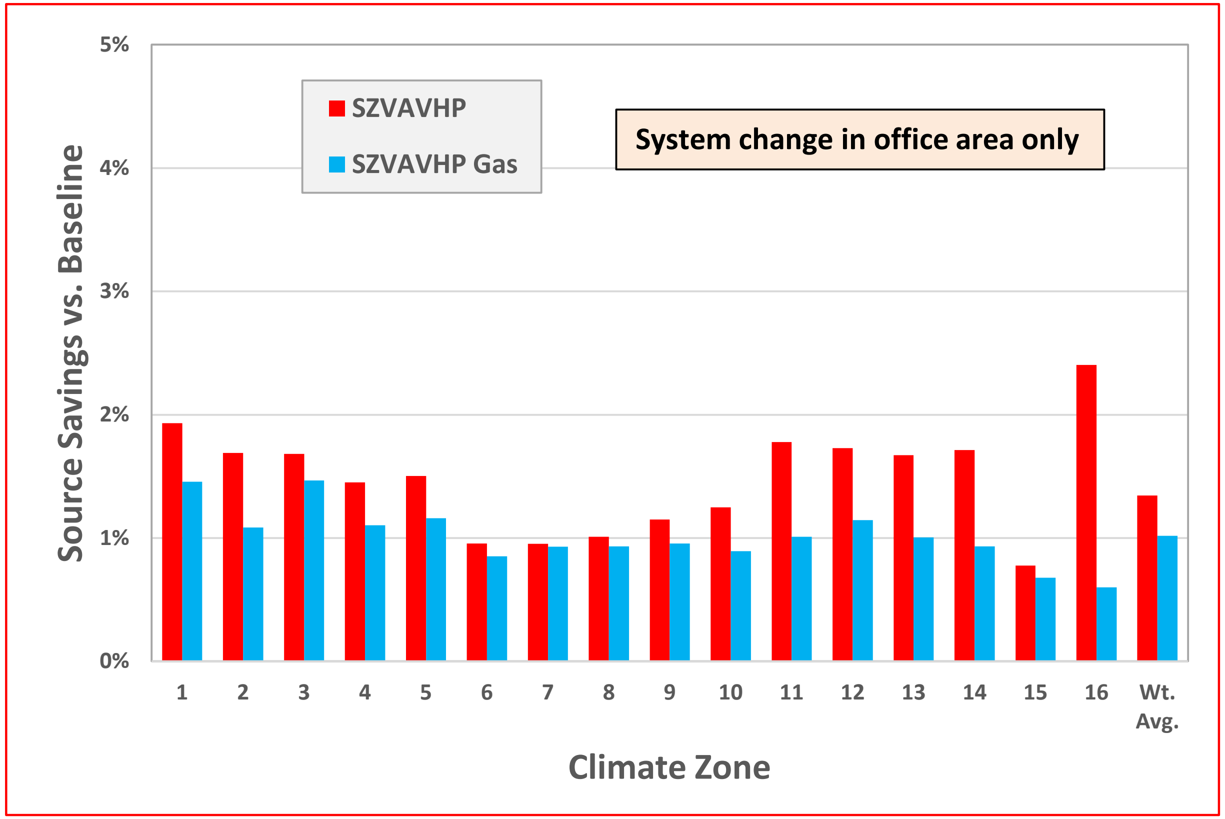
WAREHOUSE – SOURCE ENERGY RESULTS

- Increased stringency as a percentage skewed because the system only serves part of the building
- Gas supplemental heat mitigates the increased stringency in source energy



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CONCLUSIONS

- Switch of standard design from gas furnace to heat pump appears viable
  - Very small TDV increases (reduced stringency) in some climate zones and prototypes
  - Significant TDV increases in climate zone 16
- Electric alternatives to gas boilers problematic – significant reduction in TDV stringency
- Conventional heat pumps result in significant increases in source energy stringency in cooler climate zones, but especially CZ1
- Use of gas supplemental heat in the Standard Design:
  - Provides TDV savings in all climate zones
  - Mitigates the increase in source energy stringency

NORESCO

- **QUESTIONS??**

NORESCO

2022 CALIFORNIA ENERGY CODE (TITLE 24, PART 6)

Multifamily Heatpump Compliance Pathway

Codes and Standards Enhancement (CASE) Proposal
Multifamily

Abhijeet Pande & *Dove Feng,* *TRC*

December 8, 2020

CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

Pacific Gas and Electric Company · Southern California Edison · SDG&E · Los Angeles Department of Water & Power · SMUD

Statewide Utility Codes and Standards Team

Actively support the California Energy Commission in developing proposed changes to the Energy Code (Title 24, Part 6) to achieve significant statewide energy use reductions through the development of code change proposals for the 2022 cycle that are:

Feasible | Cost effective | Enforceable | Non-proprietary

Definition of Baseline and Proposed Conditions

Baseline Conditions

- **Heating System** – Gas Furnace
- **Cooling System** – Split Dx A/C
- Minimum efficiency meeting federal appliance standards

Proposed Conditions

- **CZ 1-15:** Split Ducted Heat Pump
- **CZ16:** Split Ducted Heat Pump with Gas Furnace Backup + Window Efficiency Upgrades
- Minimum SEER/HSPF meeting federal appliance standards

Incremental Cost Information

- Cost data collected for baseline and proposed systems using a **professional cost estimator:**
  - Based on a ‘basis of design’ prepared by an experienced engineering firm
  - Using existing products available in the market that meet minimum federal appliance efficiency standards
  - Using strategies utilized in real world projects
  - Baseline system costs include natural gas piping to individual furnaces
  - Proposed system costs include additional electrical circuits/panel capacity as needed
- **All-electric designs were found to cost less at time of construction than mixed-fuel designs.**

Per Dwelling Unit Costs

Heat Pump Space Heating

Items		Mid-Rise Mixed-Use		High-Rise Mixed-Use	
		Gas Furnace + Split Dx	SZHP	Gas Furnace + Split Dx	SZHP
Equipment	Dwelling Unit HVAC	$5,619	$4,121	$5,567	$4,092
	Common Area Ventilation	$307	$376	$351	$373
	Refrigerant piping	$423	$423	$442	$442
	Gas piping	$227	$0	$237	$0
	Electrical circuits	$0	$150	$0	$150
Labor		$10,996	$6,985	$11,000	$6,946
Overhead/Markup/Design/Permit		$4,833	$3,315	$4,839	$3,301
Total		**$22,405**	**$15,371**	**$22,435**	**$15,304**
Incremental Cost per Dwelling Unit			**-$7,034**		**-$7,131**

The Statewide CASE Team has not included any cost savings from eliminating natural gas infrastructure to the building in the analysis. The gas piping costs and savings shown are for gas pipelines from the building gas meter to individual space heating systems serving individual dwelling units.

Per Dwelling Unit Costs (CZ 16 only)

Heat Pump Space Heating

Items		Mid-Rise Mixed-Use/ High-Rise Mixed-Use	
		Gas-fired furnace + Split SZAC	**Gas-fired furnace + Split SZHP**
Equipment	Dwelling Unit HVAC	$5,619	$6,109
	Common Area Ventilation	$307	$307
	Refrigerant piping	$423	$423
	Gas piping	$227	$227
	Electrical circuits	$0	$0
Labor		$10,996	$10,985
Overhead/Markup/Design/Permit		$4,833	$4,844
Total		**$22,405**	**$22,895**
Incremental Cost per Dwelling Unit			**$490**

Average Statewide Cost per Dwelling Unit

Cost-Effectiveness

Ducted Heat Pump Space Heating

Heat Pump Space Heating

Mid-rise Mixed-use Multifamily

Climate Zone	TDV Energy Cost Savings (2023 PV$)	Incremental Cost Savings (2023 PV$)	Benefit-to-Cost Ratio
1	$657	$9,719	Infinite
2	$417	$12,472	Infinite
3	$404	$11,904	Infinite
4	$230	$11,950	Infinite
5	$189	$9,760	Infinite
6	$107	$9,749	Infinite
7	$92	$9,781	Infinite
8	$100	$9,857	Infinite
9	$152	$9,760	Infinite
10	$156	$10,001	Infinite
11	$552	$10,087	Infinite
12	$383	$9,954	Infinite
13	$353	$9,967	Infinite
14	$221	$9,897	Infinite
15	$65	$10,016	Infinite
16*	$1,025	($923)	1.11

High-rise Mixed-use Multifamily

Climate Zone	TDV Energy Cost Savings (2023 PV$)	Incremental Cost Savings (2023 PV$)	Benefit-to-Cost Ratio
1	$735	$9,766	Infinite
2	$404	$12,567	Infinite
3	$355	$11,979	Infinite
4	$195	$12,034	Infinite
5	$172	$9,834	Infinite
6	$78	$9,823	Infinite
7	$82	$9,860	Infinite
8	$75	$9,932	Infinite
9	$126	$9,842	Infinite
10	$140	$10,079	Infinite
11	$611	$10,170	Infinite
12	$389	$10,054	Infinite
13	$334	$10,052	Infinite
14	$235	$9,979	Infinite
15	$48	$10,122	Infinite
16*	$738	($1,031)	0.72

Climate Zone 16 is cost-effective for the combined mid-rise + high-rise multifamily new construction, with benefit-cost ratio of 1.06

Thank You

Questions?

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM

2022 Central Heat Pump Water Heater Updates

Staff Pre-Rulemaking Workshop

Presenter: Danny Tam, Mechanical Engineer

Date: December 8, 2020

CASE Team Final Report

Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

All-Electric Multifamily Compliance Pathway

2022-MF-AEP-F | Multifamily | September 2020 FINAL CASE REPORT

Prepared by TRC

Please submit comments to info@title24stakeholders.com.

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

This report was prepared by the California Statewide Codes and Standards Enhancement (CASE) Program that is funded, in part, by California utility customers under the auspices of the California Public Utilities Commission.

JA14 Qualification Requirements for Central Heat Pump Water Heater System

- New proposed Joint Appendix to include testing and design documentation requirements for central HPWH systems in multifamily and nonresidential buildings
- Manufacturers would submit self-certified performance data with the following performance specification:
  - Water heater input power
  - Water heater output capacity
  - Water heater COP

JA14 Qualification Requirements for Central Heat Pump Water Heater System

- The central HPWH shall be tested at the following conditions
  - Inlet ambient air temperature: Maximum, minimum, and two midpoint temperatures of the manufacturer specified operating range. Minimum shall be equal to or lower than 40 °F.
  - Inlet water temperature: Maximum, minimum, and two midpoint temperatures of the manufacturer specified operating range.
  - Outlet water temperature: Maximum, midpoint, and minimum of outlet water (setpoint) temperatures of the manufacturer specified operating range. Maximum shall be equal to or greater than 140 °F.

Prescriptive Option for Central HPWH

- New proposed prescriptive option for central HPWH systems
  - HPWH certified as JA14
  - Requires recirculation loop tank.
  - Loop tank heater must be electric capable of multipass operation.
  - Setpoint at least 140°F for the primary storage tank; at least 20°F lower than the primary storage tank temperature for the loop tank.
  - Piping configuration requirements to ensure efficient operation
  - Minimum HP compressor cut-off ≤ 40°F

Questions ?

Comments for Todays Workshop

Due Date: December 24, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03

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Energy+Environmental Economics

Nonresidential PV and Battery Cost-Effectiveness with Draft Code Sizes

For CEC Public Workshop

December 8, 2020

Snuller Price
Mike Sontag
Jun Zhang
Emily Peterson
Brian Conlon
Sierra Spencer
Sumin Wang

Agenda

- **Background and Context**
  - Goal of Analysis and Key Findings
  - Modeling Inputs and Dimensions
- **PV + Storage Cost Effectiveness Results**
  - Medium Office Deep Dive
  - All Building Types and Climate Zones
  - Reliability Sensitivity Analysis
- **Source Energy & Emissions Results**
- **First-Year Statewide Impacts**
- **EV Charging Compliance Option Framework**
- **Conclusions and Next Steps**
- **Appendix**

Goals of this Analysis

- Evaluate participant benefits and cost effectiveness of behind-the-meter (BTM) PV and storage in HRMF and nonresidential new construction for proposed requirement size
- Study multiple configurations and sizes of PV and storage, with focus on limited grid exports (see October 6th workshop)
- Cost-effectiveness measured under both TDV-based rates and current utility retail rates
  - TDV cost-effectiveness evaluated with multiple configurations to bound potential future rate design
- Evaluation covers HRMF and nonresidential prototype buildings in all 16 climate zones
- Present data inputs and methodology in a transparent manner

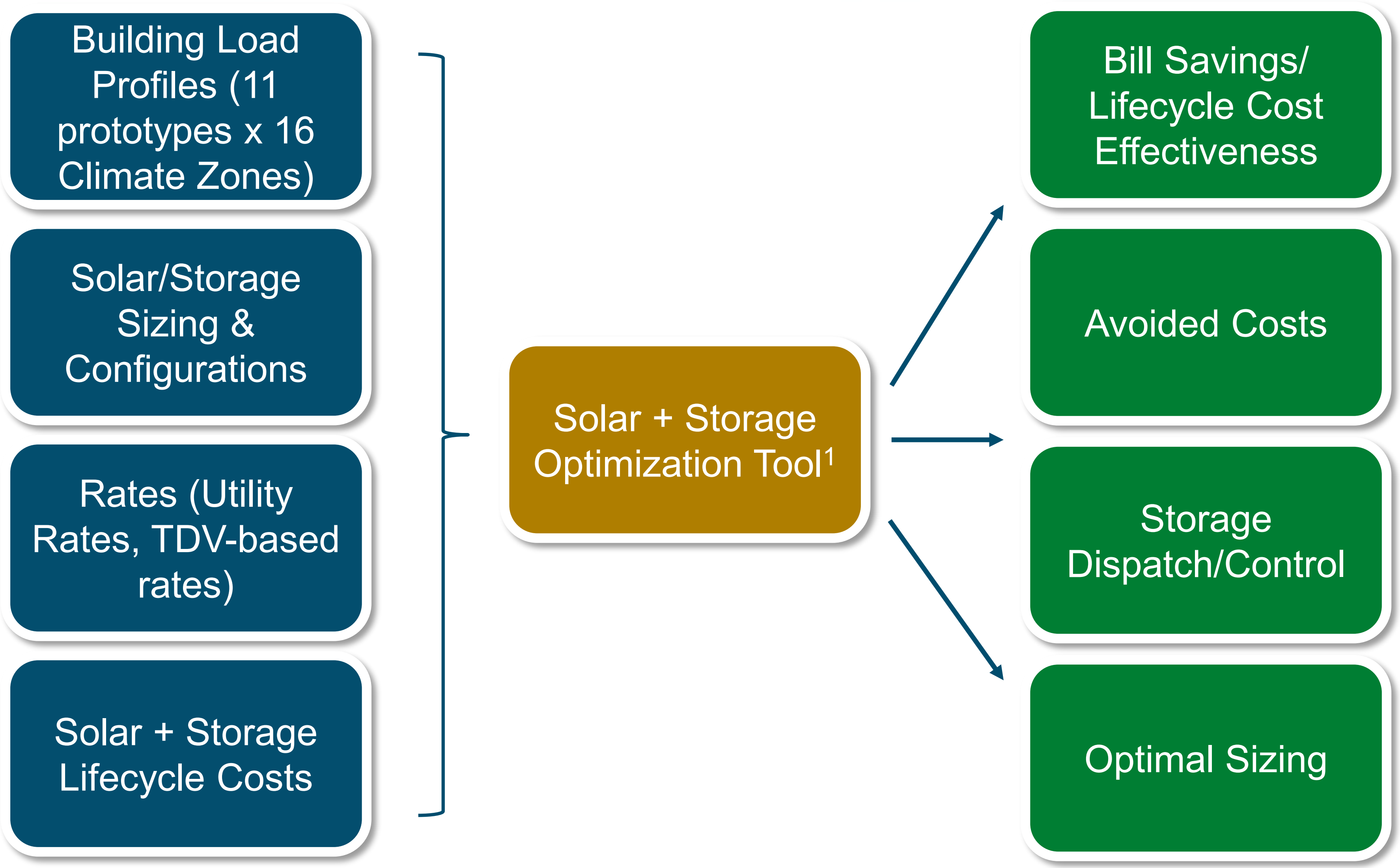
Key Findings

- **Proposed PV + Storage package and configurations are cost-effective for all building categories due to co-benefits of combined systems, except warehouse (PV-only is cost-effective)**
  - PV + Storage provides additional participant benefits, including reliability and resiliency
  - Climate zone 1 is least cost effective due to limited solar generation
- **PV + Storage is cost effective even under conservative dispatch, compensation scenarios**
- **Cost-effectiveness by building type largely driven by cost declines for larger systems**
  - Smaller buildings are least cost-effective, due to more expensive PV and storage ($/W)
- **Proposed PV and storage requirement reduces source energy and emissions by 10-50%, depending on building type and climate zone**
- **Proposed requirement will yield an estimated 280 MW of behind the meter PV and 100 MW, 400 MWh of battery storage per year**

Energy+Environmental Economics

Modeling Inputs and Dimensions

Cost-Effectiveness Modeling Framework



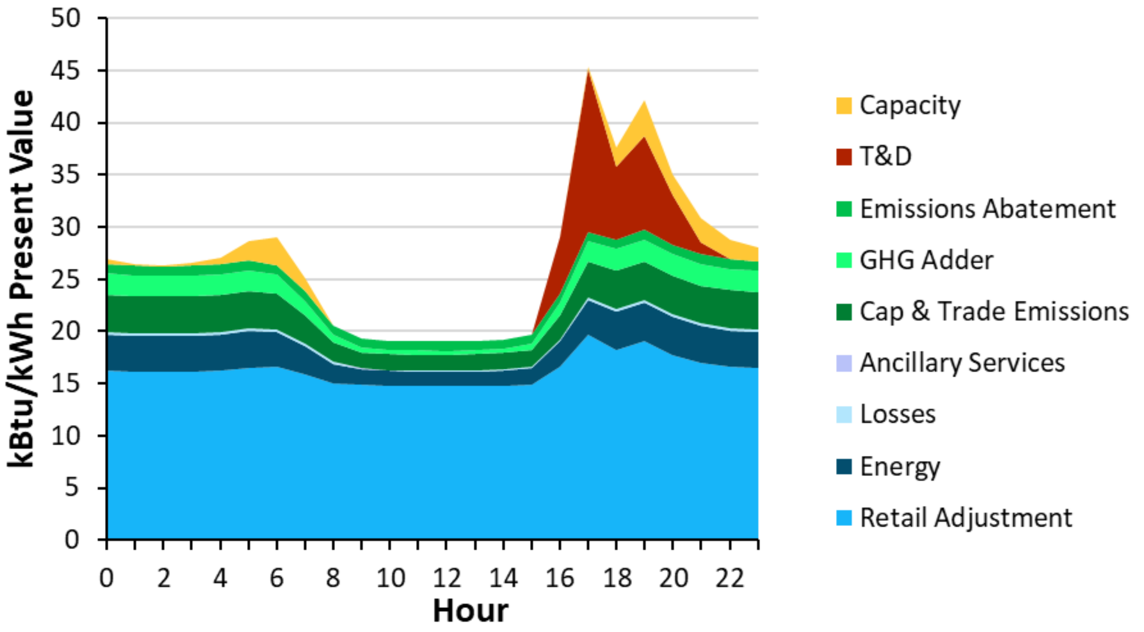
[1]See CEC Docket Log 19-MISC-04 for additional information and documentation: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-MISC-04

What are TDVs?

- The TDVs (Time Dependent Value) are a long-term forecast of hourly electricity, natural gas and propane costs to building owners and are used for cost-effectiveness activities in Title 24 Building Code
- The TDVs answer the question of what is cost-effective in the long term, as required by the Warren-Alquist Act

- Time-differentiation reflects the underlying marginal cost of producing and delivering energy
- Area-correlation reflects underlying marginal cost shapes correlated with each climate zones weather file

Sample Annual Average Electric TDV, 2022, CZ12



Scope of Results Presented in this Analysis

+ 9 major sensitivities – many combinations!

Rates	PV Size	Storage Size	Storage Dispatch	Configurations	Building Types	Building Fuels	Climate Zones	Reliability & Resiliency
Full TDV	Full NEM Compliant	PV Capacity	**Optimal**	PV only	**Small Office**	**Mixed Fuel**	**All CZs**	Not included
Export on Avoided Costs	Self Utilization	Minimize Solar Export	**TOU**	Storage Only	**Medium Office**	**All-Electric**		Included
Export on Wholesale Costs	**Draft Code Language**	**Draft Code Language**		**PV+ Storage**	**Large Office**			
Avoided Cost for All	Roof Space Constraint				**Small Retail**			
Utility Rates					**Medium Retail**			
					Large Retail			
					Small School			
					Large School			
					Warehouse			
					High-Rise Res			
					Mid-Rise Res			

Rates Sensitivities Considered

Rate Name	Compensation for Self-Utilized Electricity (Imports)	Compensation for Exports
Existing Utility Retail Rates	Retail Rate + Non-bypassable charge	Retail Rate
Full TDV (NEM2.0)	Full TDV	Full TDV – Non-bypassable charges
Export on Avoided Costs	Full TDV	Avoided Costs
Export on Wholesale Costs	Full TDV	Wholesale Costs
Self-utilized/Export on Avoided Costs	Avoided Costs	Avoided Costs

Increasing NEM rate reform

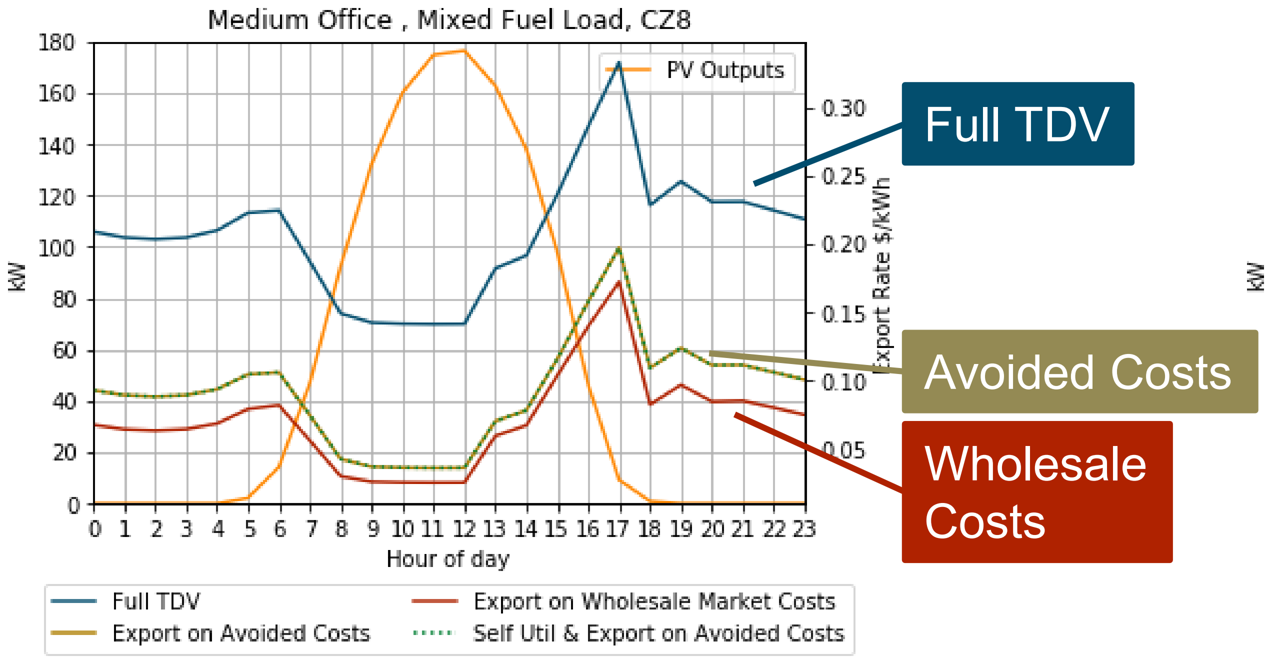
+ **Self-utilized electricity is generated and consumed behind the meter**
+ **Imported electricity is taken from the grid to power end-use loads**
+ **Exported electricity is generated behind the meter and sent to the grid**

This analysis uses TDV with exports on avoided costs as conservative benchmark for cost-effectiveness

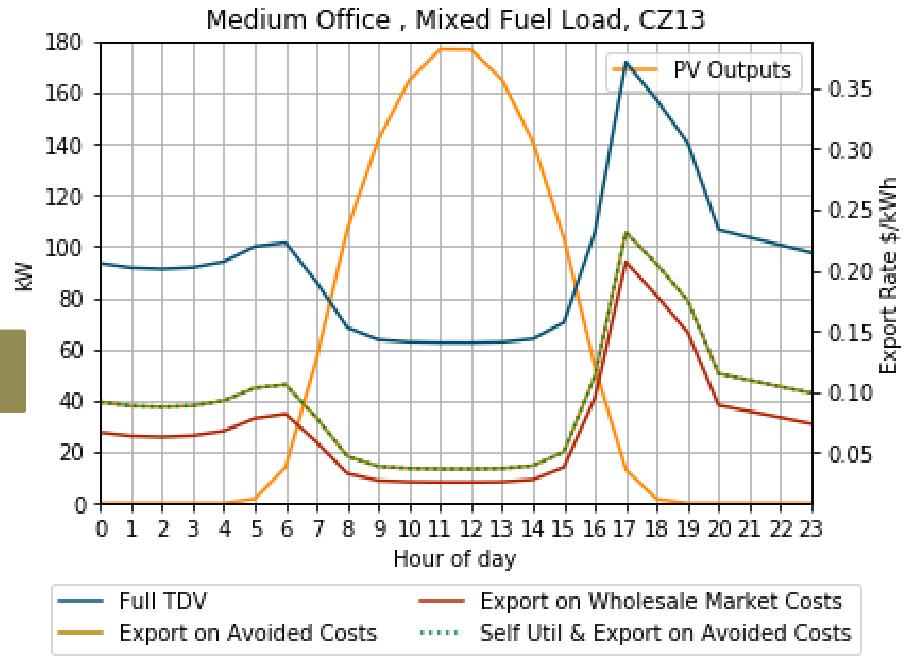
TDV Rate Sensitivities

+ **Full TDV is highest, avoided costs and wholesale costs are similar in magnitude**
+ **Different climate zones have different hourly profiles due to local Transmission & Distribution peaks**
  - Climate zones in inland LA Basin have slightly higher midday rates

Medium Office, Mixed Fuel Load, CZ8



Medium Office, Mixed Fuel Load, CZ13

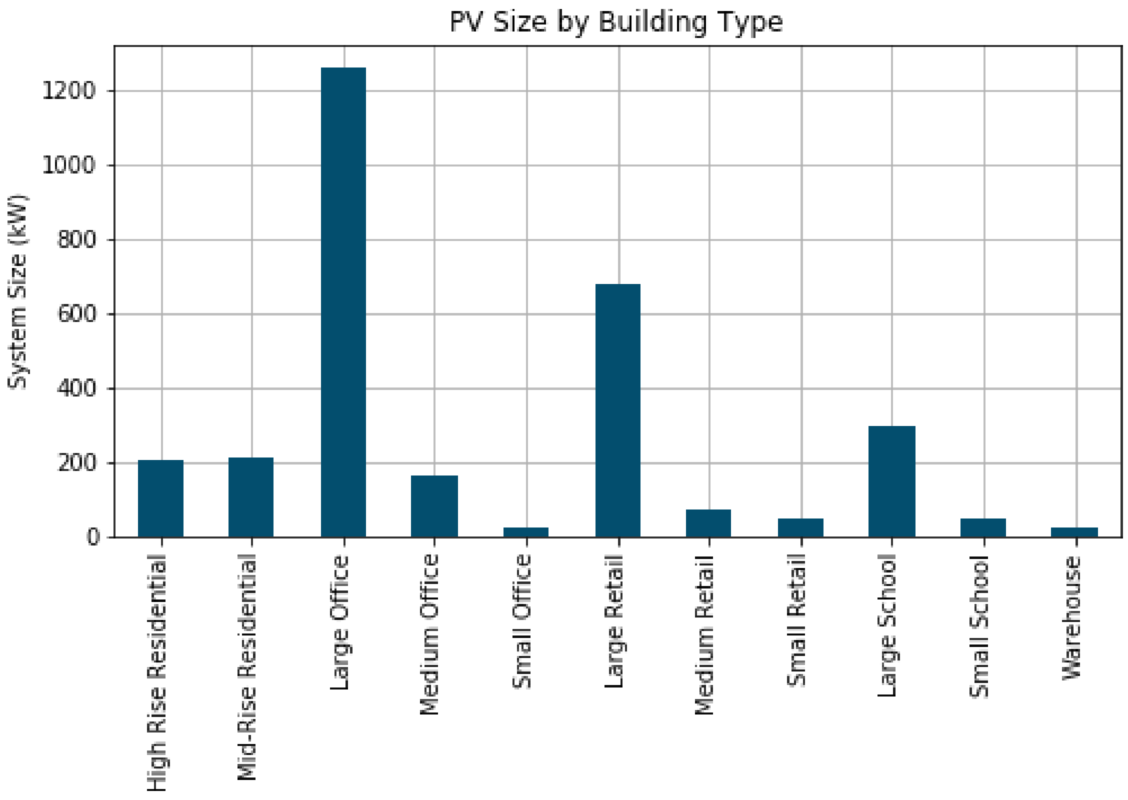


Note: TDV rate on y-axis is levelized lifetime present value

PV Sizing – Draft Requirement

- **Draft Requirement sizing is designed such that building will self-utilize 80% of annual PV generation (20% exports)**
- **Sizes calculated independent of roof area constraint**
  - Effective Annual Solar Access Area (EASAA) constraint may limit sizes in actual buildings
- **Sizes in prototype buildings range from ~20 kW_{DC} (Small Office, Warehouse) to as much as ~1300 kW_{DC} for Large Office**

Average PV Size across All Climate Zones by Building Type



Key PV Inputs

- **PV Costs**
  - Consider full lifetime capital & replacement costs, fixed O&M costs, and investment tax credit (ITC)
  - 2% inflation rate
  - 3% real discount rate
- **Fixed O&M: \$11/kW$_{DC}$-yr (2018\$)[2]**
- **ITC: 10%**
- **Lifetime: 30 years**
- **PV Tilt: assumed zero tilt, to maximize roof utilization**
- **PV Azimuth: south-facing**
- **Inverter Load Ratio (ILR): 1.0**

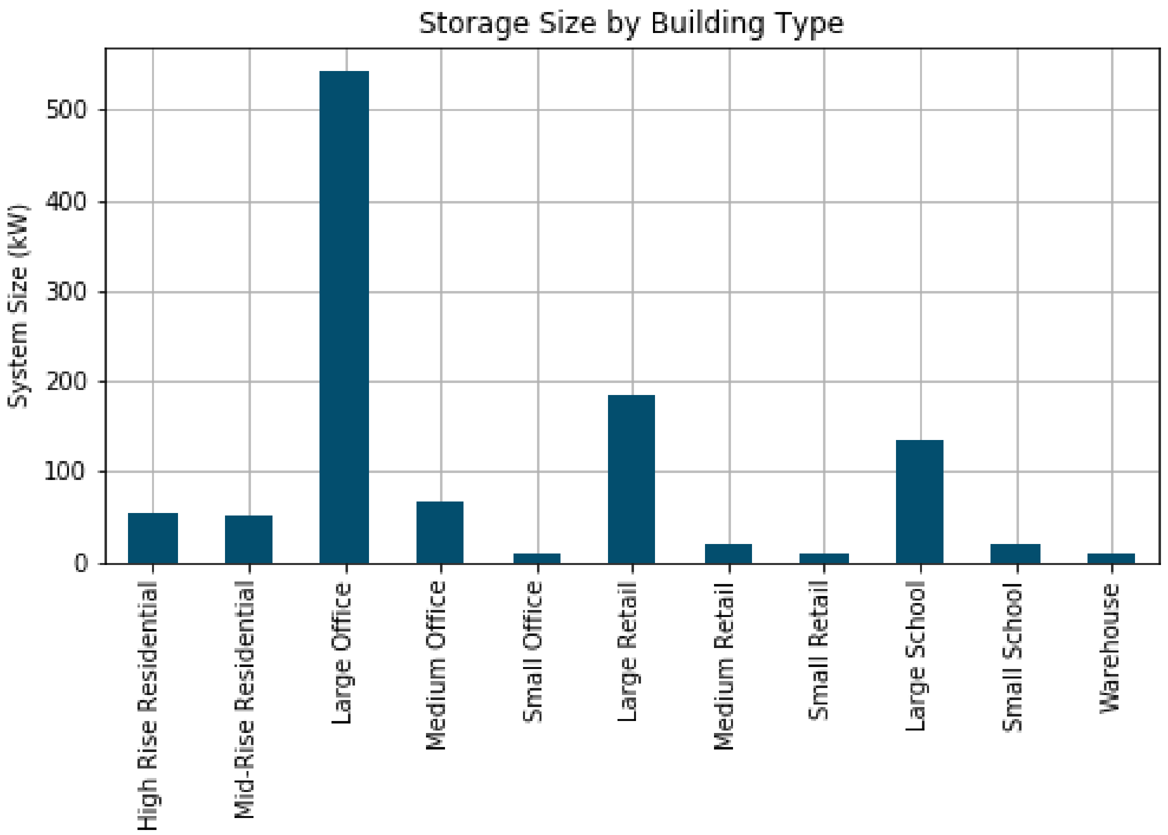
PV (kWdc)	CAPEX[1] (2020\$/W$_{DC}$)	Lifetime NPV Costs (\$2023/kW$_{DC}$)
10	\$3.16	\$3,263
20	\$2.84	\$2,957
50	\$2.46	\$2,594
100	\$2.21	\$2,355
200	\$1.99	\$2,145
500	\$1.73	\$1,897
1000	\$1.55	\$1,725

[1] NORESCO Slides on PV and Storage Cost Presented on October 6: https://efiling.energy.ca.gov/GetDocument.aspx?tn=235137&DocumentContentId=68017
[2] NREL 2020 Annual Technology Baseline https://atb.nrel.gov/electricity/2020/index.php?t=sd
*Fixed OM costs in 2020 NREL ATB include annualized large component replacement costs over technical life (e.g., inverters at 15 years)

Storage Sizing

+ **Draft Requirement sizing is designed so that battery storage will reduce annual solar exports from 20% to ~10%**
    - Buildings with PV + storage will self-utilize ~90% of PV generation
+ **Storage sizes for prototype buildings range from 10 kW, 40 kWh to as much as 550 kW, 2200 kWh**
+ **Assumes that battery has 4 hours worth of usable energy – i.e. battery can discharge at full capacity for 4 hours**
    - Energy physically stored in battery must exceed 4-hour duration to account for discharge efficiency losses

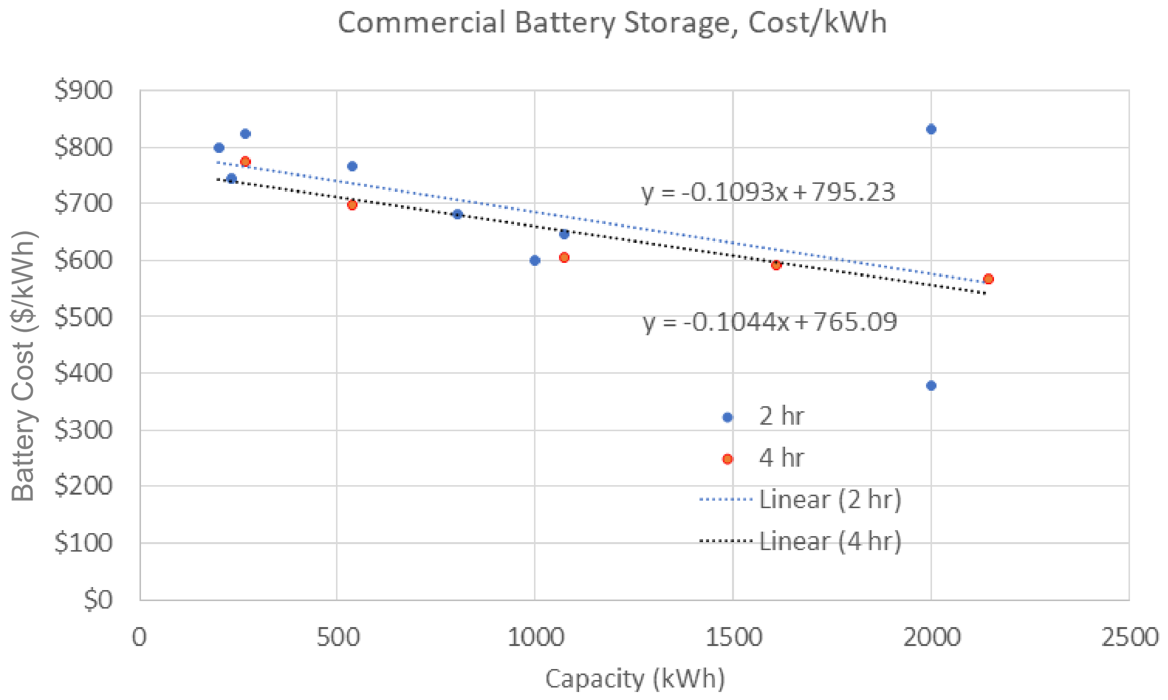
Average Storage Size across All Climate Zones by Building Type



Key Storage Inputs

- **Storage Costs**
  - Consider full lifetime capital & replacement costs, fixed O&M costs, and investment tax credits (ITC)
- **Fixed O&M: $29.61/kW$_{DC}$-yr (2018$)[2]**
- **10% ITC**
- **Storage RTE: 85%**
- **Storage Duration: 4 hours at full capacity**
- **Storage Lifetime: 10 years (cell replacement)**
- **AC-coupled**
- **Inverter Load Ratio (ILR) : 1.0**
  - No PV generation "clipping"
- **Exclude SGIP incentive in cost-effectiveness evaluation for code requirement**
- **Assumed only charge from solar to maximize ITC**

Commercial Battery Storage Capital Cost (2020$/kWh)[1,+]



[+] Note: Equation assumes no further $/kWh cost declines beyond 600 kW$_{DC}$, 2400 kWh

[1] NORESCO Slides on PV and Storage Cost Presented on October 6: https://efiling.energy.ca.gov/GetDocument.aspx?tn=235137&DocumentContentId=68017
[2] NREL 2020 Annual Technology https://atb.nrel.gov/electricity/2020/index.php?t=st

Prescriptive PV Sizing Example – Med Office, CZ12

- Find values in prescriptive sizing table
- Conditioned Floor Area: 53,628 sqft
- PV Adjustment Factor (A): 3.13 W/sqft
  - Climate Zone: 12

Table 140.10-A PV Adjustment Factors

	Minimum PV Capacity (W/ft² of conditioned floor area) – Adjustment Factor A		
Climate Zone	1, 3, 5, 16	2, 4, 6-14	15
Highrise Multifamily	1.82	2.21	2.77
Office, Large	2.16	2.64	3.00
Office, Medium	2.59	3.13	3.80
Office, Small	4.04	4.44	5.02
Retail/Grocery, Large	2.58	2.87	3.39
Retail/Grocery, Medium	2.62	2.91	3.53
Retail/Grocery, Small	4.35	4.62	5.17
School, Small	1.44	1.78	2.93
School, Large	0.39	0.44	0.58
Warehouse	0.39	0.44	0.58
All Other: Auditorium, Convention Center, Financial Institution, Grocery store, Hotel/Motel, Library, Religious Facility, Medical/Clinic, Restaurant, Theater	0.39	0.44	0.85

EQUATION 140.10- PHOTOVOLTAIC DIRECT CURRENT SIZE

kW_{PVdc} = (CFA x A)/1000

WHERE:

kW_{PVdc} = kW_{dc} size of the PV system in kW

CFA = Conditioned floor area in square feet

A = PV adjustment factor specified in Table 140.10-A for the building type

Example Calculation:

kW_{PVdc} = (53,628 sqft x 3.13 W/sqft)/1000 W/kW =

167 kW_{DC} PV System

Prescriptive Storage Sizing Example – Medium Office

+ Roundtrip Efficiency: 85%

Table 140.10-B – Battery Storage Adjustment Factors

	Minimum Battery Capacity	
	Power – Adjustment Factor B	Energy – Adjustment Factor C
Storage to PV Ratio	W/W	Wh/W
Highrise Multifamily	0.26	1.03
Office, Large	0.43	1.73
Office, Medium	0.42	1.68
Office, Small	0.37	1.48
Retail/Grocery, Large	0.27	1.07
Retail/Grocery, Medium	0.26	1.03
Retail/Grocery, Small	0.23	0.93
School, Small	0.48	1.93
School, Large	0.45	1.81
Warehouse	0.47	1.87
All Other: Auditorium, Convention Center, Financial Institution, Grocery store, Hotel/Motel, Library, Religious Facility, Medical/Clinic, Restaurant, Theater	0.47	1.87

EQUATION 140.10-B - BATTERY STORAGE RATED POWER CAPACITY

$$kW_{batt} = kW_{PVdc} \text{ x } B$$

WHERE:

kW_{batt} =Power capacity of the battery storage system in kWdc

kW_{PVdc} = kW_{dc} size of the PV system required by section 140.10A

B =Battery storage capacity adjustment factor specified in Table 140.10-B for the building type

EQUATION 140.10-C - BATTERY STORAGE RATED ENERGY CAPACITY

$$kWh_{batt} = kW_{PVdc} \text{ x } C / D^{0.5}$$

WHERE:

kWh_{batt} = Rated energy capacity of the battery storage system in kWh

kW_{PVdc} = kW_{dc} size of the PV system required by section 140.10A

C = Battery storage energy adjustment factor specified in Table 140.10-B for the building type

D = Rated single charge-discharge cycle AC to AC (round-trip) efficiency of the battery storage system

Equation 140.10-B Example: $kW_{batt} = 167\ kW_{PVdc}$ x $0.42\ W_{batt,\ dc}/W_{PVdc}$ = 70 kWdc Battery

Equation 140.10-C Example : $kWh_{batt} = 167\ kW_{PVdc}$ x $1.68\ W_{batt,\ dc}/W_{PVdc} / .85^{0.5}$ = 304 kWh Battery

Battery Control Sensitivities

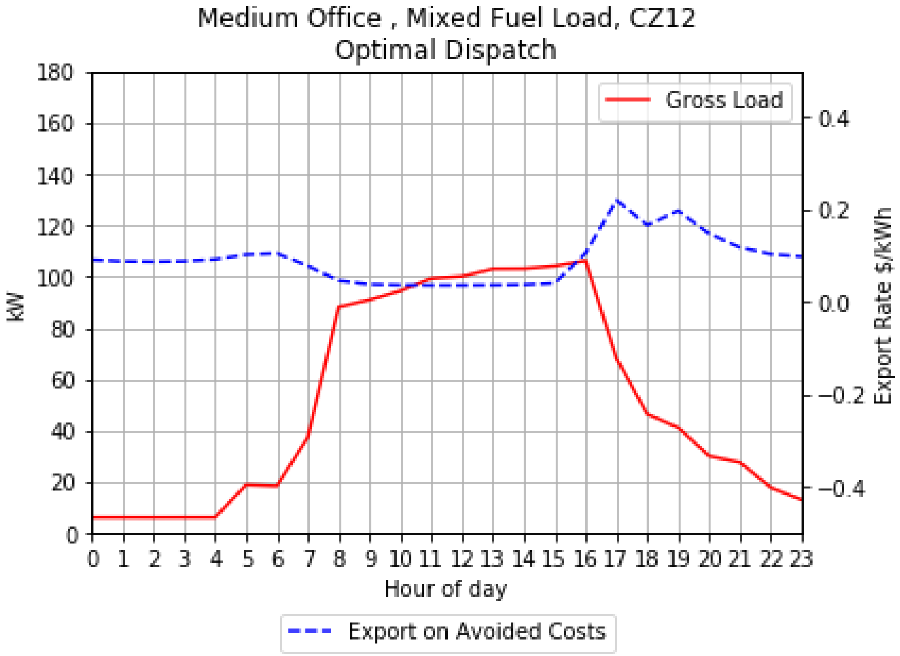
+ **Two major factors impact energy storage economic benefit**
  - **Controls scheme**: Commercially available energy storage does have sophisticated controls, but cannot match perfect foresight. TOU Dispatch scheme used in this analysis as conservative baseline
  - **Price signal**: Current retail rates have limited alignment between participant benefits and grid benefits

	Near-term Proxy	Aspirational
Controls Scheme	Time-of-Use (TOU) Dispatch	Optimal Dispatch (Perfect Foresight)
Rate Signal/ Participant Benefits	Retail Rates	Full TDV-based Rate Signal

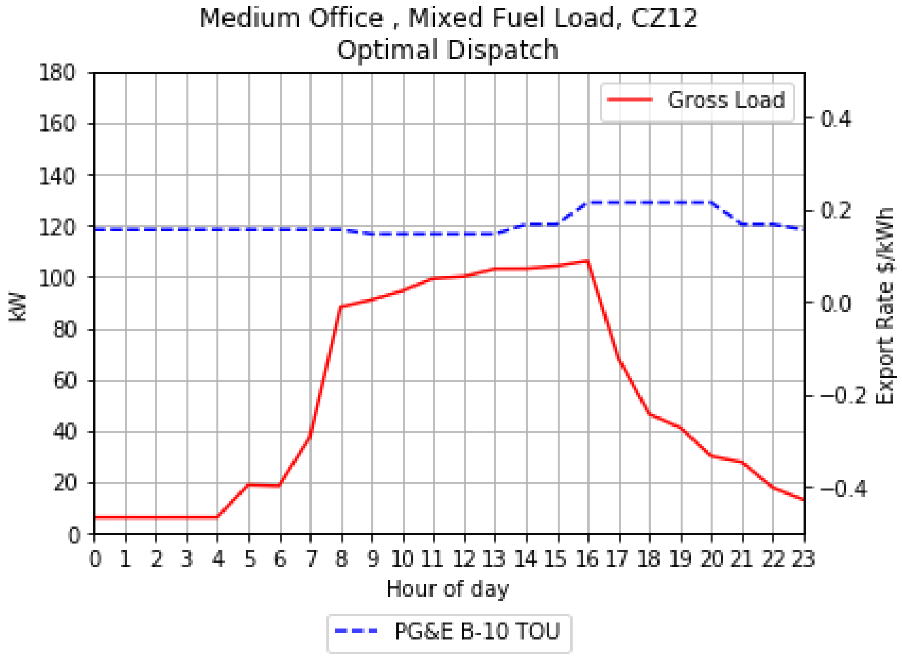
Optimal Dispatch Option

- Optimal dispatch responds based on customer load, PV generation, different rate signals to maximize customer benefit
- These plots show annual average of rate signals
- Commercial TOU retail rate also includes demand charges (not shown)

TDV - Export on Avoided Cost



PG&E B-10 TOU



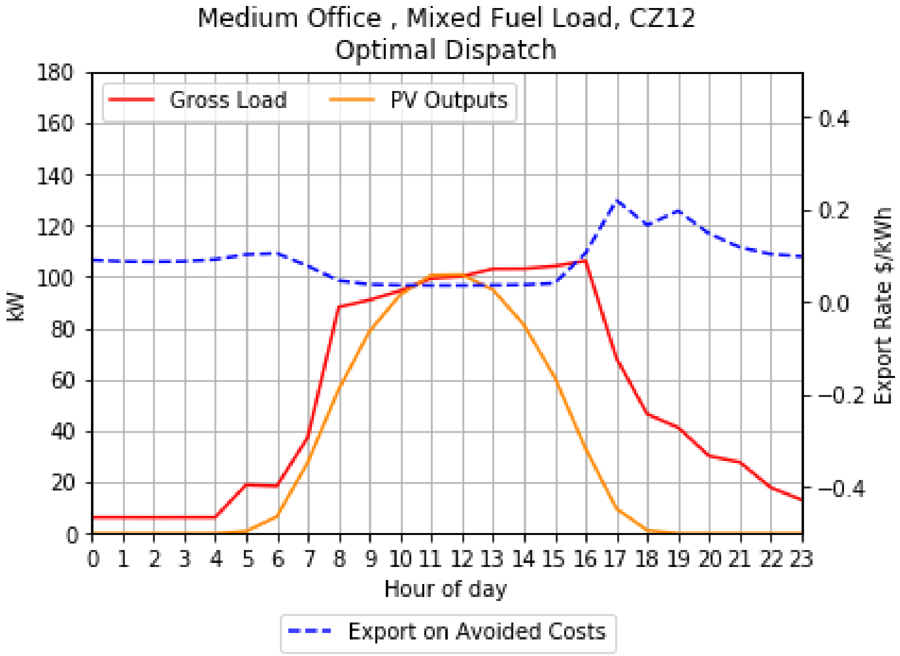
TDV and retail rates are both in levelized lifetime present value

Optimal Dispatch Option

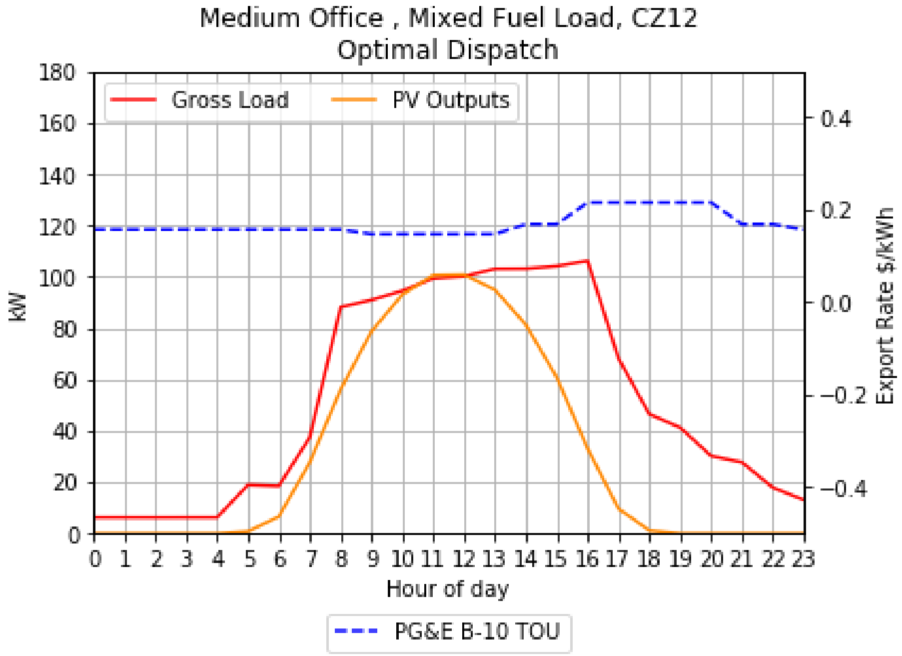
+ Behind-the-meter (BTM) PV largely coincides with Medium Office load profile

- Some continued load after PV generation decreases, contributing to duck curve

TDV - Export on Avoided Cost



PG&E B-10 TOU

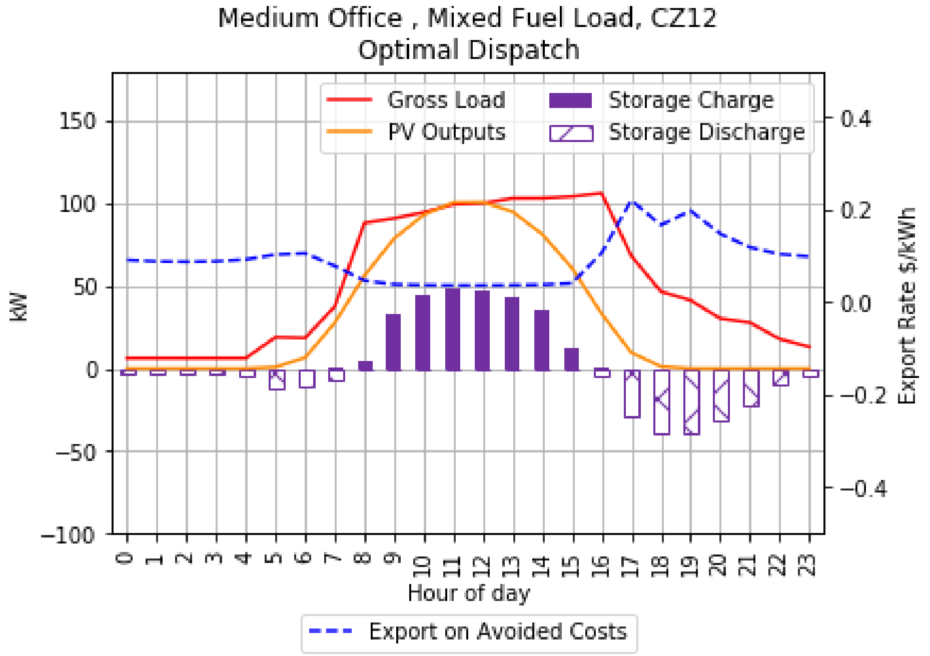


TDV and retail rates are both in levelized lifetime present value

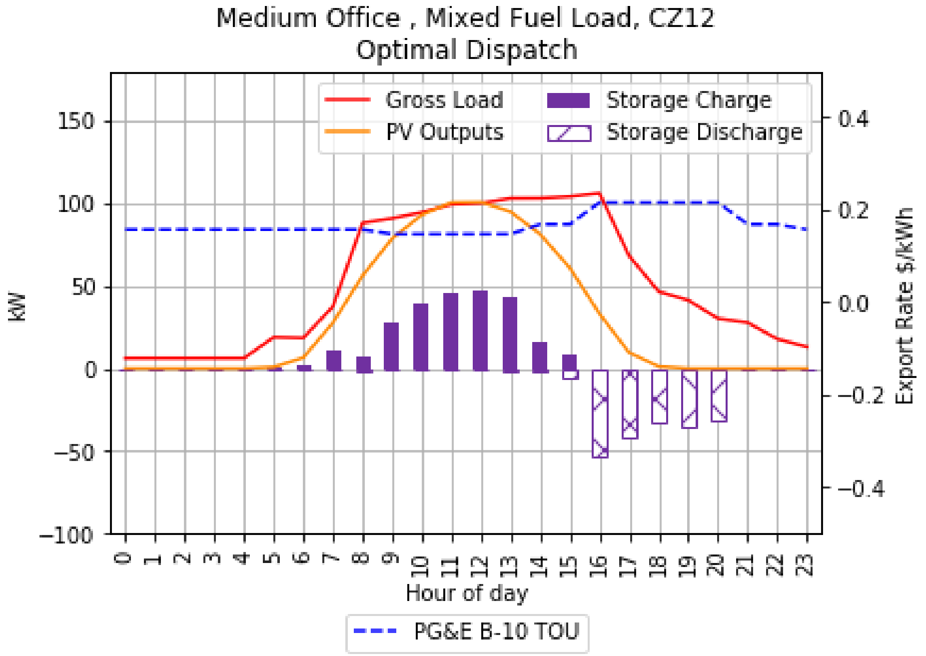
Optimal Dispatch Option

- Under TDV-based rate, optimal storage charging is mid-day, and discharges in evening (spring, summer, fall) and morning (winter), matching grid marginal costs
- Commercial retail rates are dominated by demand charges, and optimal dispatch focuses on more lucrative demand charge clipping

TDV - Export on Avoided Cost



PG&E B-10 TOU

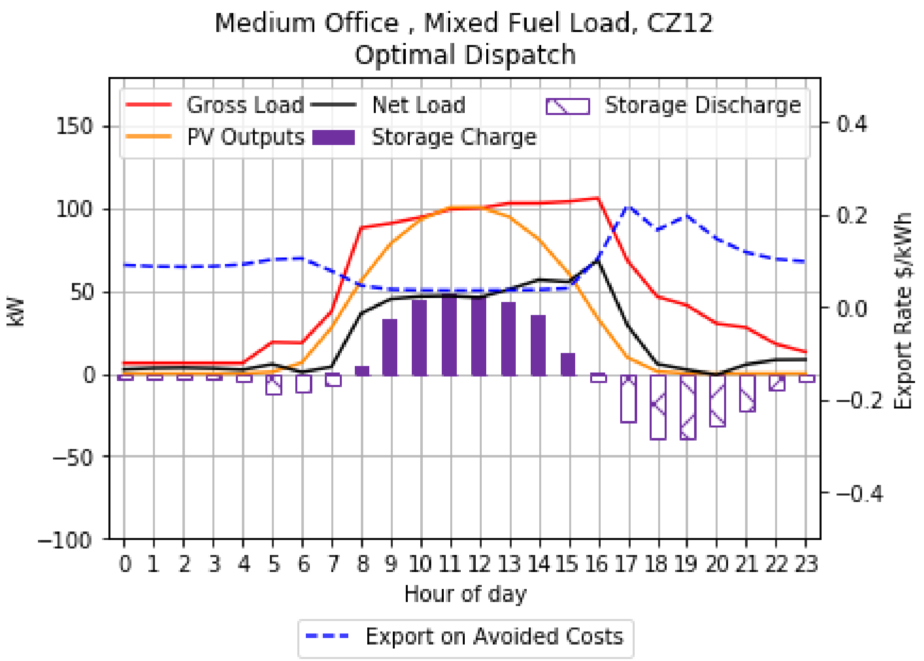


TDV and retail rates are both in levelized lifetime present value

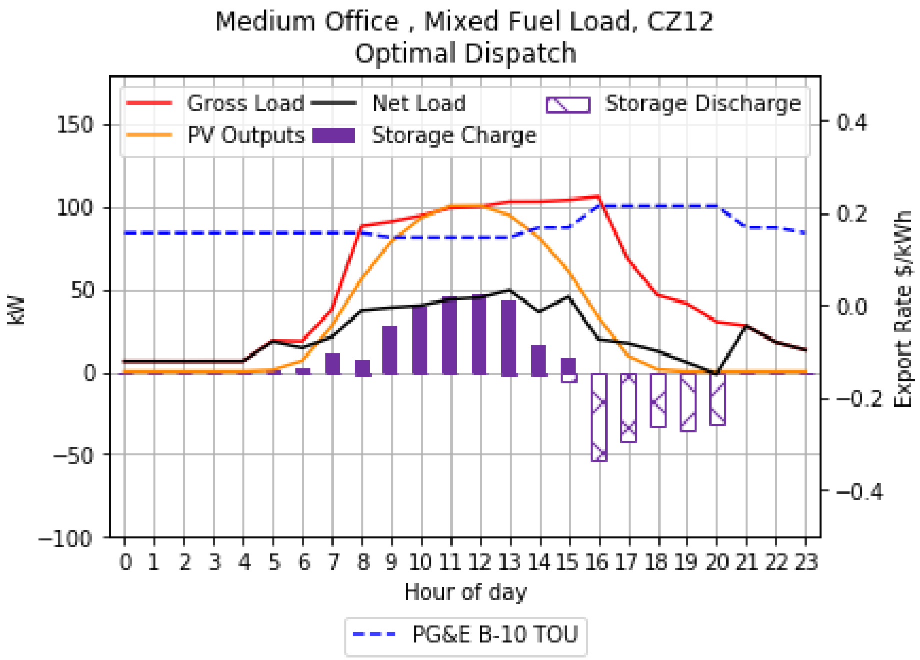
Optimal Dispatch Option

- Under TDV-based rate, net load is increased mid-day to take advantage of cheap electricity, decreased in late evening to avoid expensive grid power
- Under retail rate signal, net demand is minimized, even though it does not necessarily align with grid peak

TDV - Export on Avoided Cost



PG&E B-10 TOU

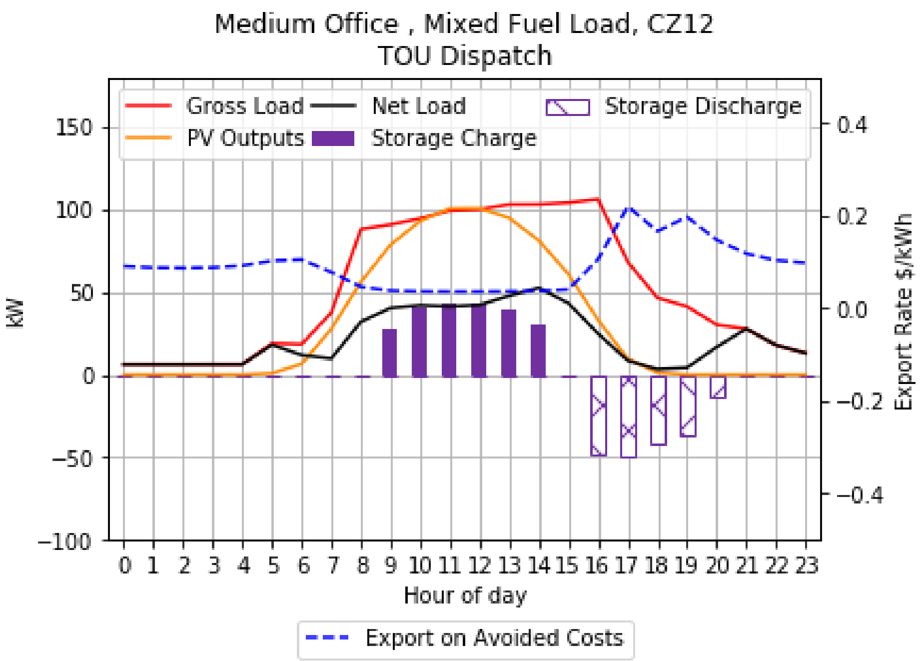


TDV and retail rates are both in levelized lifetime present value

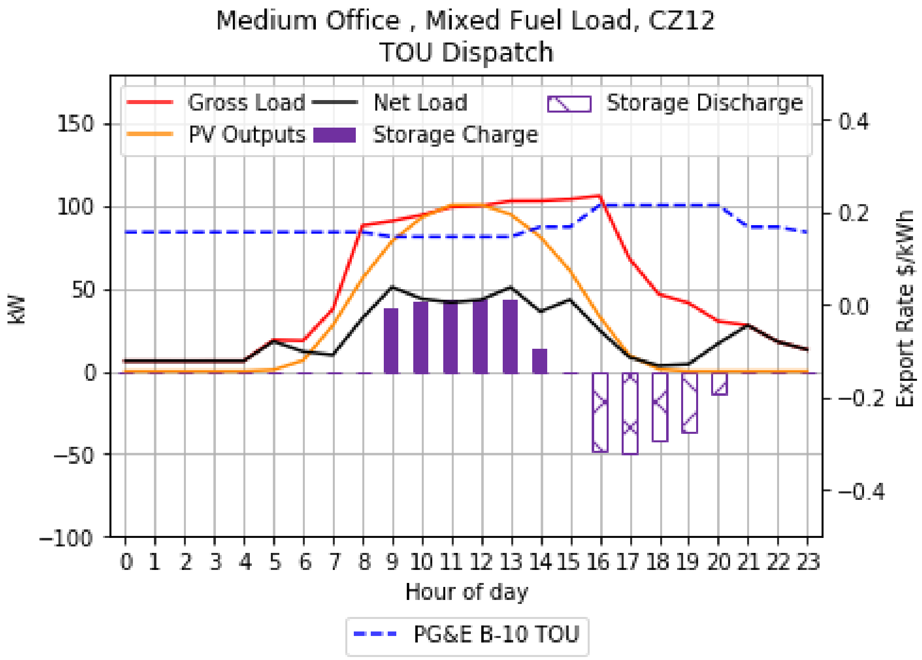
TOU Dispatch Option

- **TOU dispatch controls are limited to charging during midday hours, and limited to discharging during TOU peak period from 4PM to 9PM**
  - Schedule applied to full year
  - No additional controls for peak demand clipping
  - Storage can only offset on-site customer load and is not allowed to export to the grid

TDV - Export on Avoided Cost



PG&E B-10 TOU



TDV and retail rates are both in levelized lifetime present value

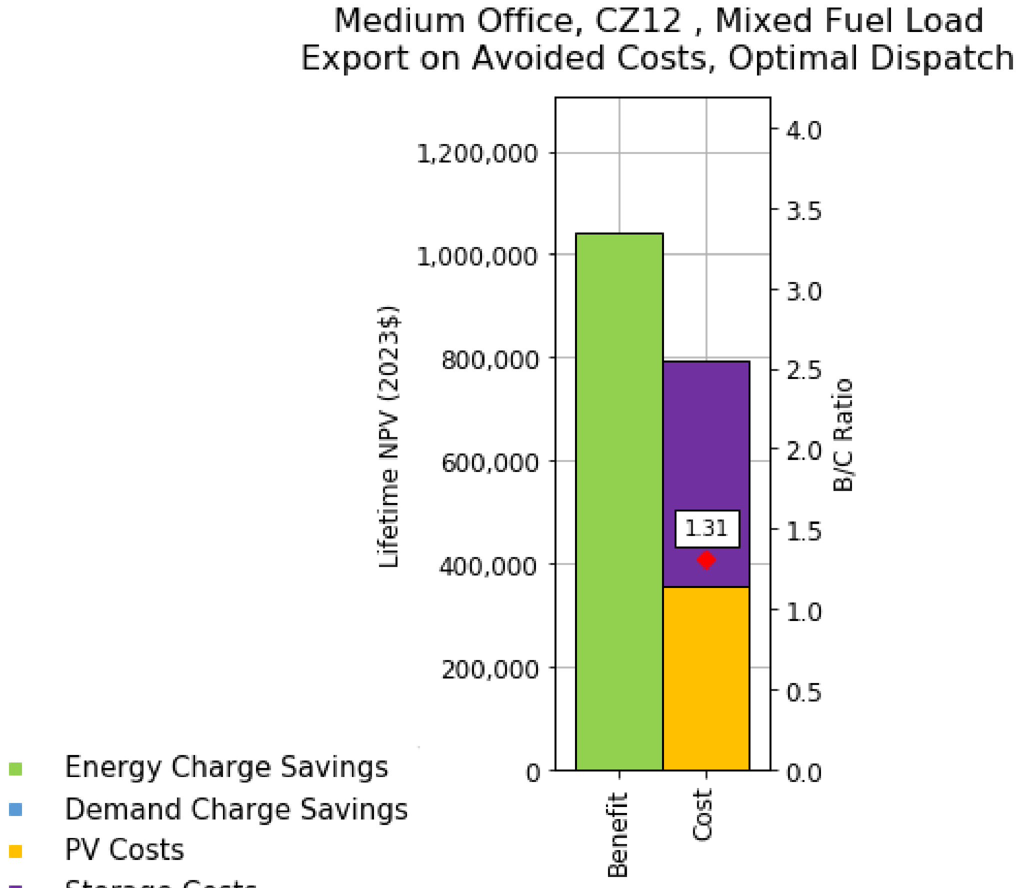
Energy+Environmental Economics

PV+Storage Cost-Effectiveness

PV+Storage Cost-Effectiveness on TDV/Exported on Avoided Costs with Optimal Dispatch

- Calculated lifetime benefit and lifetime costs for each modeled sensitivity (building type, climate zone, rate, battery controls)
- This example for medium office, CZ 12, on the self-utilization on TDV/export on avoided costs rate shows approximately $1M in lifetime benefits with $800k in lifetime costs
- This yields a Benefit-cost ratio of 1.3
- This rate scenario is a conservative assumption, based on potential retail rate reform, showing robust cost effectiveness across potential rate reform scenarios

Cost Effectiveness

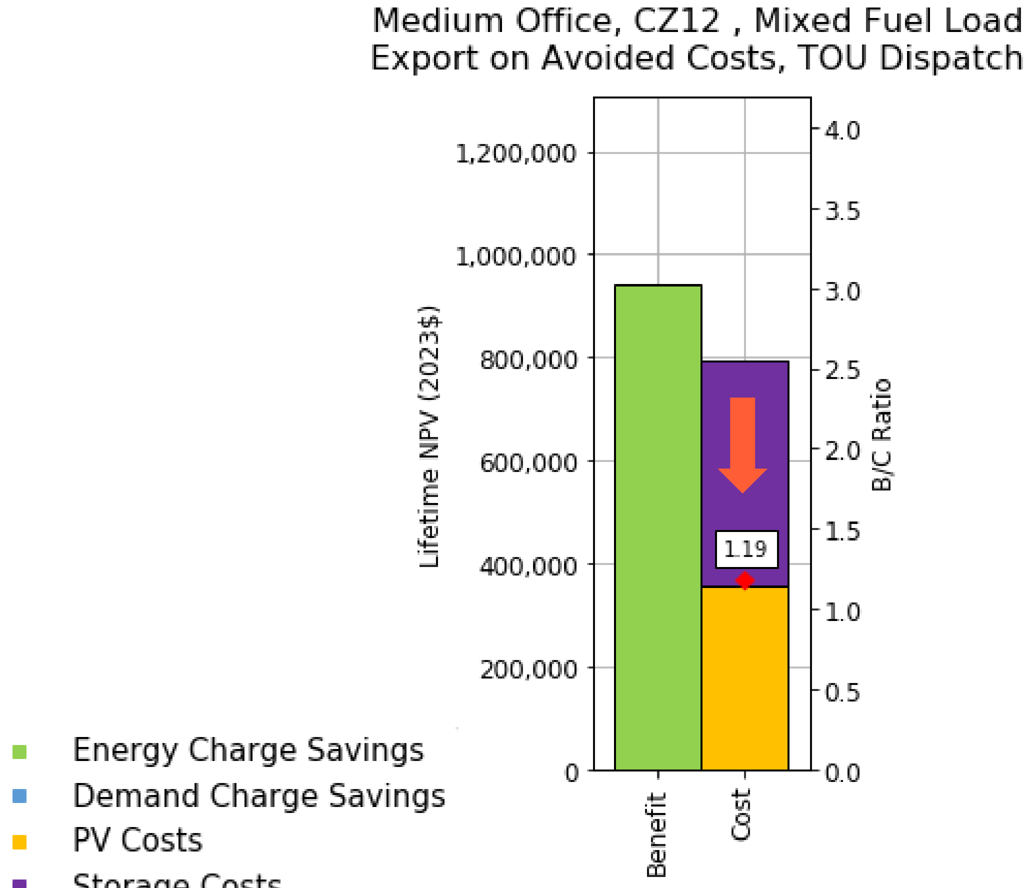


167 kW PV
70 kW Storage

PV+Storage Cost-Effectiveness on TDV/Exported on Avoided Costs with TOU Dispatch

- **By constraining battery storage dispatch to a TOU-based schedule, total PV + Storage benefit is decreased by approximately 10%**
  - Note: Benefit from PV-only does not change, so storage benefit decreases by more than 10%
- **Benefit-cost ratio is 1.2**
- **On conservative rate scenario, with conservative battery storage controls, packaged system is still cost-effective**
- **This serves as a low-bookend for potential benefit for this specific prototype building**

Cost Effectiveness – TOU Dispatch, Exported on Avoided Costs

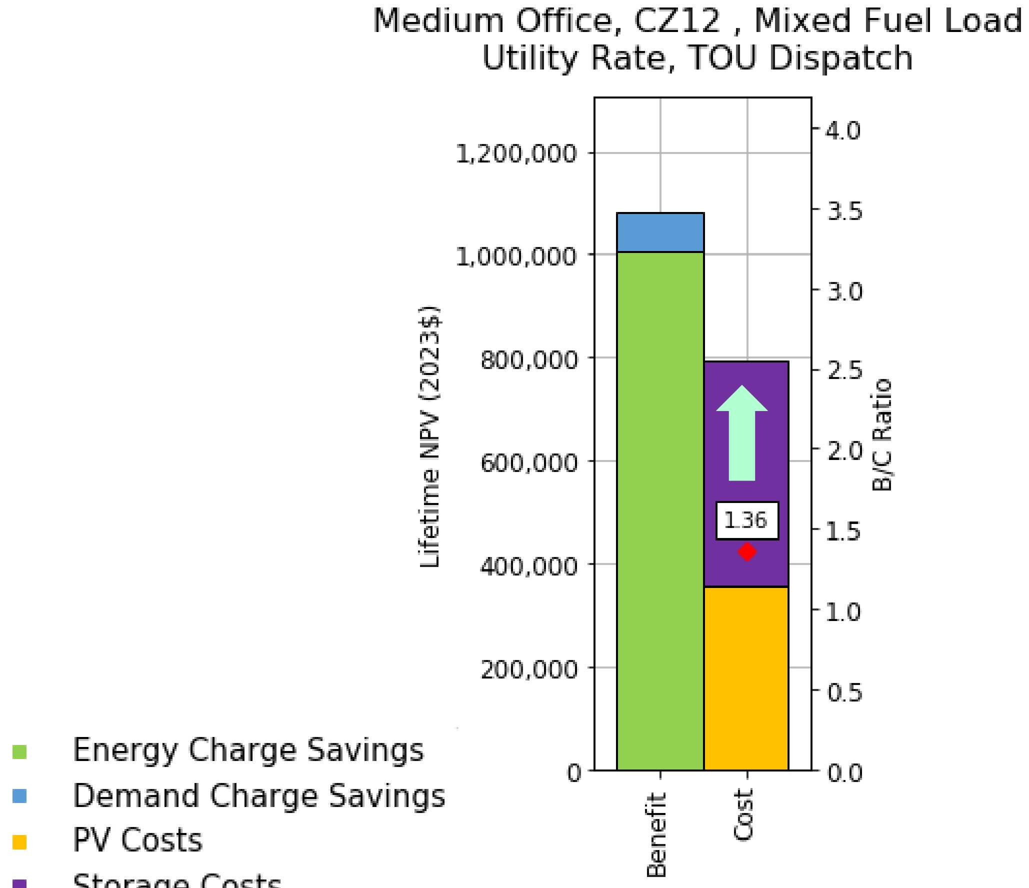


167 kW PV
70 kW Storage

PV+Storage Cost-Effectiveness on Utility Rates with TOU Dispatch

+ **TOU dispatch still yields a cost-effective system under existing retail rates**
+ **For Medium Office, the PV + Storage package is slightly more cost-effective under existing utility commercial TOU rates**
  - Demand charge savings are significant driver of cost effectiveness for batteries on existing retail rates
  - TOU dispatch does not capture full demand charge savings benefit compared to optimal dispatch
+ **Benefit-cost ratio is 1.36**

Cost Effectiveness – TOU Dispatch, Utility Rate

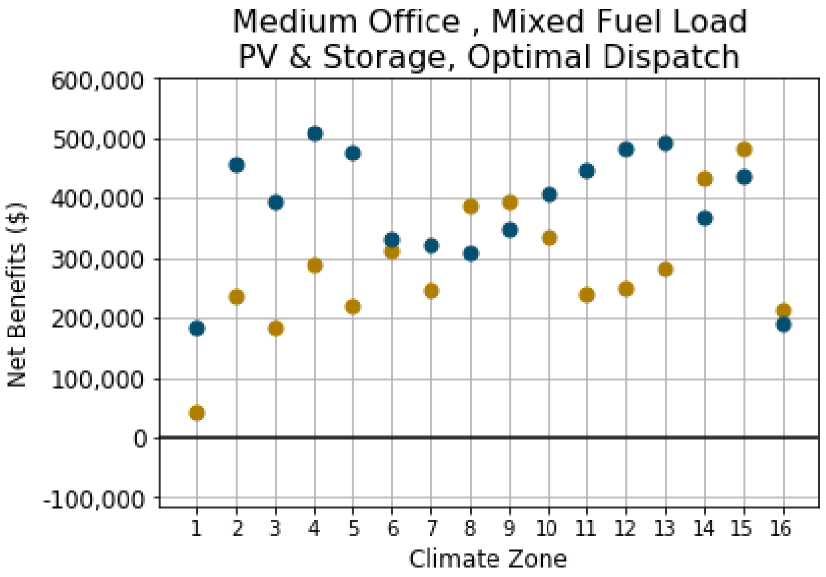


167 kW PV
70 kW Storage

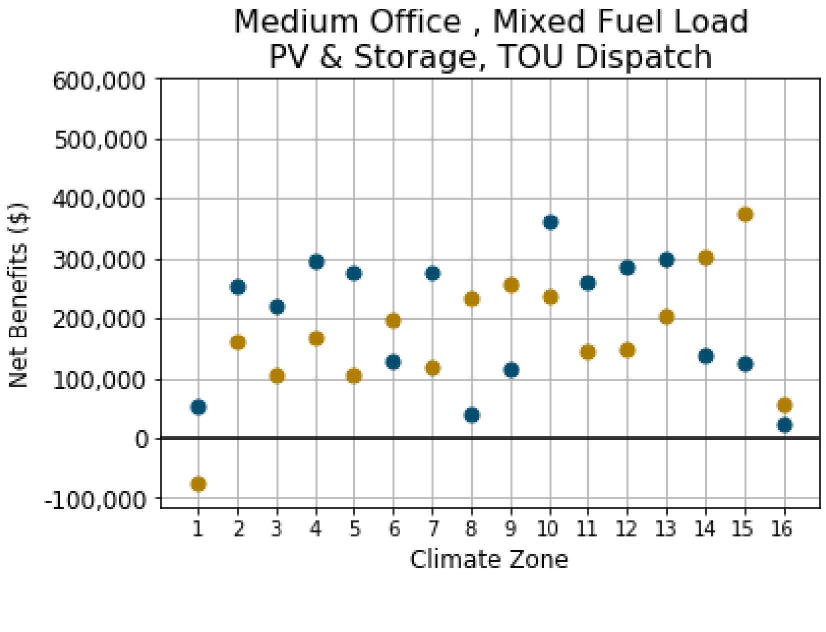
PV+Storage System Net Benefits for All Climate Zones

+ **Expanding to medium office, all climate zones, general trend stays consistent**
  - Lifetime net benefit across all climate zones
+ **Climate zone 1 and 16 are less cost-effective than other climate zones due to limited PV output**
+ **Utility rates have mixed impacts on cost-effectiveness**
+ **TOU dispatch limits cost-effectiveness**

All Rates & Climate Zones, Optimal Dispatch



All Rates & Climate Zones, TOU Dispatch



PV + Storage TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types

+ This chart shows benefit-cost ratio of each building type and climate zone. All combinations, except warehouse and some of CZ1, are cost-effective

Export on Avoided Costs
Mixed Fuel Load, TOU Dispatch

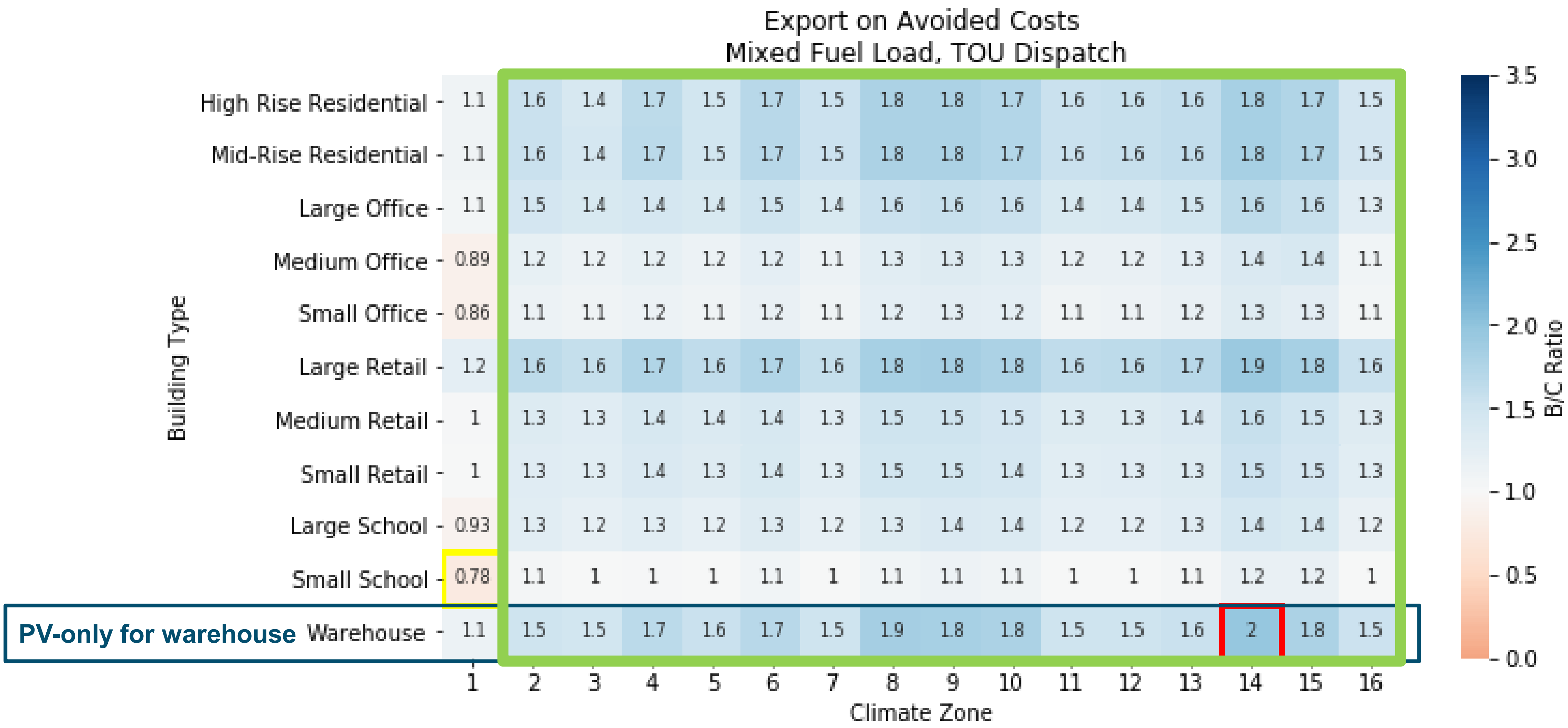
B/C Ratio (color scale 0.0 – 3.5)

Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	1.1	1.6	1.4	1.7	1.5	1.7	1.5	1.8	1.8	1.7	1.6	1.6	1.6	1.8	1.7	1.5
Mid-Rise Residential	1.1	1.6	1.4	1.7	1.5	1.7	1.5	1.8	1.8	1.7	1.6	1.6	1.6	1.8	1.7	1.5
Large Office	1.1	1.5	1.4	1.4	1.4	1.5	1.4	1.6	1.6	1.6	1.4	1.4	1.5	1.6	1.6	1.3
Medium Office	0.89	1.2	1.2	1.2	1.2	1.2	1.1	1.3	1.3	1.3	1.2	1.2	1.3	1.4	1.4	1.1
Small Office	0.86	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.3	1.2	1.1	1.1	1.2	1.3	1.3	1.1
Large Retail	1.2	1.6	1.6	1.7	1.6	1.7	1.6	1.8	1.8	1.8	1.6	1.6	1.7	1.9	1.8	1.6
Medium Retail	1	1.3	1.3	1.4	1.4	1.4	1.3	1.5	1.5	1.5	1.3	1.3	1.4	1.6	1.5	1.3
Small Retail	1	1.3	1.3	1.4	1.3	1.4	1.3	1.5	1.5	1.4	1.3	1.3	1.3	1.5	1.5	1.3
Large School	0.93	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.4	1.4	1.2	1.2	1.3	1.4	1.4	1.2
Small School	0.78	1.1	1	1	1	1.1	1	1.1	1.1	1.1	1	1	1.1	1.2	1.2	1
Warehouse (Not Cost-Effective)	0.68	0.91	0.89	0.95	0.9	1	0.89	1.1	1.1	1	0.9	0.91	0.93	1.1	1	0.92

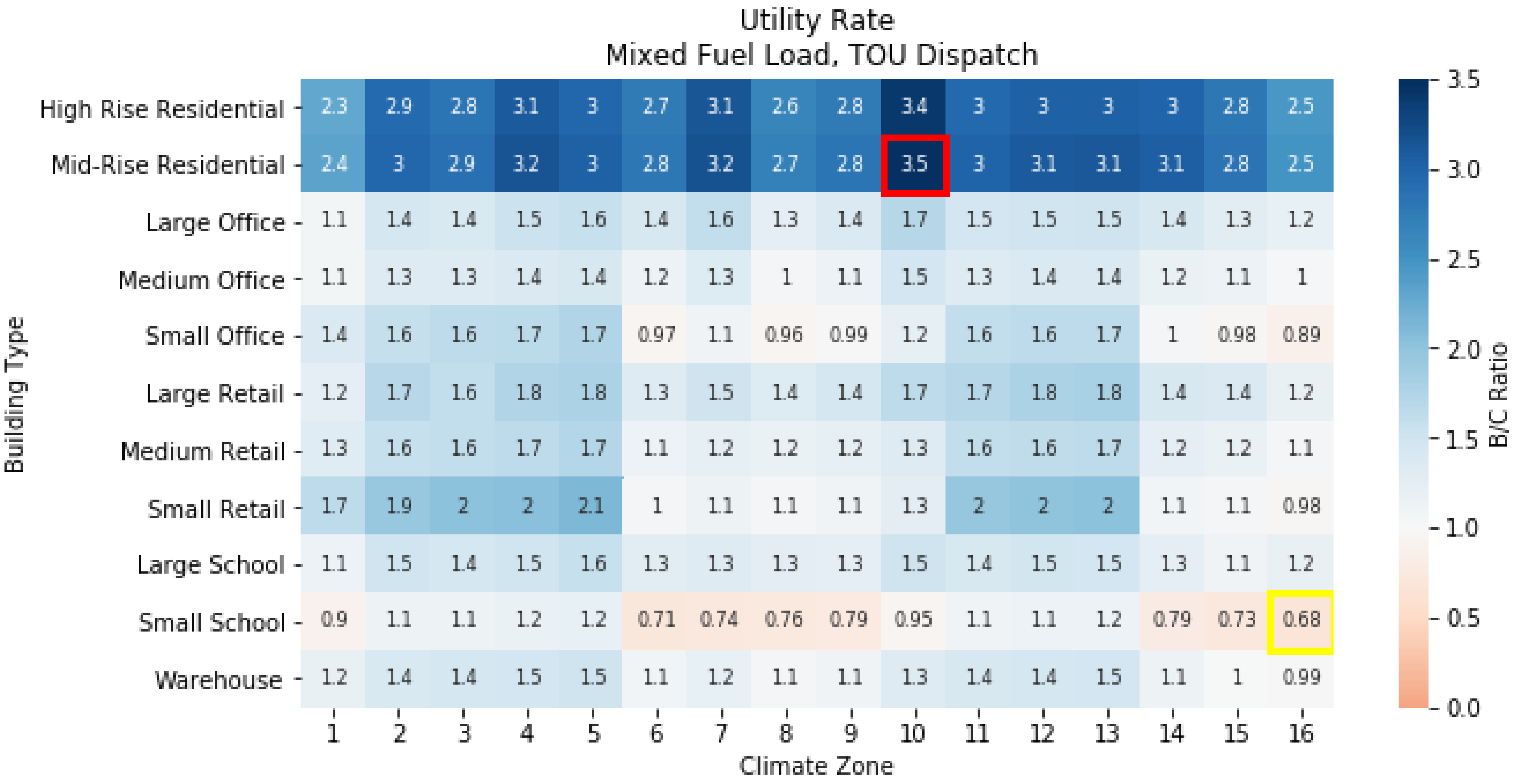
Not Cost-Effective

PV + Storage TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types

+ This chart shows benefit-cost ratio. Removing storage requirement makes warehouse cost-effective



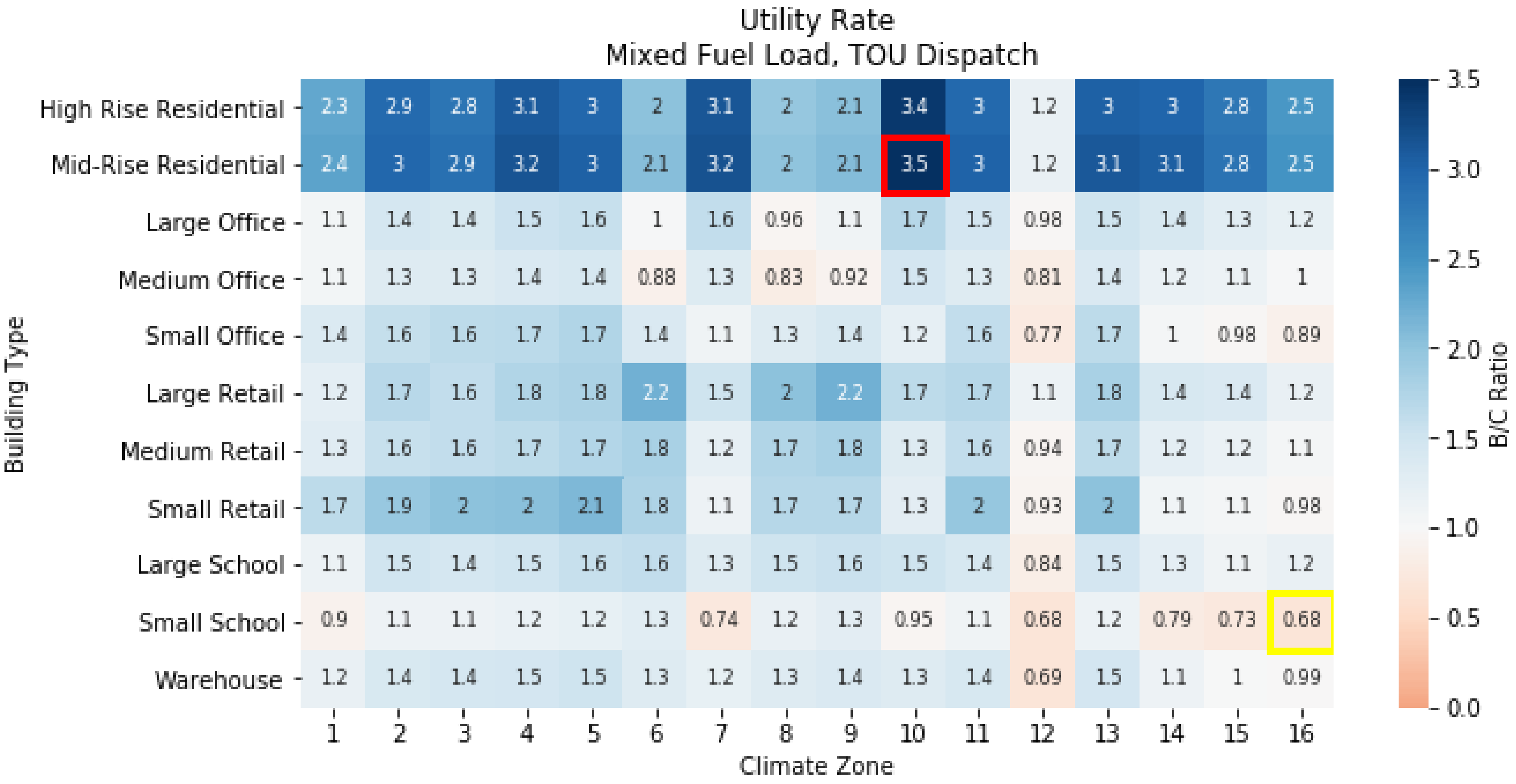
PV + Storage TOU Dispatch on Utility Rates Across Building Types



Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	2.3	2.9	2.8	3.1	3	2.7	3.1	2.6	2.8	3.4	3	3	3	3	2.8	2.5
Mid-Rise Residential	2.4	3	2.9	3.2	3	2.8	3.2	2.7	2.8	3.5	3	3.1	3.1	3.1	2.8	2.5
Large Office	1.1	1.4	1.4	1.5	1.6	1.4	1.6	1.3	1.4	1.7	1.5	1.5	1.5	1.4	1.3	1.2
Medium Office	1.1	1.3	1.3	1.4	1.4	1.2	1.3	1	1.1	1.5	1.3	1.4	1.4	1.2	1.1	1
Small Office	1.4	1.6	1.6	1.7	1.7	0.97	1.1	0.96	0.99	1.2	1.6	1.6	1.7	1	0.98	0.89
Large Retail	1.2	1.7	1.6	1.8	1.8	1.3	1.5	1.4	1.4	1.7	1.7	1.8	1.8	1.4	1.4	1.2
Medium Retail	1.3	1.6	1.6	1.7	1.7	1.1	1.2	1.2	1.2	1.3	1.6	1.6	1.7	1.2	1.2	1.1
Small Retail	1.7	1.9	2	2	2.1	1	1.1	1.1	1.1	1.3	2	2	2	1.1	1.1	0.98
Large School	1.1	1.5	1.4	1.5	1.6	1.3	1.3	1.3	1.3	1.5	1.4	1.5	1.5	1.3	1.1	1.2
Small School	0.9	1.1	1.1	1.2	1.2	0.71	0.74	0.76	0.79	0.95	1.1	1.1	1.2	0.79	0.73	0.68
Warehouse	1.2	1.4	1.4	1.5	1.5	1.1	1.2	1.1	1.1	1.3	1.4	1.4	1.5	1.1	1	0.99

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage TOU Dispatch on Utility Rates Across Building Types w/ LADWP & SMUD



CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

PV+Storage Cost Effectiveness Across Building Types

+ **Proposed PV + Storage package is cost effective across building types and climate zones, even under conservative compensation assumptions (TDV rate with exports on avoided costs), and current utility rates**
    - Some utility rates do not yield cost effective systems, partially due to limited demand charge reductions of TOU dispatch
    - Climate zone 1 is least cost effective due to limited solar generation
+ **TOU dispatch diminishes cost effectiveness across building types, but still yields cost-effective systems**
+ **Cost-effectiveness by building type largely driven by cost declines for larger systems**
    - Smaller buildings are least cost-effective, due to more expensive PV and storage ($/W)
+ **Under TDV rates, some further variation in cost effectiveness between building types, likely driven by building load profile and ability for PV + Storage to impact net load**

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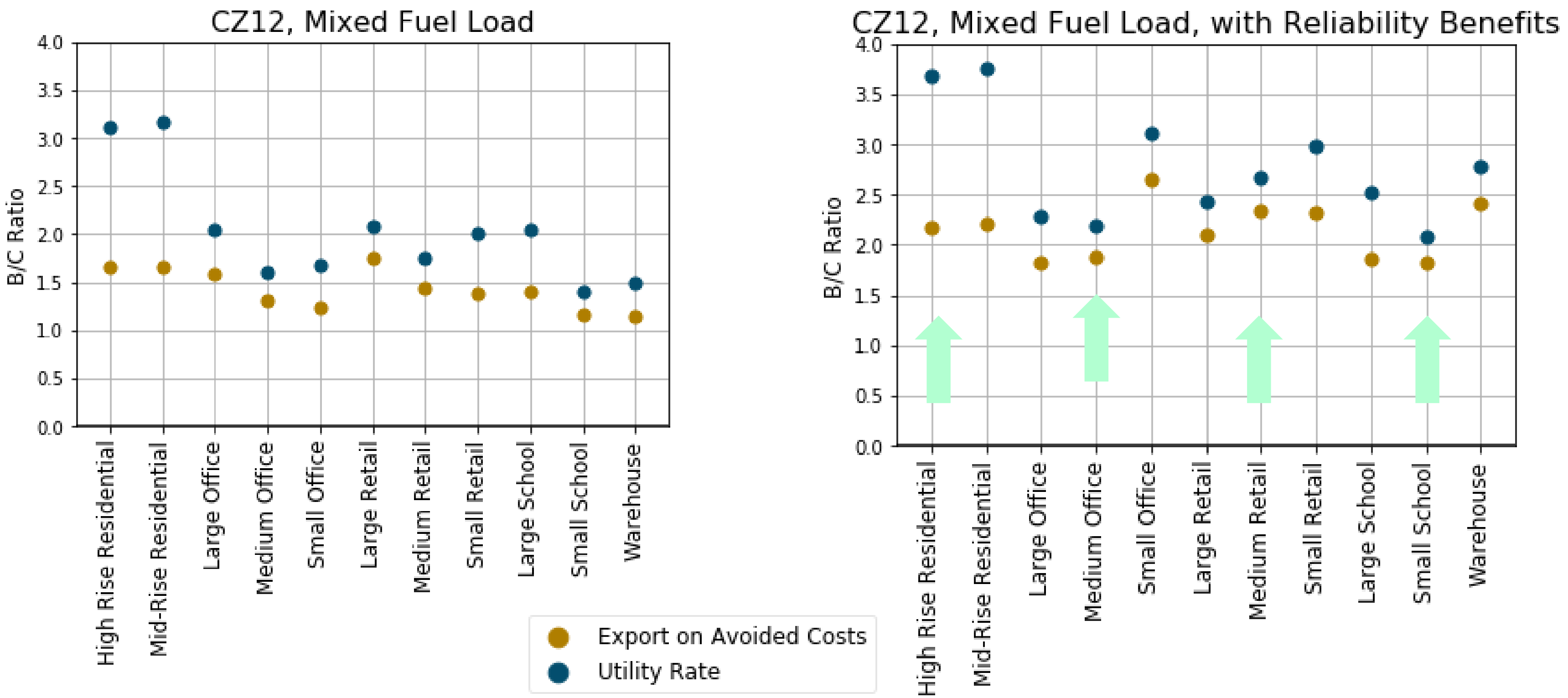
Reliability Value Sensitivity

Reliability Benefit Improves Cost-Effectiveness Optimal Dispatch

+ Behind-the-meter PV and battery storage has substantial reliability benefit

- Reliability benefit comes from having PV generation or reserving storage energy for unplanned short Transmission & Distribution power interruptions
- Not considered in cost-effectiveness tests, but this is a substantial participant benefit

Without Reliability Value | **With Reliability Value**

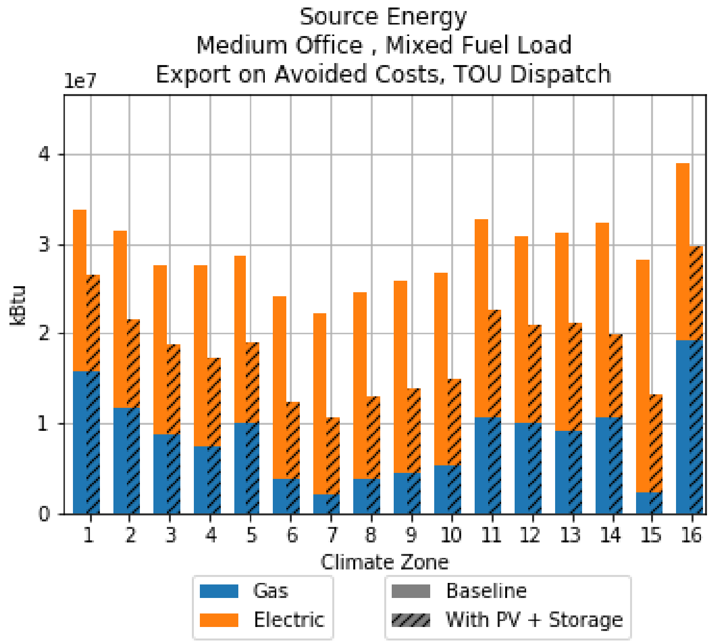


Source Energy & Emissions Results

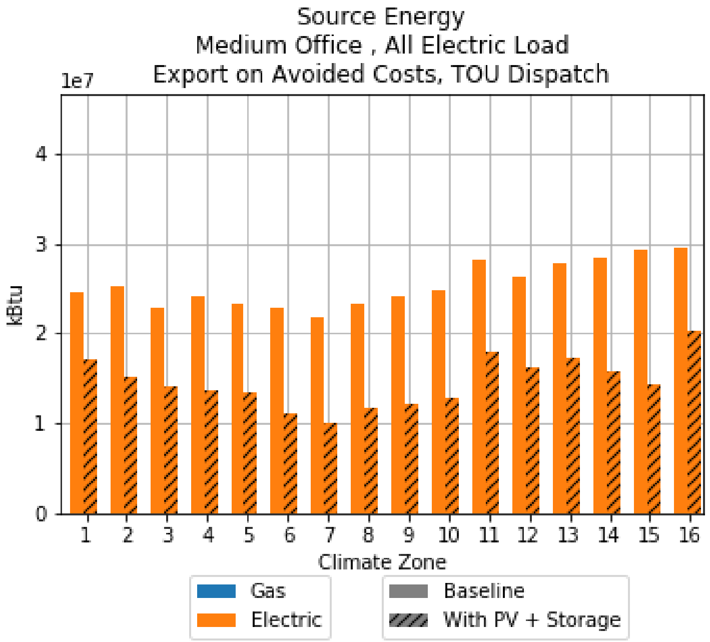
Source Energy, TOU Dispatch on TDV/Exported on Avoided Costs

- For Medium Office prototype, proposed PV + Storage systems yield substantial lifecycle source energy reductions in all climate zones for both mixed-fuel and all-electric buildings, ranging from 20% to over 50%
- All-electric buildings have lower source energy consumption across all climate zones, so PV + Storage yields larger % reduction in source energy savings

Mixed Fuel Load

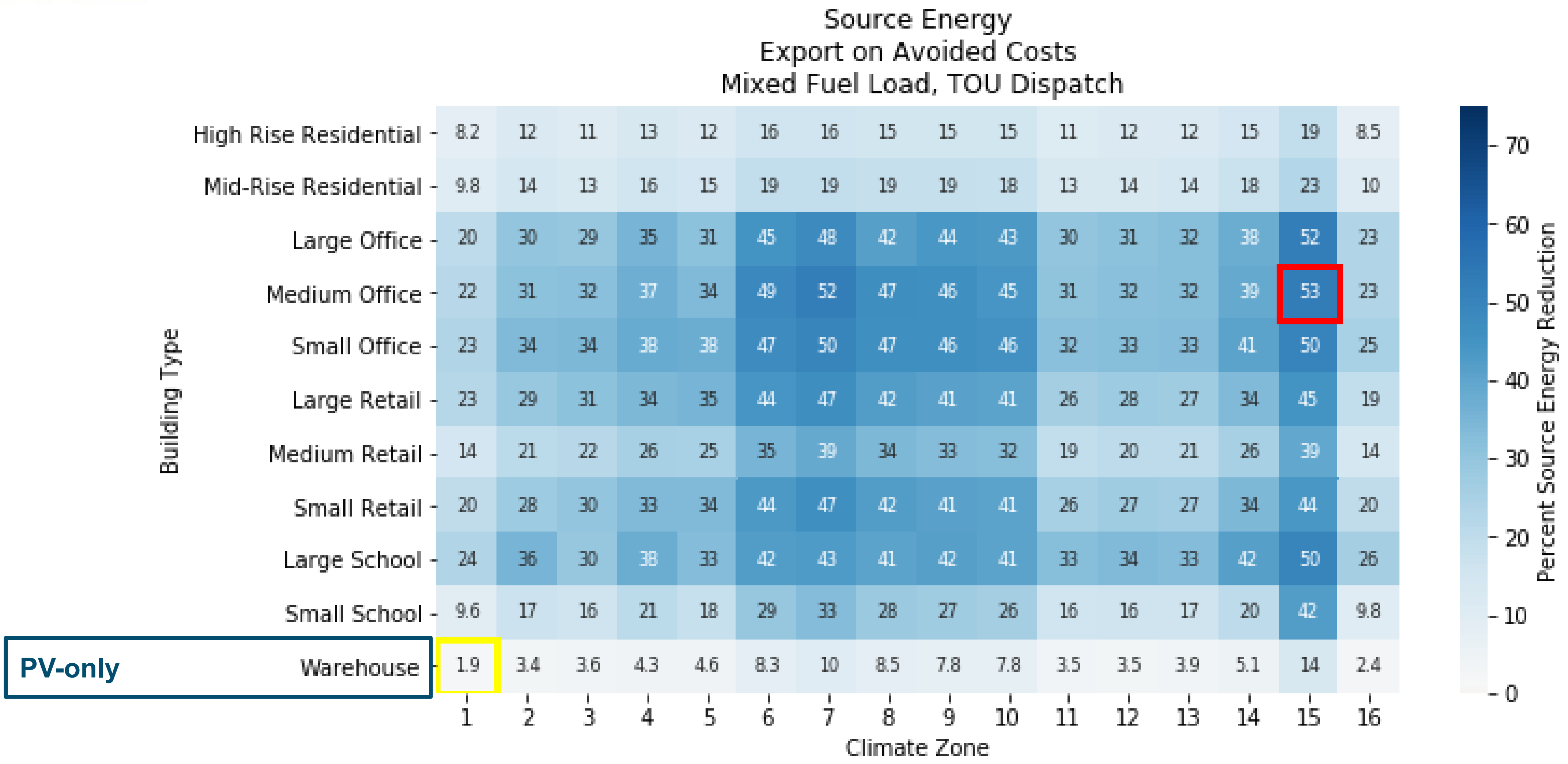


All-Electric Load



* Lifecycle emissions calculated based on TDV source energy metric

Source Energy, TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types



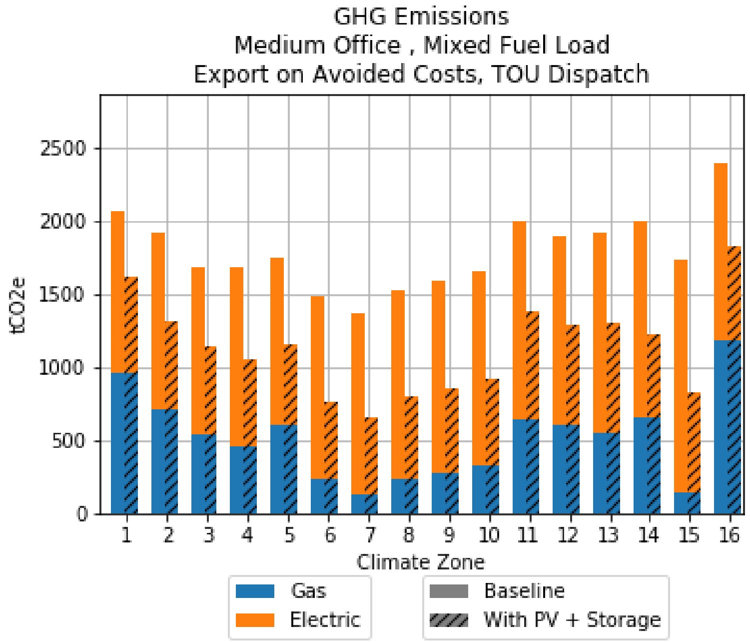
Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	8.2	12	11	13	12	16	16	15	15	15	11	12	12	15	19	8.5
Mid-Rise Residential	9.8	14	13	16	15	19	19	19	19	18	13	14	14	18	23	10
Large Office	20	30	29	35	31	45	48	42	44	43	30	31	32	38	52	23
Medium Office	22	31	32	37	34	49	52	47	46	45	31	32	32	39	53	23
Small Office	23	34	34	38	38	47	50	47	46	46	32	33	33	41	50	25
Large Retail	23	29	31	34	35	44	47	42	41	41	26	28	27	34	45	19
Medium Retail	14	21	22	26	25	35	39	34	33	32	19	20	21	26	39	14
Small Retail	20	28	30	33	34	44	47	42	41	41	26	27	27	34	44	20
Large School	24	36	30	38	33	42	43	41	42	41	33	34	33	42	50	26
Small School	9.6	17	16	21	18	29	33	28	27	26	16	16	17	20	42	9.8
Warehouse	1.9	3.4	3.6	4.3	4.6	8.3	10	8.5	7.8	7.8	3.5	3.5	3.9	5.1	14	2.4

+ This chart shows % reduction in source energy from PV and storage. Reductions are as high as 53%

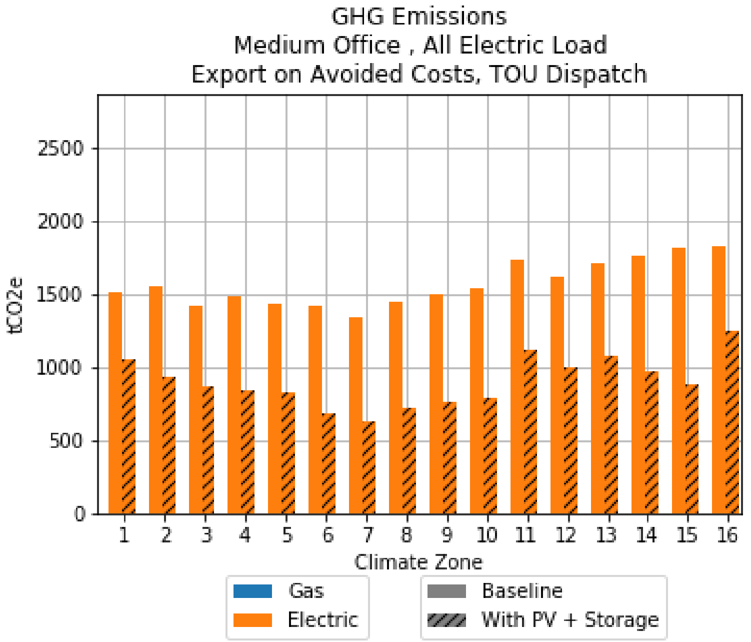
Lifecycle GHG Emissions, TOU Dispatch on TDV/Exported on Avoided Costs

- For Medium Office prototype, proposed PV + Storage systems yield substantial lifecycle emissions reductions in all climate zones for both mixed-fuel and all-electric buildings, ranging from 20% to over 50%
- All-electric buildings have lower GHG emissions across all climate zones, so PV + Storage yields larger % reduction in source energy savings

Mixed Fuel Load

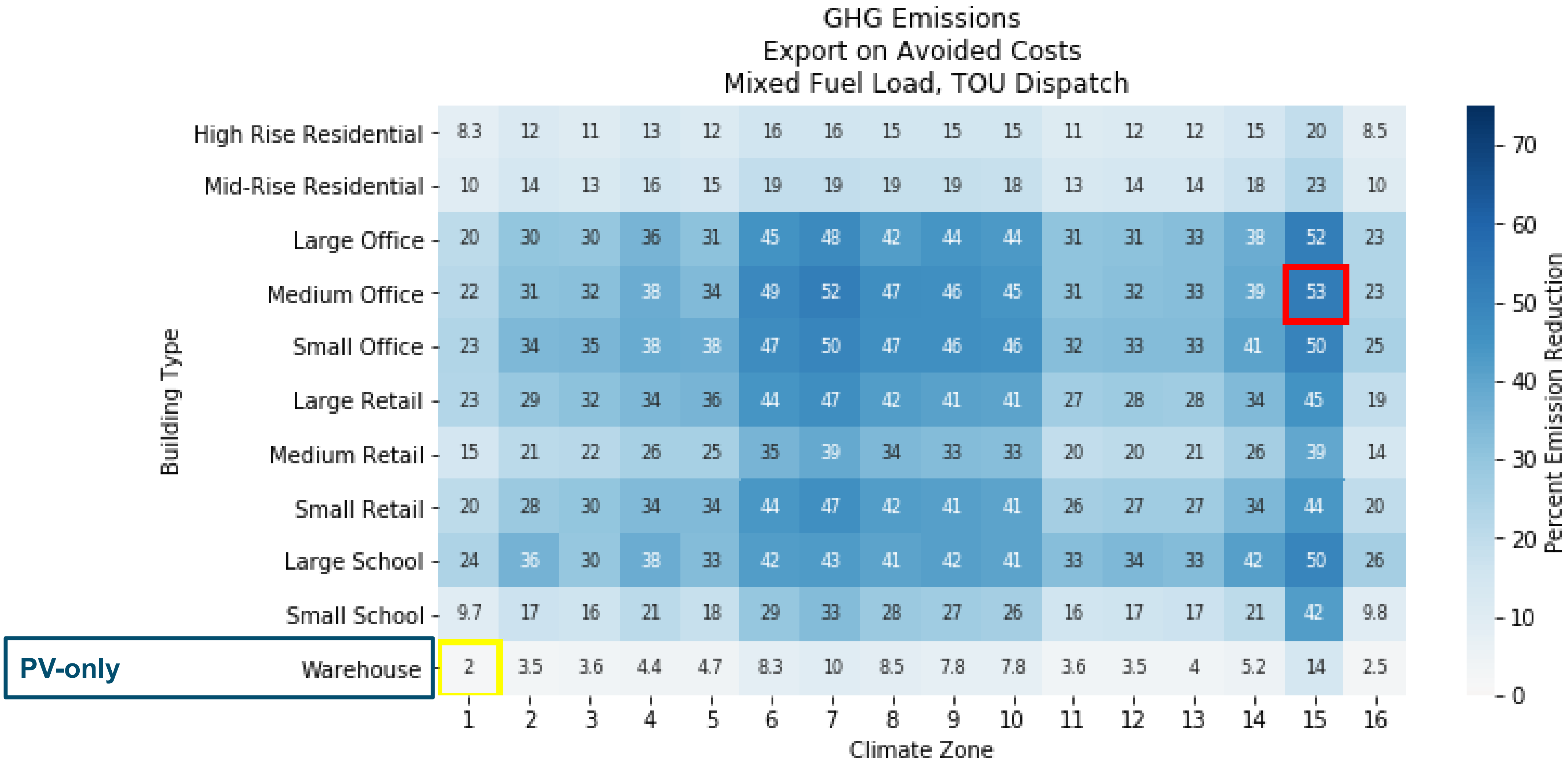


All-Electric Load



* Lifecycle emissions calculated based on TDV hourly emissions factors

Lifetime GHG Emissions, TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types



+ **This chart shows % reduction in lifetime GHG Emissions from PV and storage. Reductions are as high as 53%**

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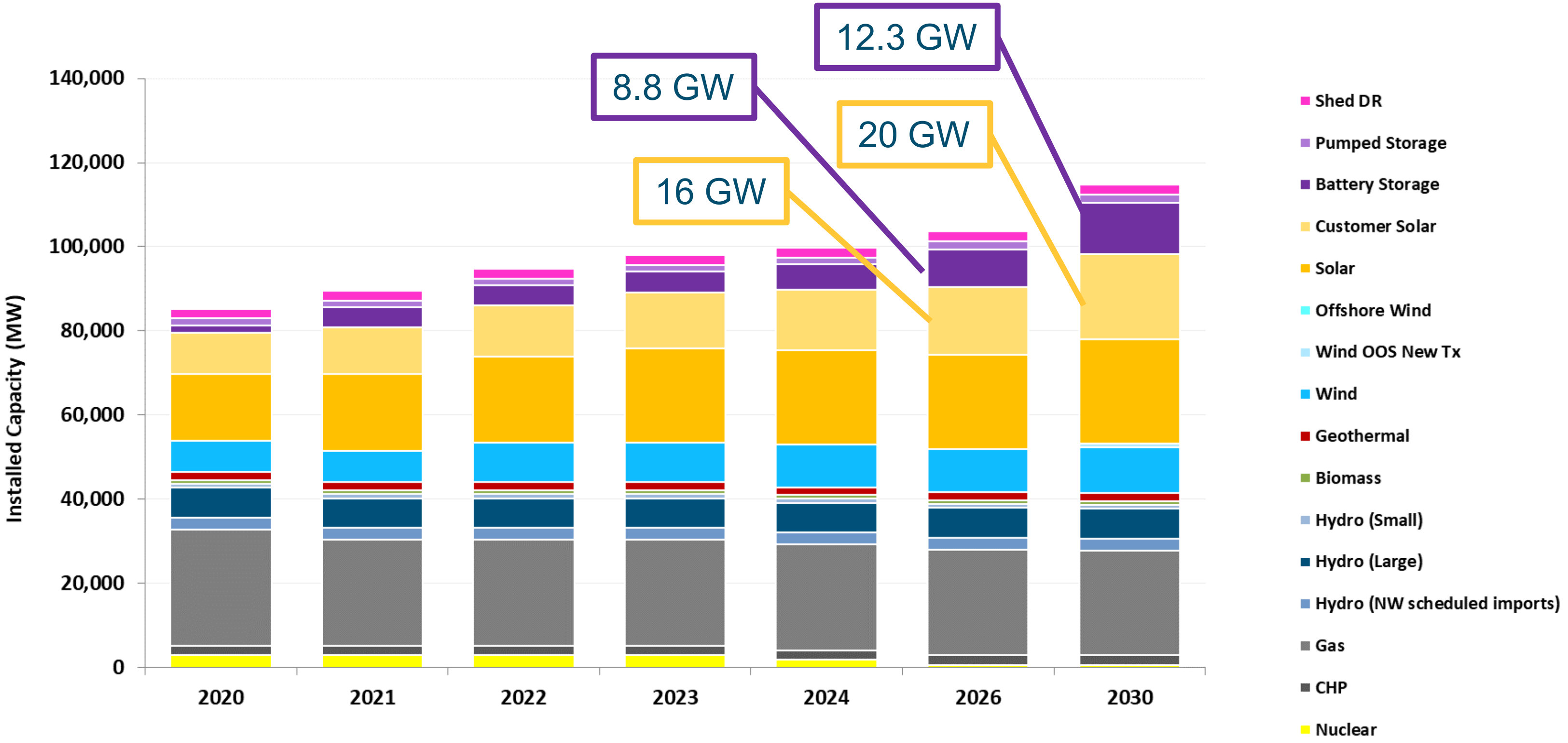
First-Year Statewide Impacts

Impacts - Statewide PV and Storage Capacity

- **Based on proposed requirement, first year forecasted installed capacity (2023)**
  - PV – 280 MW/yr
  - Battery Storage – 100 MW, 400MWh/yr
- **CPUC IRP Reference System Plan (Total Installed Capacity) – Not including proposed requirement**



Forecast based on 46MMT_20200207_2045_2GWPRM_NOOTCEXT_RSP_PD case from 2019 CPUC RSP: https://www.cpuc.ca.gov/General.aspx?id=6442459770

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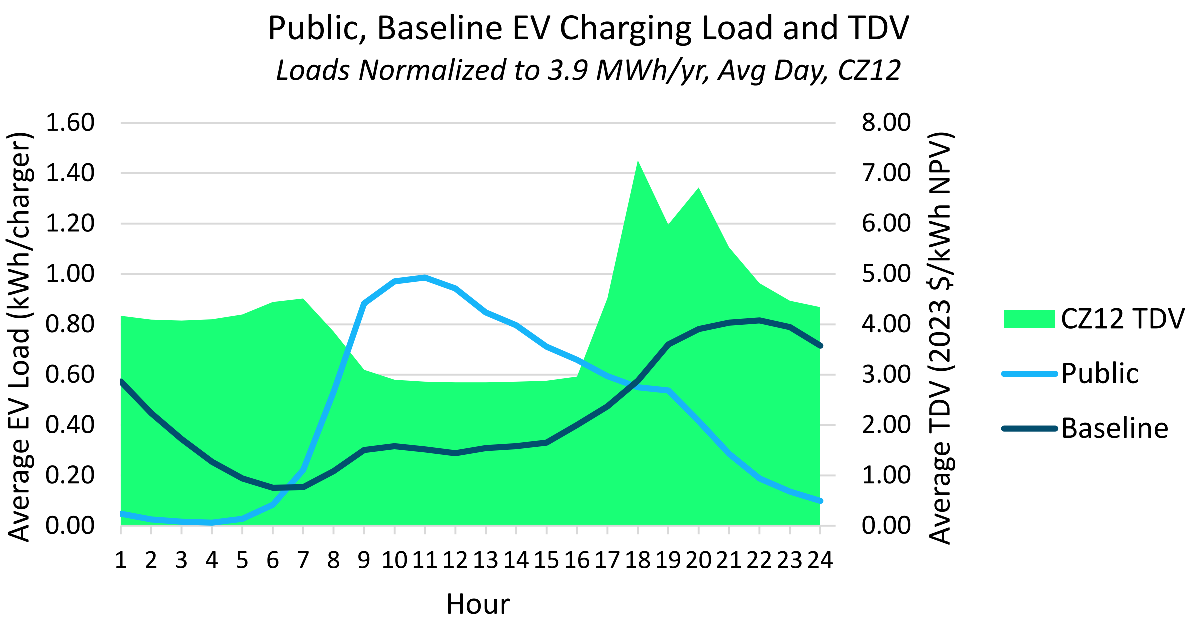
EV Charging Compliance Option Framework

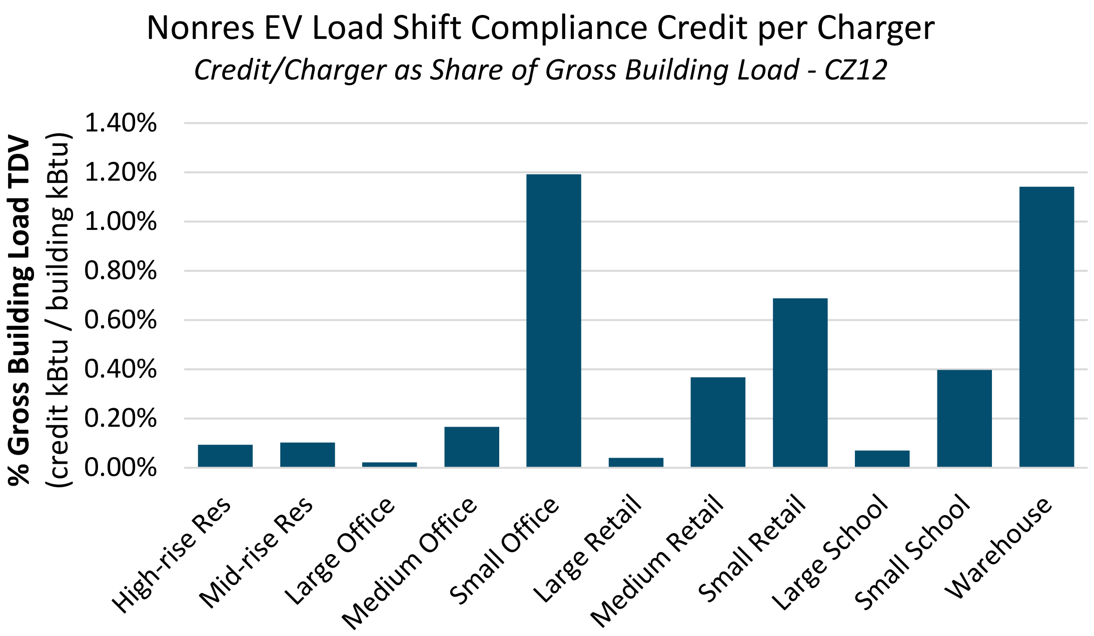
Proposed framework for nonresidential EV compliance credit and initial example

+ In order to meet California's 2025 ZEV goals, CARB estimates an additional need of 8,000-76,000 public/workplace level 2 (L2, ~7 kW) EV chargers, beyond those forecast under current building codes and incentives
+ Proposed Title 24, Part 11 (CALGreen) requires ~10% of a building's parking spaces be "EV Capable" – cable raceway and sufficient panel capacity to support Electric Vehicle Supply Equipment (EVSE) – and one L2 EV charger per building
+ Granting Title 24, Part 6 compliance credit for EVSE installation in non-residential buildings could help fill this gap
+ Designing Part 6 proposal so that it does not double count with Low Carbon Fuel Standard (LCFS) or CALGreen
+ This compliance credit is based on chargers in daytime charging locations that provide grid benefits:
  - TDV value of shifting EV charging load from a typical residential charging shape (during peak or evening hours) to a more solar-aligned workplace charging shape

How significant would the credit be?

- **Compliance Credit per Charger**
  - TDV 5,000 to 22,000 kBtu per charger lifecycle in likely usage scenarios
  - Levelized Source Energy 3,000 to 5,200 kBtu per charger per year in likely usage scenarios
  - Savings of 0.11 to 0.76 Tonnes CO2-e per charger per year in likely usage scenarios
- **CEC EVI-Pro preliminary charging profiles levelized to annual load of work L2 charger: 3.9 MWh**
  - Baseline-Public comparison represents switching from status quo charging (Res & Nonres) to all public charging





Interactions with proposed CALGreen Requirement

- **Title 24, Part 11 proposal to expand Nonres EVSE requirement to include**
  - ~10% of parking spaces to be "EV-Capable" - cable raceway and sufficient panel capacity to support EVSE
  - 1 Level 2 charger
- **Current installation rate of chargers in EV-Capable spaces is 30%**
  - May increase due to growing EV market and new requirement to install 1 L2 charger
- **Part 6 compliance credit should be carefully designed to encourage EVSE incremental to Part 11 requirement and natural charger installations in EV-Capable spaces, as well as local reach codes**

Proposed CALGreen Requirement for EV Capable Spaces

TOTAL NUMBER OF ACTUAL PARKING SPACES	NUMBER OF REQUIRED EV CHARGING SPACES
0-9	0
10-25	2
26-50	4
51-75	7
76-100	9
101-150	13
151-200	18
201 and over	10 percent of total[1]

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Conclusions

Key Findings

- **Proposed PV + Storage package and configurations are cost-effective for all building categories due to co-benefits of combined systems, except warehouse (PV-only is cost-effective)**
  - PV + Storage provides additional participant benefits, including reliability and resiliency
  - Climate zone 1 is least cost effective due to limited solar generation
- **PV + Storage is cost effective even under conservative dispatch, compensation scenarios**
- **Cost-effectiveness by building type largely driven by cost declines for larger systems**
  - Smaller buildings are least cost-effective, due to more expensive PV and storage ($/W)
- **Proposed PV and storage requirement reduces source energy and emissions by 10-50%, depending on building type and climate zone**
- **Proposed requirement will yield an estimated 280 MW of behind the meter PV and 100 MW, 400 MWh of battery storage per year**

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Thank you!

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Appendix

Appendix Contents

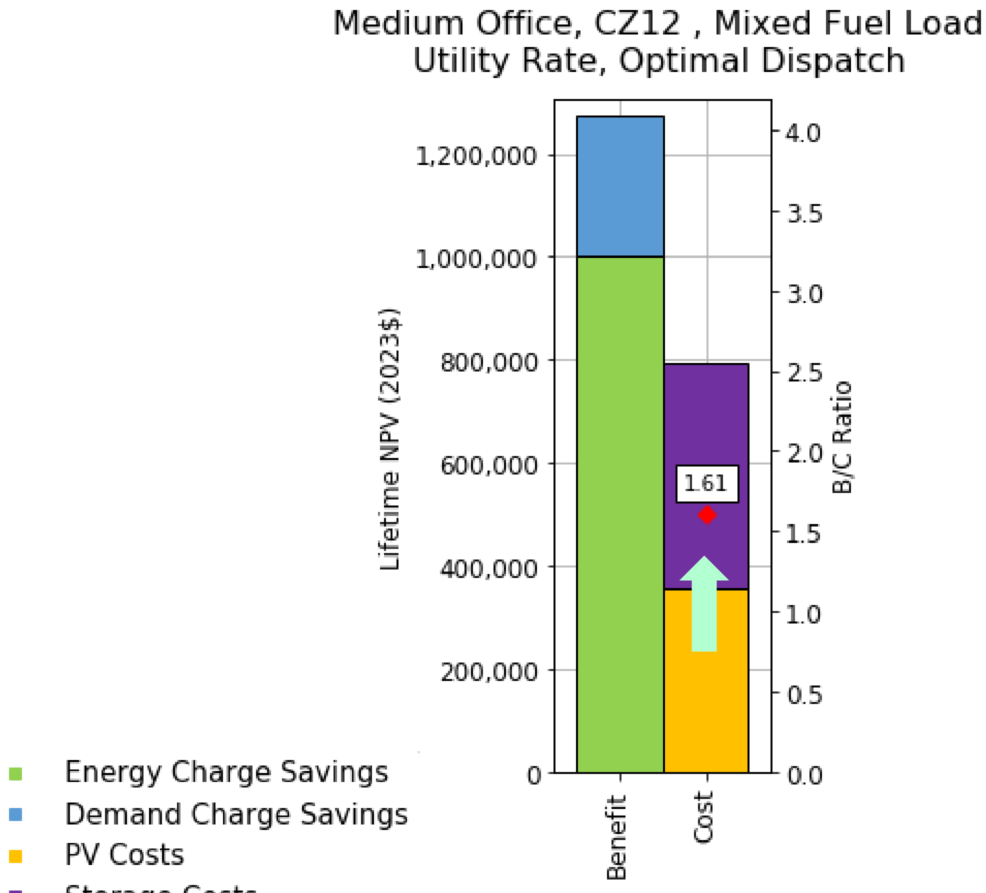
Key Updates since October 6 Workshop

- **Refined technology cost assumption**
  - Smooth technology cost curve for battery storage
- **Oversized storage energy capacity to make sure it discharges full 4 hours**
- **Switched lower bound to TOU dispatch**
- **Corrected roof constraint calculation**
  - Does not impact cost effectiveness results for configurations as proposed in draft measure language
- **Generalized PV and storage sizing by climate zone**
  - Only showing results for configurations as proposed in draft measure language
  - Changed PV self-use size to be defined as 20% exports
  - Changed Storage sizing scenario to 10% exports
- **Calculated source energy and emission results**
- **Other minor bug fixes**
  - Reliability value converted from 2016$ to 2023$

Cost-effectiveness – Optimal Dispatch w/ Utility rates

- For Medium Office, the PV + Storage package is more cost-effective under existing utility commercial TOU rates
- Benefit-cost ratio is 1.6
- Demand charge savings are a significant portion of potential benefit for battery storage in existing retail rates

Cost Effectiveness – B10-TOU Rate

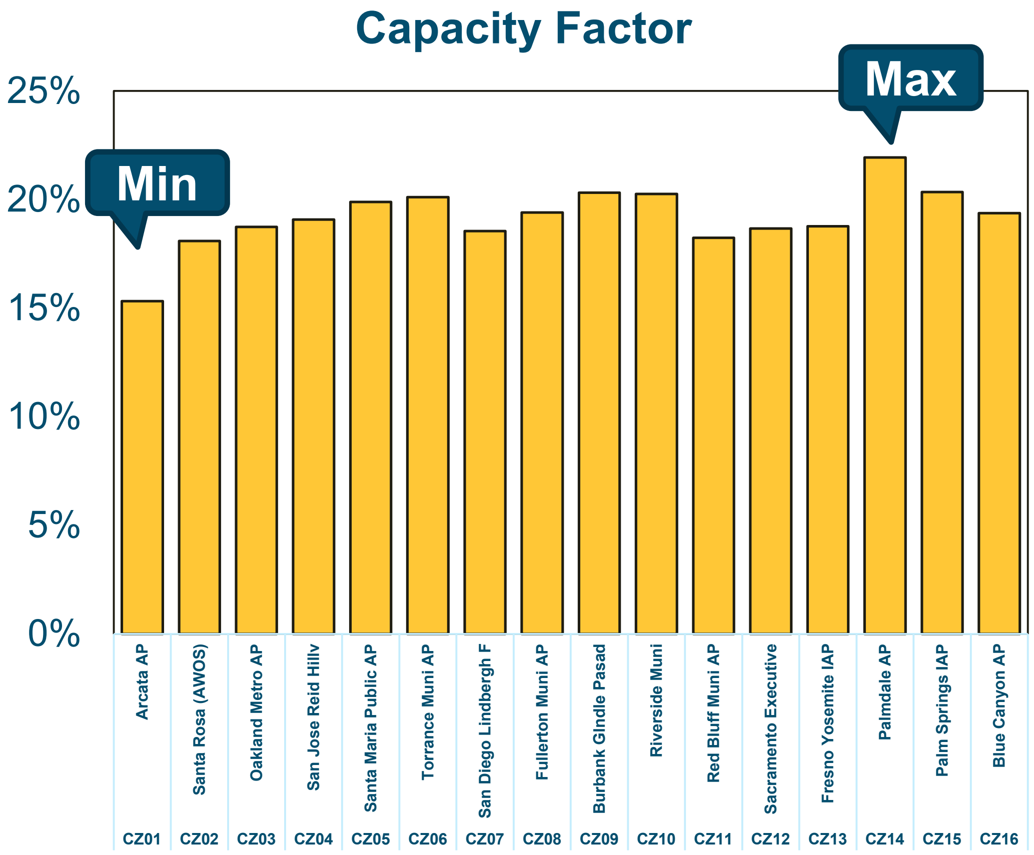


167 kW PV
70 kW Storage

PV Capacity Factor

+ **CZ01 has much lower PV output (les cost-effective), CZ14 has much higher PV output (more cost-effective)**

Climate Zone	Weather Station Name	Capacity Factor
CZ01	Arcata AP	15.3%
CZ02	Santa Rosa (AWOS)	18.1%
CZ03	Oakland Metro AP	18.7%
CZ04	San Jose Reid Hillv	19.1%
CZ05	Santa Maria Public AP	19.9%
CZ06	Torrance Muni AP	20.1%
CZ07	San Diego Lindbergh F	18.6%
CZ08	Fullerton Muni AP	19.4%
CZ09	Burbank Glndle Pasad	20.3%
CZ10	Riverside Muni	20.3%
CZ11	Red Bluff Muni AP	18.2%
CZ12	Sacramento Executive	18.7%
CZ13	Fresno Yosemite IAP	18.8%
CZ14	Palmdale AP	21.9%
CZ15	Palm Springs IAP	20.3%
CZ16	Blue Canyon AP	19.4%



Appendix – Key Reliability Assumptions

Key Reliability Assumptions

+ Reliability benefit calculation methodology

- Reliability (ability to cover short-duration unplanned T&D power interruptions)
  - average T&D interruption probability * energy availability in PV and storage * interruption costs (VoLL)

+ Reliability metrics

- CA statewide data from NREL dGen Model[1]
- SAIDI – 195.1
- SAIFI – 0.954

+ Interruption costs (VoLL)

- From LBNL Interruption Cost Estimate (ICE)[2]
- By prototype building type
- Based on CZ12 mixed-fuel electric load as a proxy
  - annual load kWh are close across different CZs

VoLL Assumptions by Building Type

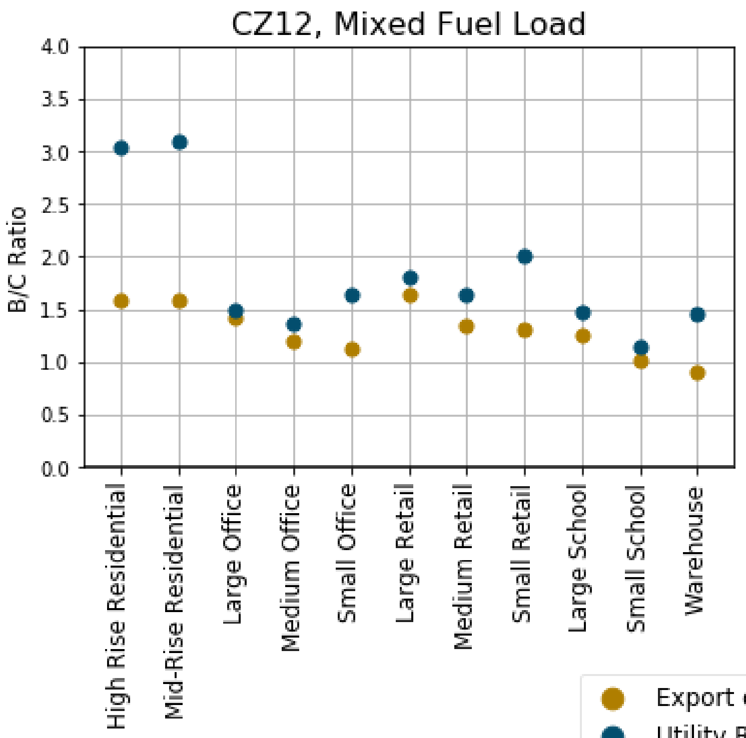
Building Type	Load Type	MWh	Sector	VoLL 2023 $/kWh
High-rise Res	Mixed-fuel	691	Medium and Large C&I	**69.21**
Mid-rise Res	Mixed-fuel	645	Medium and Large C&I	**71.66**
Large Office	Mixed-fuel	3609	Medium and Large C&I	**29.98**
Medium Office	Mixed-fuel	453	Medium and Large C&I	**85.63**
Small Office	Mixed-fuel	62	Small C&I	**233.68**
Large Office	Mixed-fuel	1754	Medium and Large C&I	**43.23**
Medium Retail	Mixed-fuel	188	Medium and Large C&I	**133.28**
Small Retail	Mixed-fuel	103	Small C&I	**150.99**
Large School	Mixed-fuel	1035	Medium and Large C&I	**56.43**
Small School	Mixed-fuel	179	Small C&I	**93.64**
Warehouse	Mixed-fuel	73	Small C&I	**203.10**

1 https://www.nrel.gov/analysis/dgen/index.html
2 https://www.icecalculator.com/

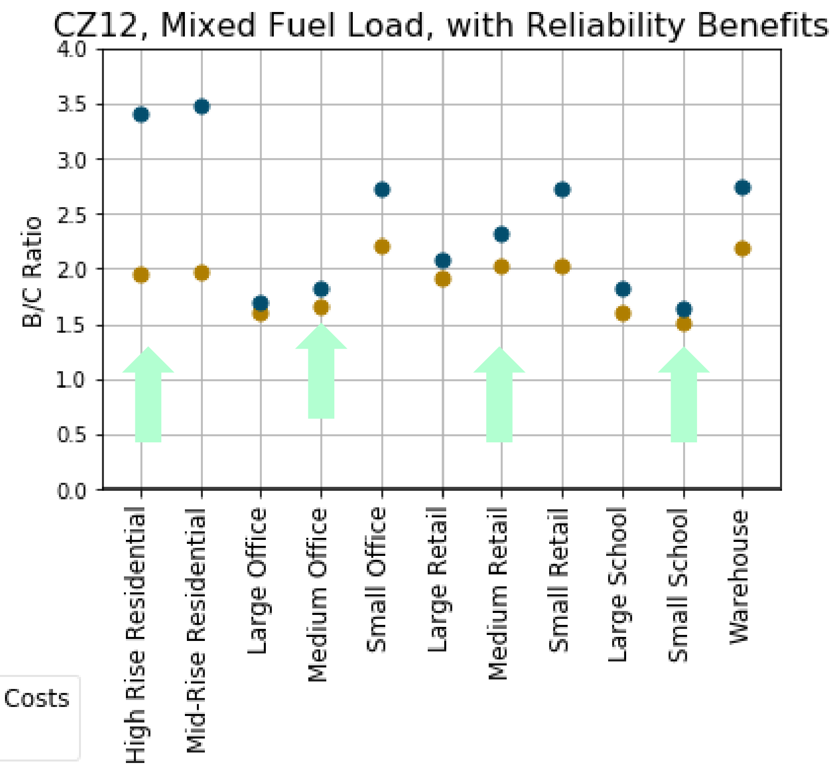
Reliability Benefit Improves Cost-Effectiveness TOU Dispatch

+ **Behind the meter PV and battery storage has substantial reliability benefit**
  - Reliability benefit comes from having PV generation or reserving storage energy for unplanned short T&D power interruptions
  - Not considered in cost-effectiveness tests, but a substantial benefit

Without Reliability Value



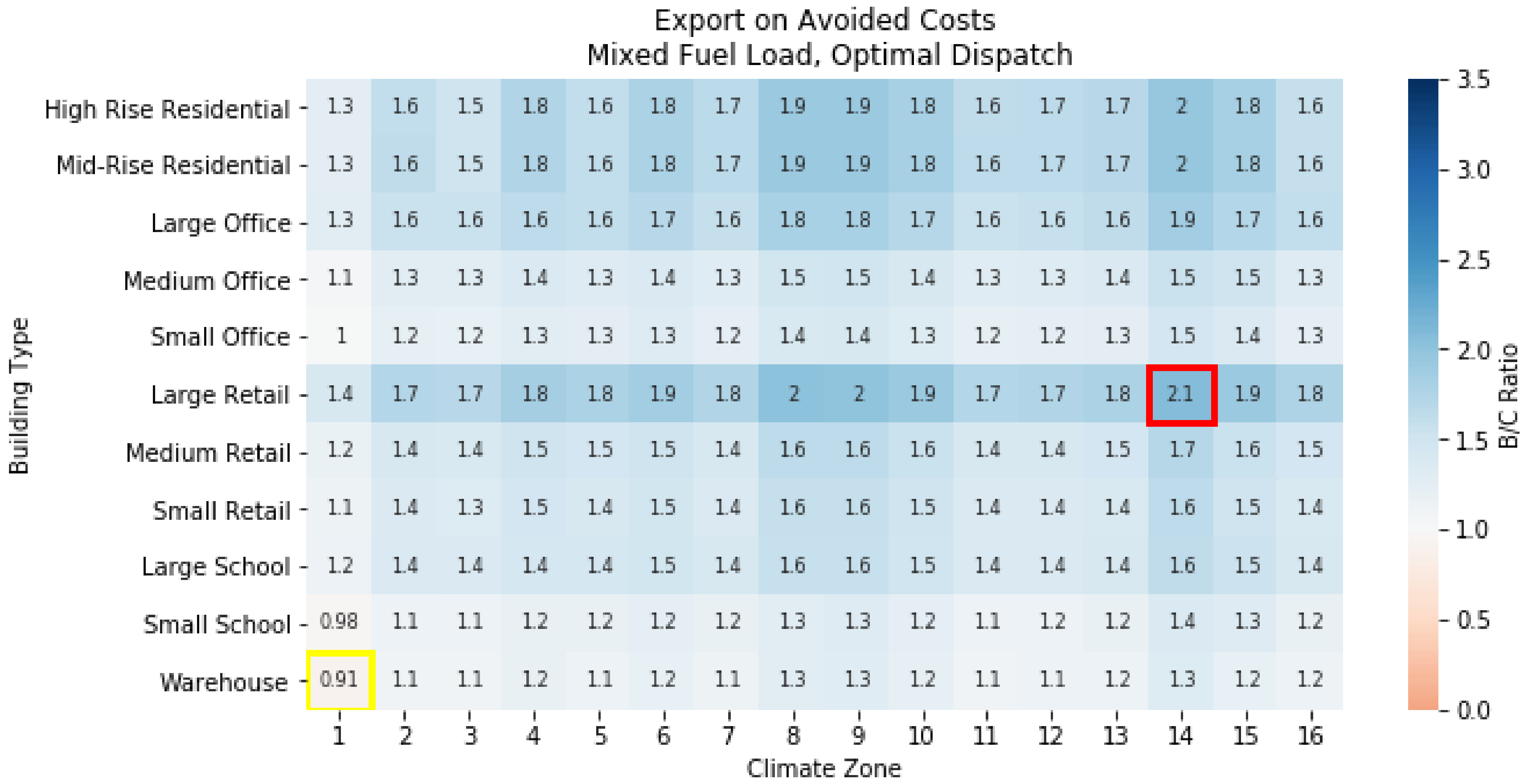
With Reliability Value



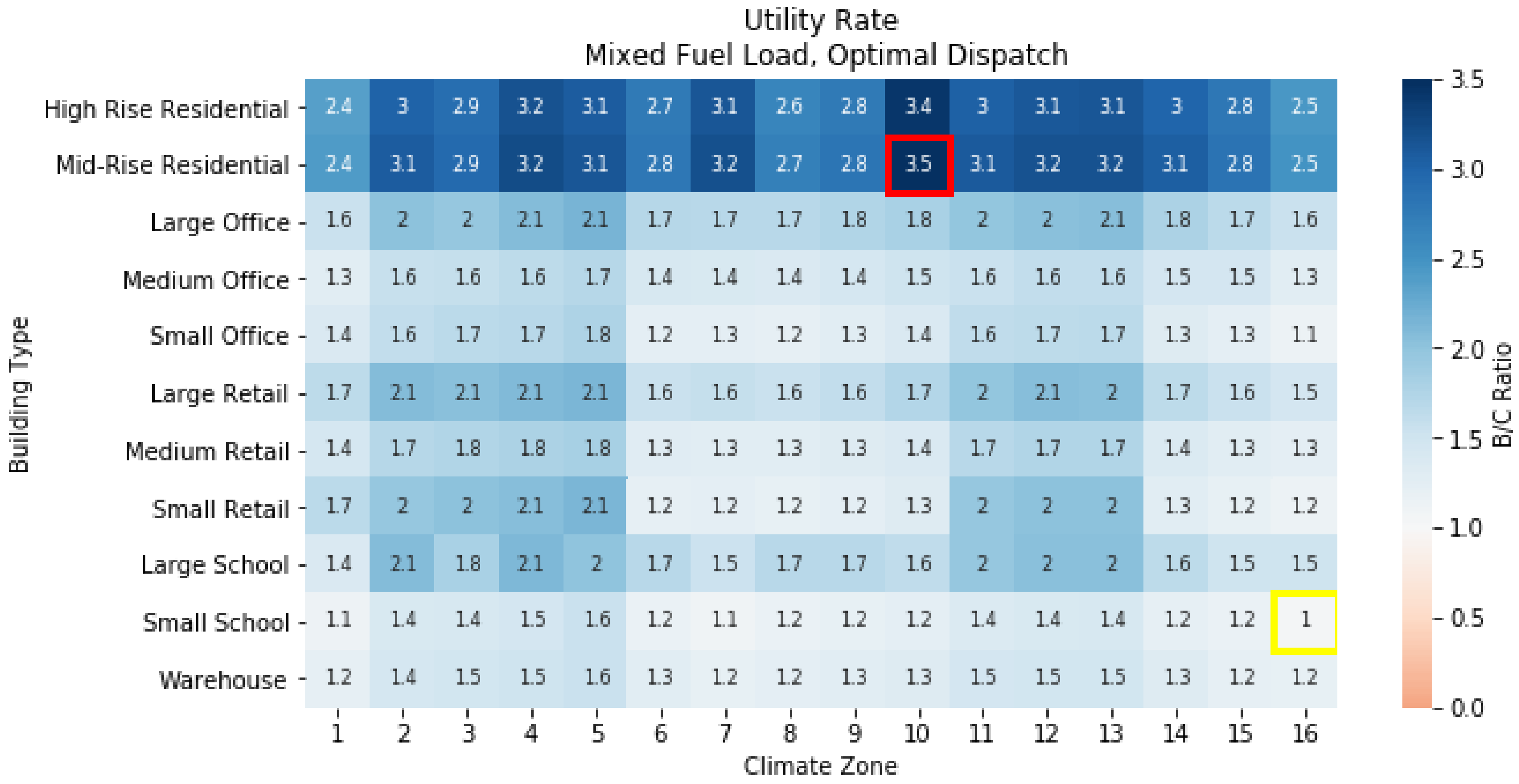
- Export on Avoided Costs
- Utility Rate

Appendix - Net Benefit Results for Mixed Fuel Load

PV + Storage Optimal Dispatch on TDV/Exported on Avoided Costs Across Building Types

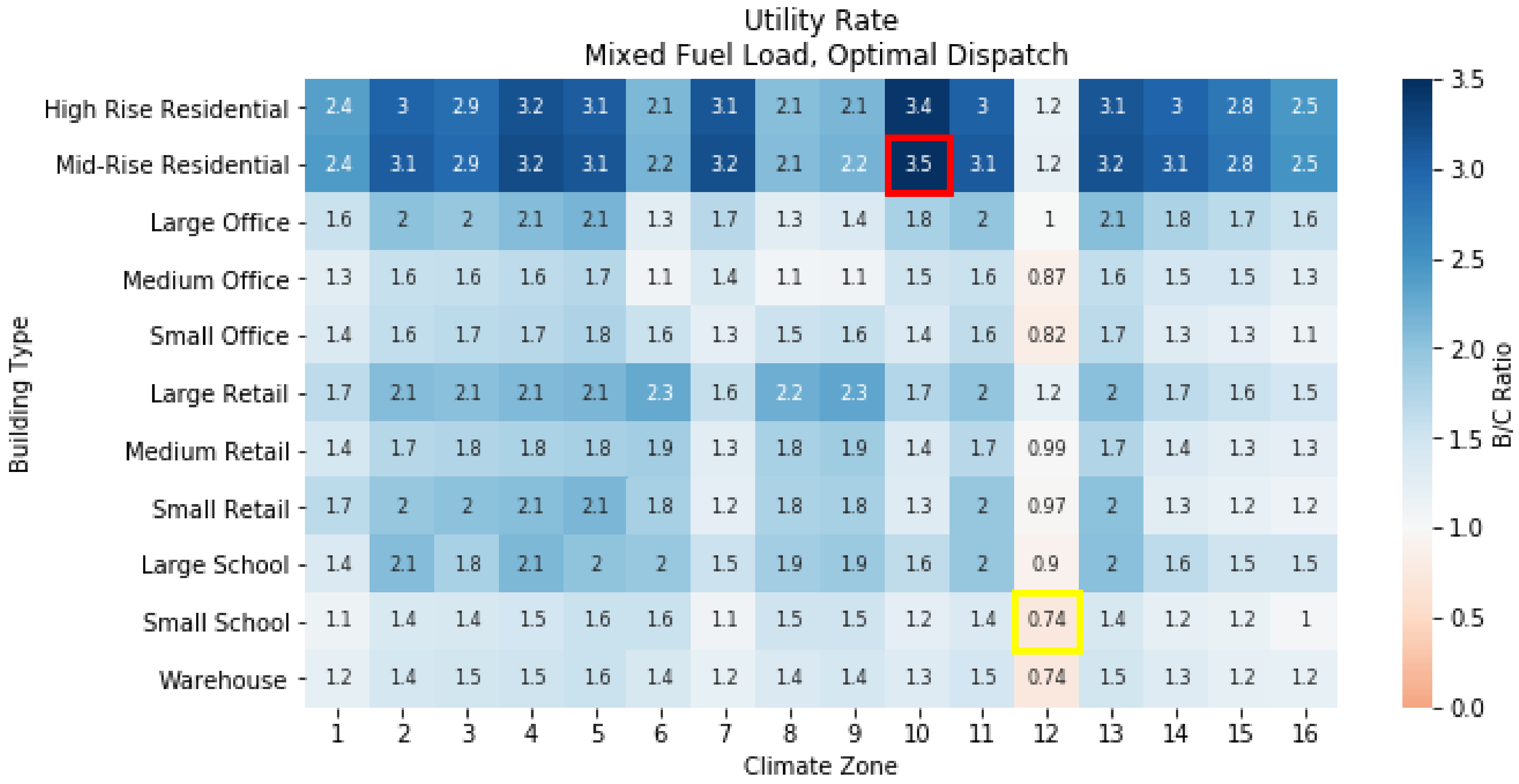


PV + Storage Optimal Dispatch on Utility Rates Across Building Types



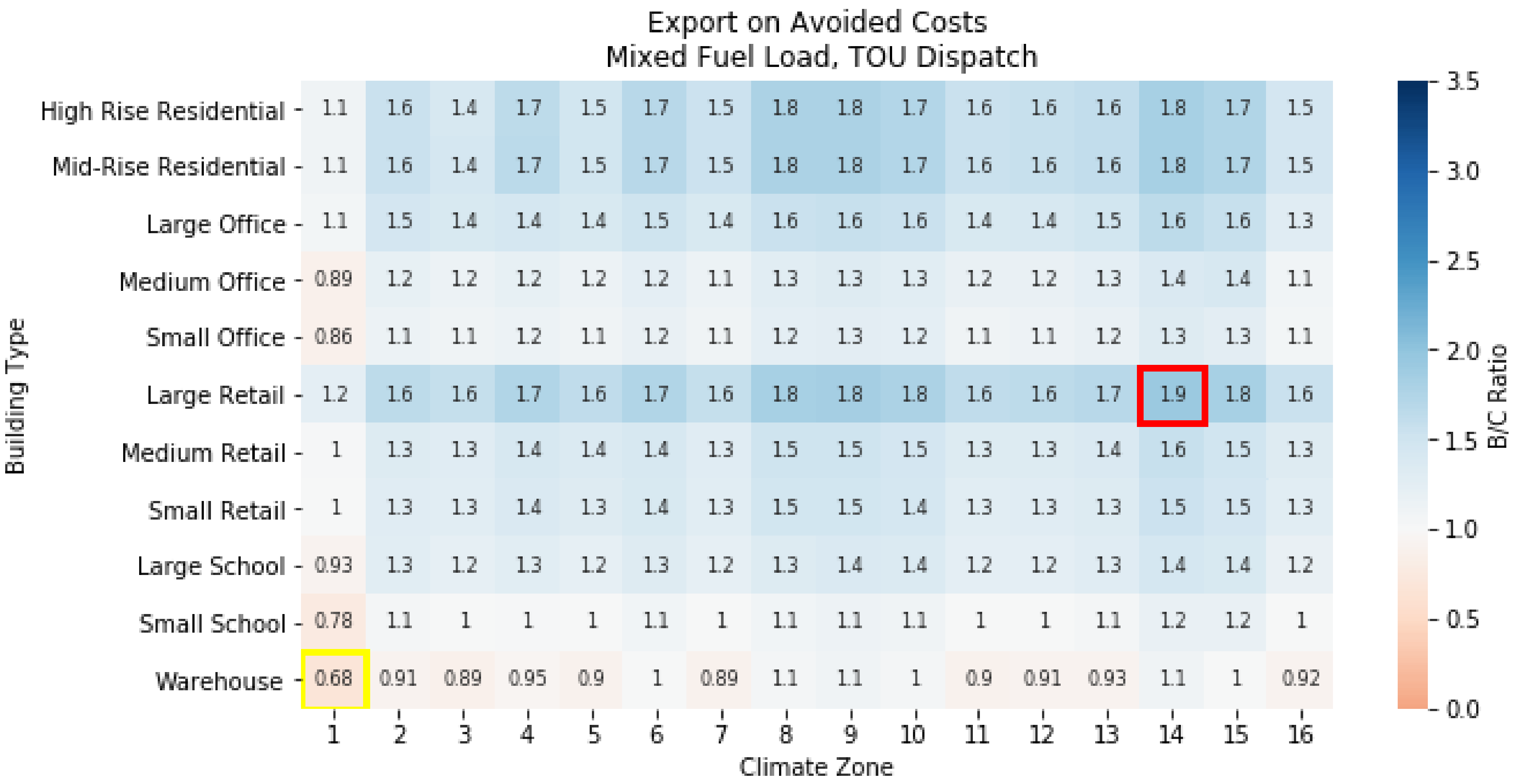
CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage Optimal Dispatch on Utility Rates Across Building Types w/ LADWP & SMUD



CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types



Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	1.1	1.6	1.4	1.7	1.5	1.7	1.5	1.8	1.8	1.7	1.6	1.6	1.6	1.8	1.7	1.5
Mid-Rise Residential	1.1	1.6	1.4	1.7	1.5	1.7	1.5	1.8	1.8	1.7	1.6	1.6	1.6	1.8	1.7	1.5
Large Office	1.1	1.5	1.4	1.4	1.4	1.5	1.4	1.6	1.6	1.6	1.4	1.4	1.5	1.6	1.6	1.3
Medium Office	0.89	1.2	1.2	1.2	1.2	1.2	1.1	1.3	1.3	1.3	1.2	1.2	1.3	1.4	1.4	1.1
Small Office	0.86	1.1	1.1	1.2	1.1	1.2	1.1	1.2	1.3	1.2	1.1	1.1	1.2	1.3	1.3	1.1
Large Retail	1.2	1.6	1.6	1.7	1.6	1.7	1.6	1.8	1.8	1.8	1.6	1.6	1.7	1.9	1.8	1.6
Medium Retail	1	1.3	1.3	1.4	1.4	1.4	1.3	1.5	1.5	1.5	1.3	1.3	1.4	1.6	1.5	1.3
Small Retail	1	1.3	1.3	1.4	1.3	1.4	1.3	1.5	1.5	1.4	1.3	1.3	1.3	1.5	1.5	1.3
Large School	0.93	1.3	1.2	1.3	1.2	1.3	1.2	1.3	1.4	1.4	1.2	1.2	1.3	1.4	1.4	1.2
Small School	0.78	1.1	1	1	1	1.1	1	1.1	1.1	1.1	1	1	1.1	1.2	1.2	1
Warehouse	0.68	0.91	0.89	0.95	0.9	1	0.89	1.1	1.1	1	0.9	0.91	0.93	1.1	1	0.92

PV + Storage TOU Dispatch on Utility Rates Across Building Types

Utility Rate
Mixed Fuel Load, TOU Dispatch

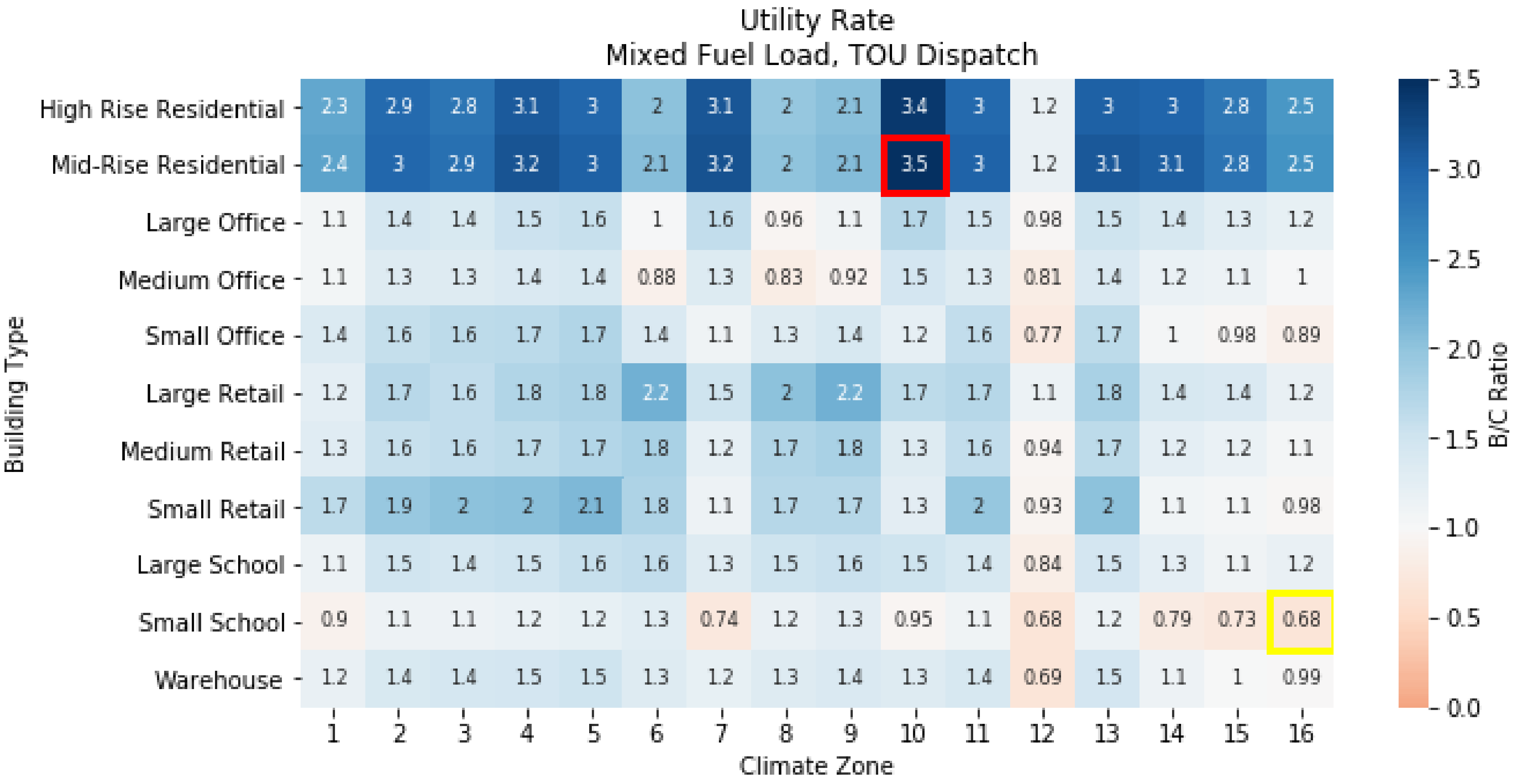
B/C Ratio by Building Type and Climate Zone

Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	2.3	2.9	2.8	3.1	3	2.7	3.1	2.6	2.8	3.4	3	3	3	3	2.8	2.5
Mid-Rise Residential	2.4	3	2.9	3.2	3	2.8	3.2	2.7	2.8	3.5	3	3.1	3.1	3.1	2.8	2.5
Large Office	1.1	1.4	1.4	1.5	1.6	1.4	1.6	1.3	1.4	1.7	1.5	1.5	1.5	1.4	1.3	1.2
Medium Office	1.1	1.3	1.3	1.4	1.4	1.2	1.3	1	1.1	1.5	1.3	1.4	1.4	1.2	1.1	1
Small Office	1.4	1.6	1.6	1.7	1.7	0.97	1.1	0.96	0.99	1.2	1.6	1.6	1.7	1	0.98	0.89
Large Retail	1.2	1.7	1.6	1.8	1.8	1.3	1.5	1.4	1.4	1.7	1.7	1.8	1.8	1.4	1.4	1.2
Medium Retail	1.3	1.6	1.6	1.7	1.7	1.1	1.2	1.2	1.2	1.3	1.6	1.6	1.7	1.2	1.2	1.1
Small Retail	1.7	1.9	2	2	2.1	1	1.1	1.1	1.1	1.3	2	2	2	1.1	1.1	0.98
Large School	1.1	1.5	1.4	1.5	1.6	1.3	1.3	1.3	1.3	1.5	1.4	1.5	1.5	1.3	1.1	1.2
Small School	0.9	1.1	1.1	1.2	1.2	0.71	0.74	0.76	0.79	0.95	1.1	1.1	1.2	0.79	0.73	0.68
Warehouse	1.2	1.4	1.4	1.5	1.5	1.1	1.2	1.1	1.1	1.3	1.4	1.4	1.5	1.1	1	0.99

Climate Zone

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage TOU Dispatch on Utility Rates Across Building Types w/ LADWP & SMUD



CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

Energy+Environmental Economics

Appendix - Net Benefit Results for All-Electric Load

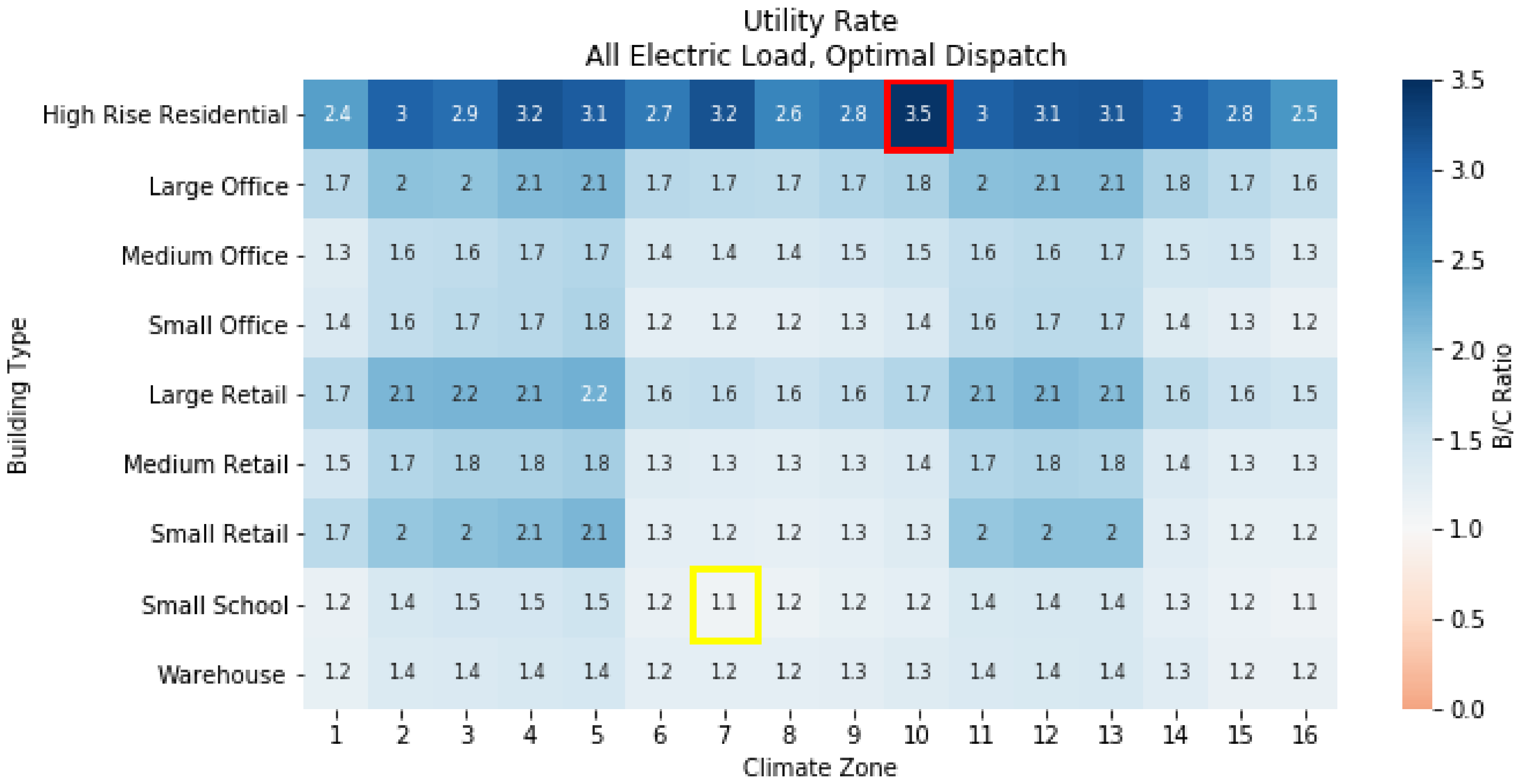
PV + Storage Optimal Dispatch on TDV/Exported on Avoided Costs Across Building Types – All-Electric

Export on Avoided Costs
All Electric Load, Optimal Dispatch

Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	1.3	1.7	1.5	1.8	1.6	1.8	1.7	1.9	1.9	1.9	1.7	1.7	1.7	2	1.9	1.6
Large Office	1.4	1.6	1.6	1.7	1.7	1.7	1.6	1.8	1.8	1.8	1.6	1.6	1.7	1.9	1.8	1.7
Medium Office	1.1	1.3	1.3	1.4	1.4	1.4	1.3	1.5	1.5	1.4	1.3	1.3	1.4	1.6	1.5	1.4
Small Office	1	1.2	1.2	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.2	1.3	1.3	1.5	1.4	1.3
Large Retail	1.5	1.8	1.8	1.9	1.9	1.9	1.8	2.1	2.1	2	1.8	1.8	1.8	2.2	2	1.8
Medium Retail	1.2	1.5	1.4	1.6	1.5	1.6	1.5	1.7	1.7	1.6	1.5	1.5	1.5	1.8	1.6	1.5
Small Retail	1.1	1.4	1.4	1.5	1.4	1.5	1.4	1.6	1.6	1.5	1.4	1.4	1.4	1.7	1.5	1.4
Small School	0.98	1.2	1.1	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.4	1.3	1.2
Warehouse	0.92	1.1	1.1	1.2	1.2	1.2	1.1	1.3	1.3	1.2	1.1	1.1	1.2	1.4	1.3	1.2

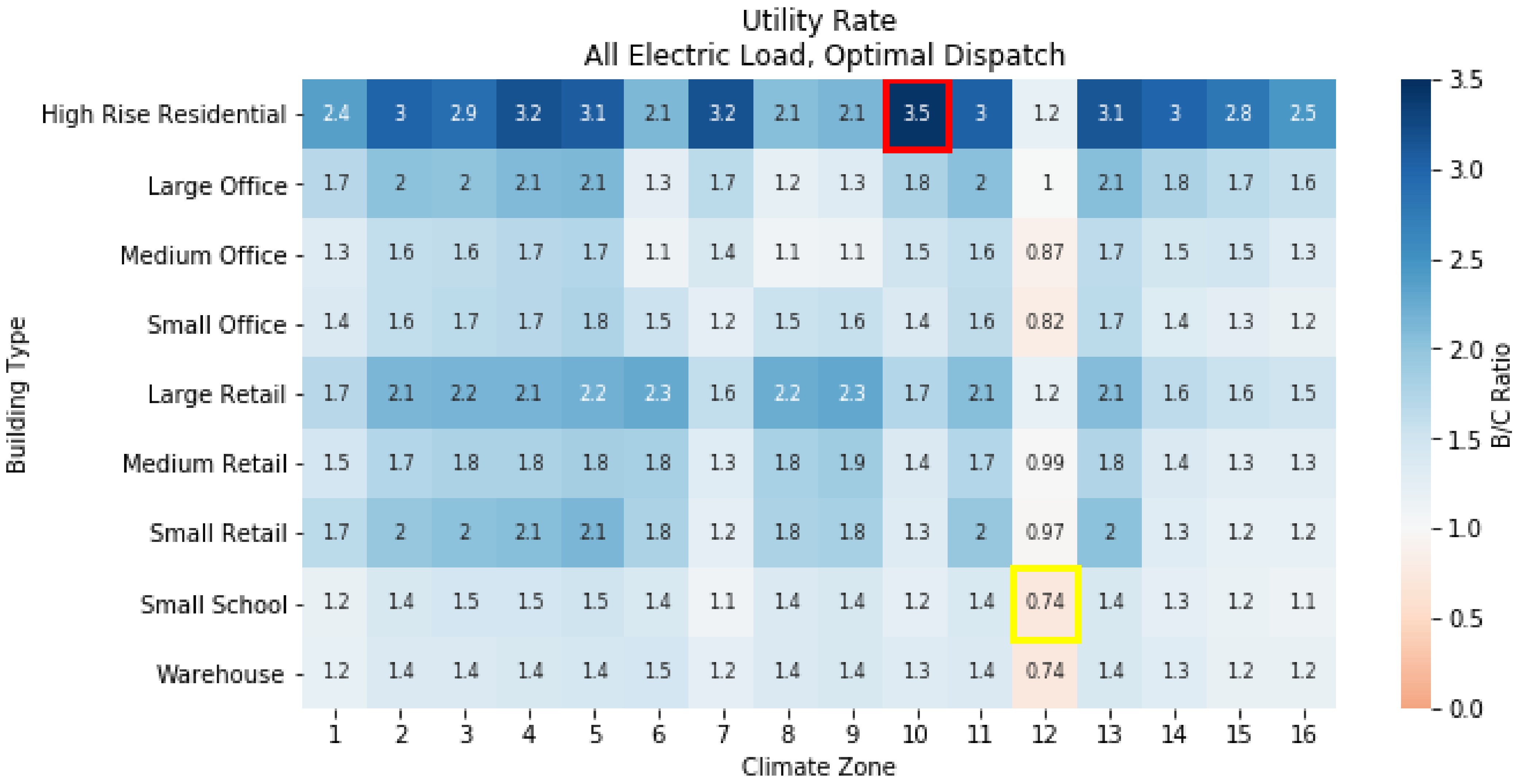
B/C Ratio
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

PV + Storage Optimal Dispatch on Utility Rates Across Building Types



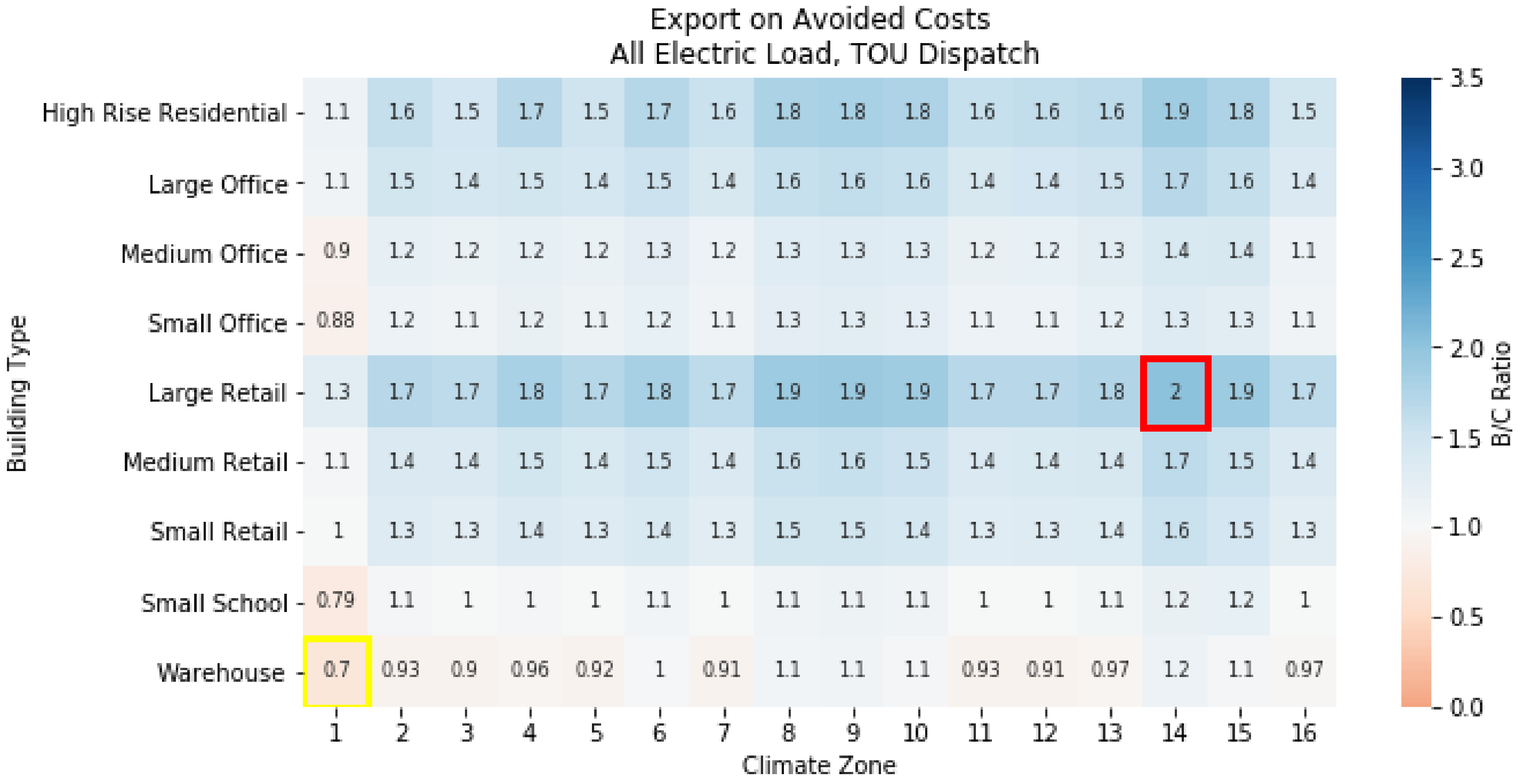
CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage Optimal Dispatch on Utility Rates Across Building Type w/ LADWP & SMUD



CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage TOU Dispatch on TDV/Exported on Avoided Costs Across Building Types – All-Electric



PV + Storage TOU Dispatch on Utility Rates Across Building Types

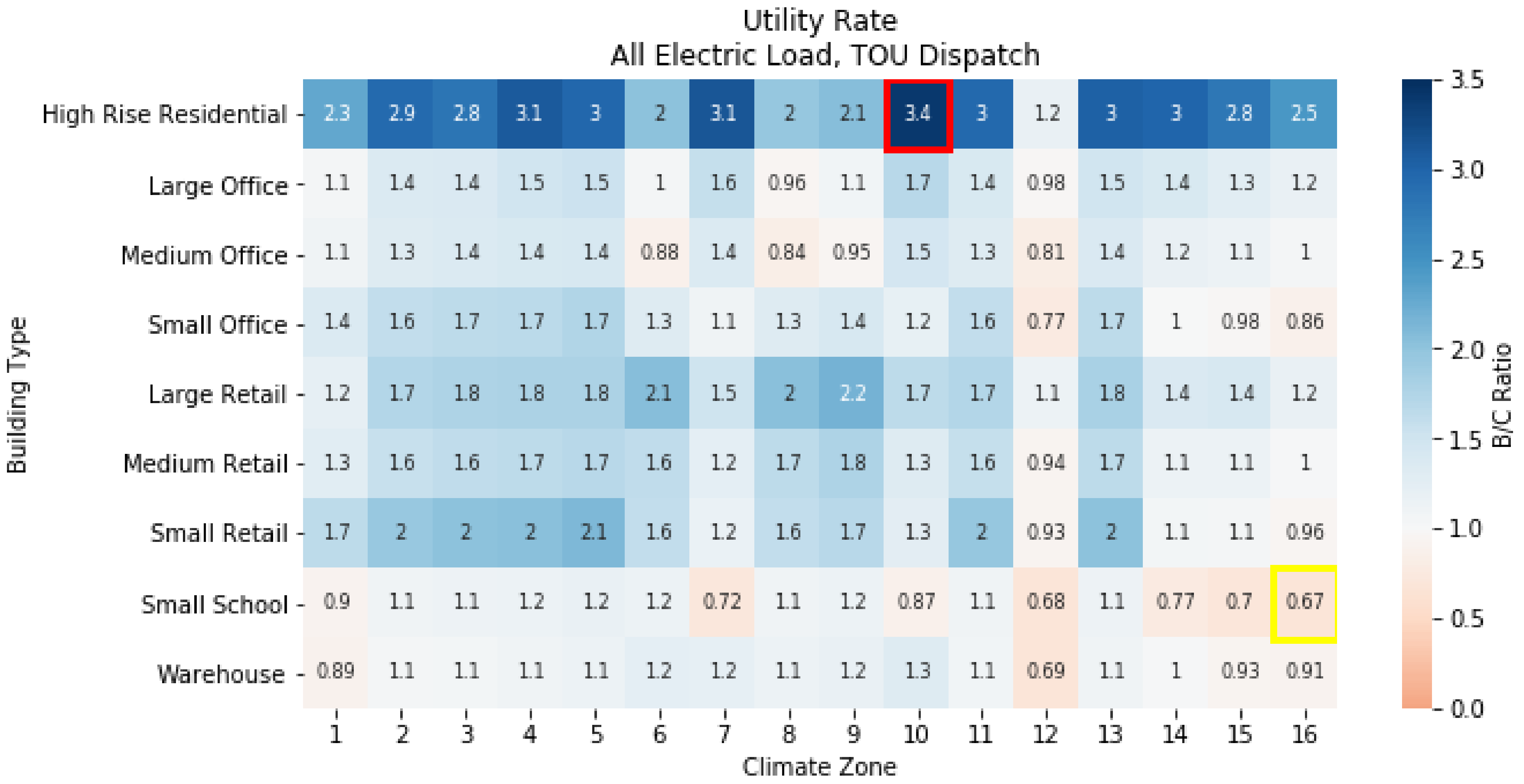
Utility Rate
All Electric Load, TOU Dispatch

Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	2.3	2.9	2.8	3.1	3	2.7	3.1	2.6	2.8	3.4	3	3	3	3	2.8	2.5
Large Office	1.1	1.4	1.4	1.5	1.5	1.4	1.6	1.3	1.3	1.7	1.4	1.4	1.5	1.4	1.3	1.2
Medium Office	1.1	1.3	1.4	1.4	1.4	1.2	1.4	1.1	1.1	1.5	1.3	1.4	1.4	1.2	1.1	1
Small Office	1.4	1.6	1.7	1.7	1.7	0.96	1.1	0.95	0.99	1.2	1.6	1.6	1.7	1	0.98	0.86
Large Retail	1.2	1.7	1.8	1.8	1.8	1.3	1.5	1.4	1.4	1.7	1.7	1.8	1.8	1.4	1.4	1.2
Medium Retail	1.3	1.6	1.6	1.7	1.7	1.1	1.2	1.2	1.2	1.3	1.6	1.6	1.7	1.1	1.1	1
Small Retail	1.7	2	2	2	2.1	1.1	1.2	1.1	1.1	1.3	2	2	2	1.1	1.1	0.96
Small School	0.9	1.1	1.1	1.2	1.2	0.69	0.72	0.72	0.77	0.87	1.1	1.1	1.1	0.77	0.7	0.67
Warehouse	0.89	1.1	1.1	1.1	1.1	0.98	1.2	0.97	0.99	1.3	1.1	1.1	1.1	1	0.93	0.91

B/C Ratio (scale 0.0 – 0.5 – 1.0 – 1.5 – 2.0 – 2.5 – 3.0 – 3.5)

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage TOU Dispatch on Utility Rates Across Building Types w/ LADWP & SMUD



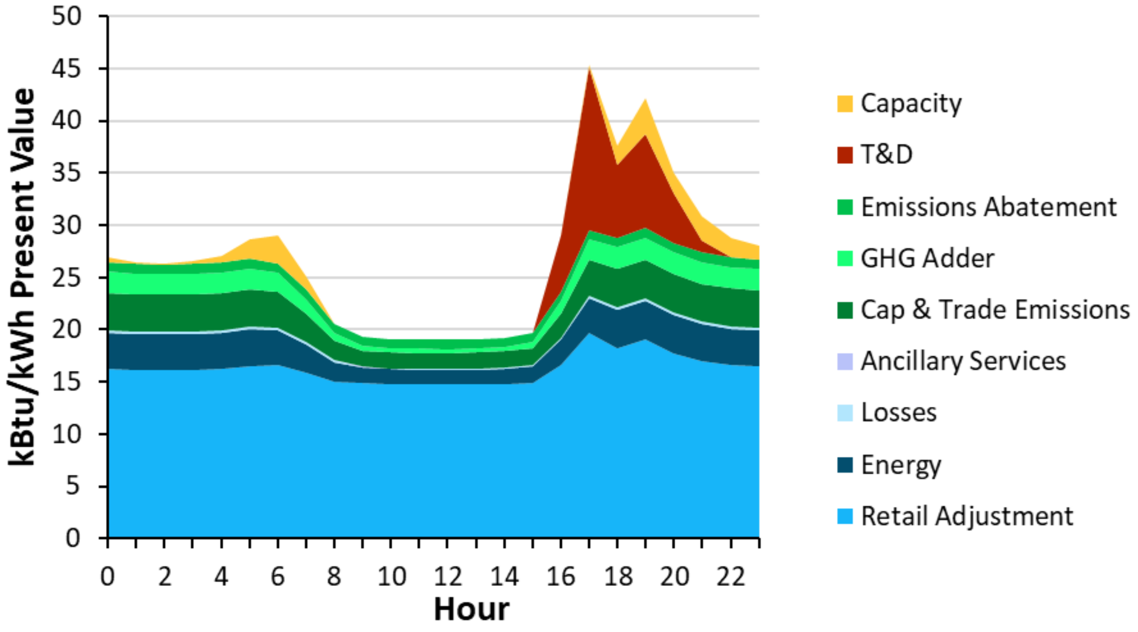
CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

Appendix - Rate Assumptions

TDV-Based Rate Sensitivity Definitions

+ **Full TDV:** All TDV cost components
+ **Non-Bypassable Charges (NBC's):** Calculated based on existing NEM2.0 NBC's
+ **Avoided Costs:** All cost components except Retail Adjustment
+ **Wholesale Costs** All cost components except Retail Adjustment, Emissions Abatement, and GHG Adder

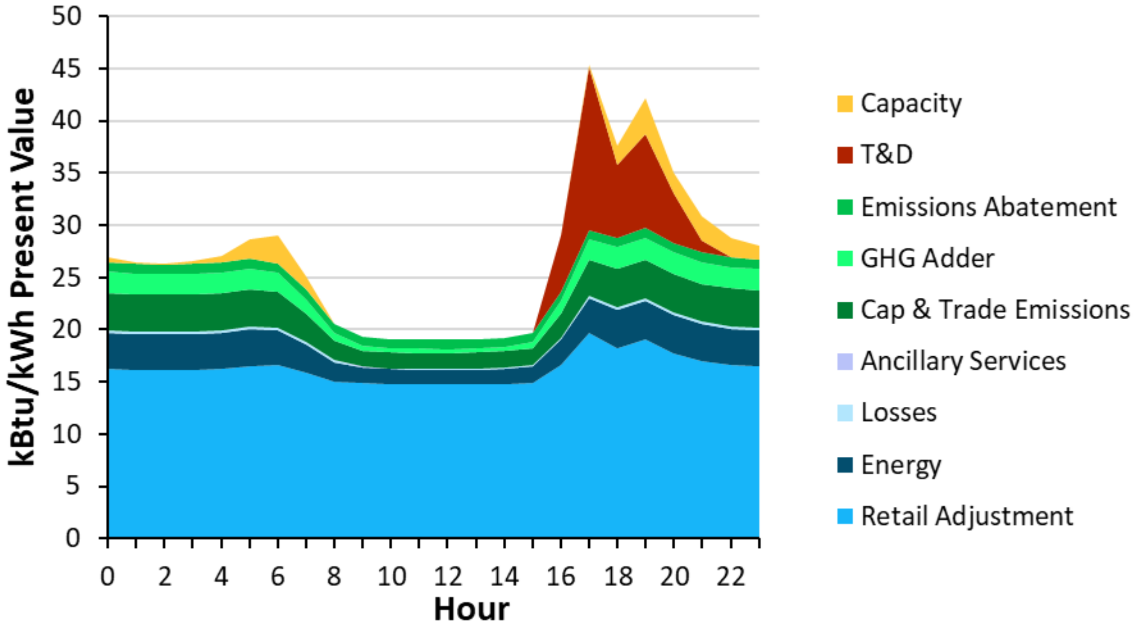
Rate Name	Compensation for Self-Utilized Electricity	Compensation for Exports
NEM 2.0	Full TDV	TDV – NBC's
Export on Avoided Costs	Full TDV	Avoided Costs
Export on Wholesale Costs	Full TDV	Wholesale Costs
Import/export on Avoided Costs	Avoided Costs	Avoided Costs



Virtual NEM Sensitivity Definitions

- **Full TDV:** All TDV cost components
- **Non-Bypassable Charges (NBC's):** Calculated based on existing NEM2.0 NBC's
- **Avoided Costs:** All cost components except Retail Adjustment
- **Wholesale Costs** All cost components except Retail Adjustment, Emissions Abatement, and GHG Adder

Rate Name	Compensation for Self-Utilized Electricity	Compensation for Exports
NEM 2.0	Full TDV – NBC's	TDV – NBC's
Export on Avoided Costs	Full TDV – NBC's	Avoided Costs
Export on Wholesale Costs	Full TDV – NBC's	Wholesale Costs
Import/export on Avoided Costs	Avoided Costs	Avoided Costs



TDV Frequently Asked Questions

- **Why do we measure cost-effectiveness with TDV instead of actual retail rate structures that are in place?**
  - We want the building code to be relatively stable over time and from cycle to cycle, the TDVs reflect a 'perfect' marginal cost of service which is a long-term signal for retail rates
  - By using the underlying system marginal costs we are reflecting building measures that provide the greatest underlying value to the energy system, even if retail rates are flat or have a different time of use period

Climate Zone/Utility Rate Mapping

Climate Zone	PG&E	SCE	SDG&E	LADWP	SMUD
CZ01	X				
CZ02	X				
CZ03	X				
CZ04	X				
CZ05	X	X			
CZ06		X		X	
CZ07			X		
CZ08		X		X	
CZ09		X		X	
CZ10		X			
CZ11	X				
CZ12	X				X
CZ13	X				
CZ14		X	X		
CZ15		X	X		
CZ16		X			

Utility Rates Assumptions - PG&E

- Retail rates are assigned based on prototype building peak load and CZ
- Climate Zones in PG&E territory, for example use these rates

Building Type	Mix-fuel Peak Load (kW)	All-electric Peak Load (kW)	PG&E Retail Rate
Large Office	1582	1611	B-20 Extra Large General - Time of Use (1000 +)
Medium Office	210	230	B-10 Medium General - Time of Use
Small Office	23	27	B-6 Small General Time of use (0-75 kW)
Large Retail	808	1012	B-19 Large General Time of use (or Extra large general TOU) (500-1000)
Medium Retail	99	118	B-10 Medium/Large General Time of use
Small Retail	40	54	B-6 Small General Time of use (0-75 kW)
Warehouse	29	210	B-6 Small/Medium General TOU
Large School	574	N/A	B-19 Large General Time of use (or Extra large general TOU) (500-1000)
Small School	87	164	B-10 Medium General TOU
High Rise Residential	5	5	E-TOU-C-NEM2 Residential - Time of Use - Rate C (NEM 2.0)
Mid Rise Residential	5	N/A	E-TOU-C-NEM2 Residential - Time of Use - Rate C (NEM 2.0)

Utility Rates Assumptions - SCE

- Retail rates are assigned based on prototype building peak load and CZ
- Climate Zones in SCE territory use these rates

Building Type	Mix-fuel Peak Load (kW)	All-electric Peak Load (kW)	SCE Retail Rate
Large Office	1610	1838	TOU-8 Large General- TOU Option D (Below 2kV) (NEM 2.0)(500+)
Medium Office	236	262	TOU-GS-3 General-TOU Demand Metered, Rate D (NEM 2.0) (200-500kW)
Small Office	25	30	TOU-GS-2 General-TOU Demand Metered, Option D (NEM 2.0) (20-200kW)
Large Retail	960	1117	TOU-8 Large General- TOU Option D (Below 2kV) (NEM 2.0)(500+)
Medium Retail	106	134	TOU-GS-2 General-TOU Demand Metered, Option D (NEM 2.0) (20-200kW)
Small Retail	46	59	TOU-GS-2 General-TOU Demand Metered, Option D (NEM 2.0) (20-200kW)
Warehouse	33	207	TOU-GS-2 General-TOU Demand Metered, Option D (NEM 2.0) (20-200kW)
Large School	685	N/A	TOU-8 Large General- TOU Option D (Below 2kV) (NEM 2.0)(500+)
Small School	104	179	TOU-GS-2 General-TOU Demand Metered, Option D (NEM 2.0) (20-200kW)
High Rise Residential	5	5	TOU-D-4-9PM-NEM2 Domestic - Time of Use, 4-9 PM (NEM 2.0)
Mid Rise Residential	5	N/A	TOU-D-4-9PM-NEM2 Domestic - Time of Use, 4-9 PM (NEM 2.0)

Utility Rates Assumptions - SDG&E

- Retail rates are assigned based on prototype building peak load and CZ
- Climate Zones in SDG&E territory use these rates

Building Type	Mix-fuel Peak Load (kW)	All-electric Peak Load (kW)	SDG&E Retail Rate
Large Office	1610	1665	AL-TOU General-Time Metered (20+)
Medium Office	236	262	AL-TOU General-Time Metered (20+)
Small Office	25	27	AL-TOU General-Time Metered (20+)
Large Retail	960	1117	AL-TOU General-Time Metered (20+)
Medium Retail	106	114	AL-TOU General-Time Metered (20+)
Small Retail	46	51	AL-TOU General-Time Metered (20+)
Warehouse	33	207	AL-TOU General-Time Metered (20+)
Large School	565	N/A	AL-TOU General-Time Metered (20+)
Small School	104	148	AL-TOU General-Time Metered (20+)
High Rise Residential	5	5	TOU-DR1-NEM2 Residential - Time of Use, DR1 (NEM 2.0)
Mid Rise Residential	5	N/A	TOU-DR1-NEM2 Residential - Time of Use, DR1 (NEM 2.0)

Utility Rates Assumptions – SMUD

- Retail rates are assigned based on prototype building peak load and CZ
- Climate Zones in SMUD territory use these rates

Building Type	Mix-fuel Peak Load (kW)	All-electric Peak Load (kW)	SMUD Retail Rate
Large Office	1423	1523	GS-TOU1 Large General -TOU (1000+)
Medium Office	204	229	GSS_T General-Demand (20+)
Small Office	22	24	GSS_T General-Demand (20+)
Large Retail	764	957	GSS_T General-Demand (20+)
Medium Retail	81	111	GSS_T General-Demand (20+)
Small Retail	40	46	GSS_T General-Demand (20+)
Warehouse	29	205	GSS_T General-Demand (20+)
Large School	574	N/A	GSS_T General-Demand (20+)
Small School	82	164	GSS_T General-Demand (20+)
High Rise Residential	5	5	R-TOD Residential - Time of Day, 5-8pm
Mid Rise Residential	5	N/A	R-TOD Residential - Time of Day, 5-8pm

Utility Rates Assumptions – LADWP

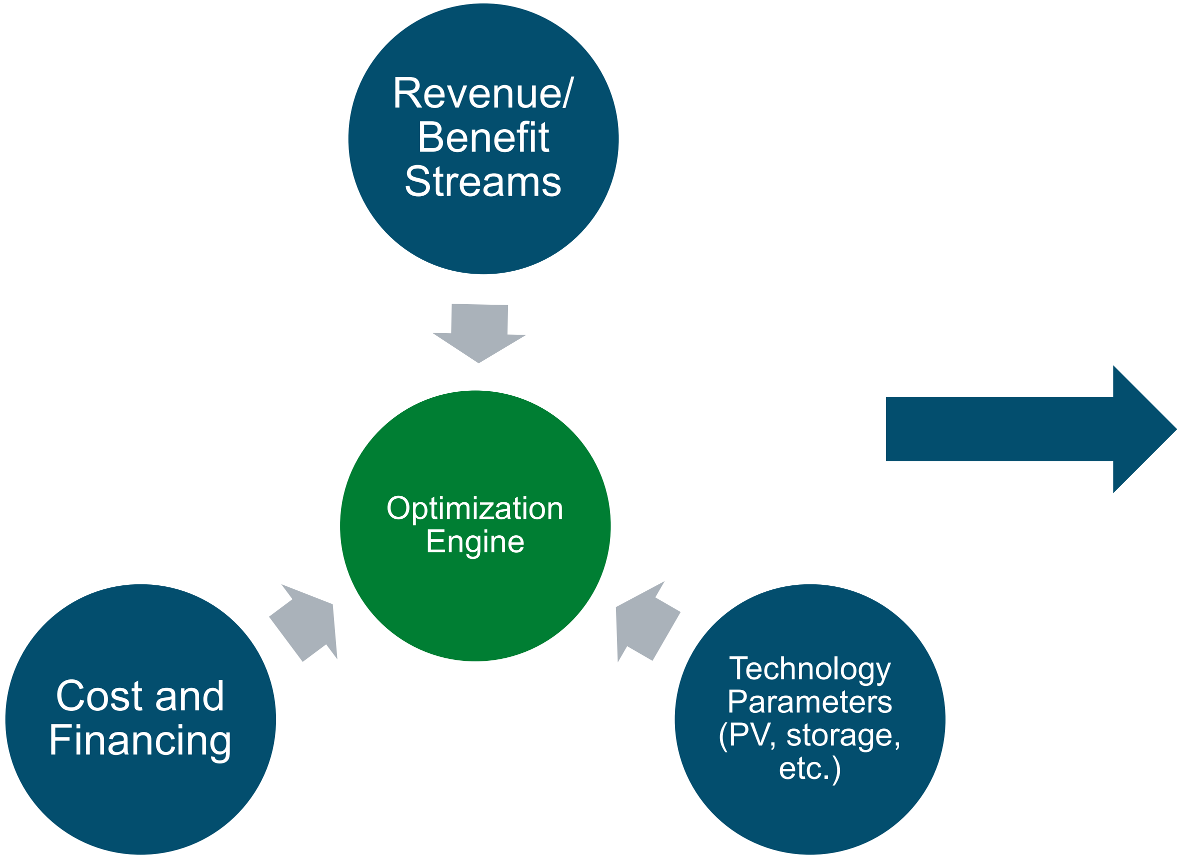
- Retail rates are assigned based on prototype building peak load and CZ
- Climate Zones in LADWP territory use these rates

Building Type	Mix-fuel Peak Load (kW)	All-electric Peak Load (kW)	LADWP Retail Rate
Large Office	1582	1485	CG-2 Customer Generation-Primary, Rate A
Medium Office	202	225	CG-2 Customer Generation-Primary, Rate A
Small Office	22	23	A-1 Small General TOU, Rate B
Large Retail	780	964	CG-2 Customer Generation-Primary, Rate A
Medium Retail	87	108	CG-2 Customer Generation-Primary, Rate A
Small Retail	40	42	CG-2 Customer Generation-Primary, Rate A
Warehouse	32	178	CG-2 Customer Generation-Primary, Rate A
Large School	589	N/A	CG-2 Customer Generation-Primary, Rate A
Small School	85	143	CG-2 Customer Generation-Primary, Rate A
High Rise Residential	5	5	R-1-B Residential - Time of Use, Rate B
Mid Rise Residential	5	N/A	R-1-B Residential - Time of Use, Rate B

Appendix – Solar + Storage Tool Details

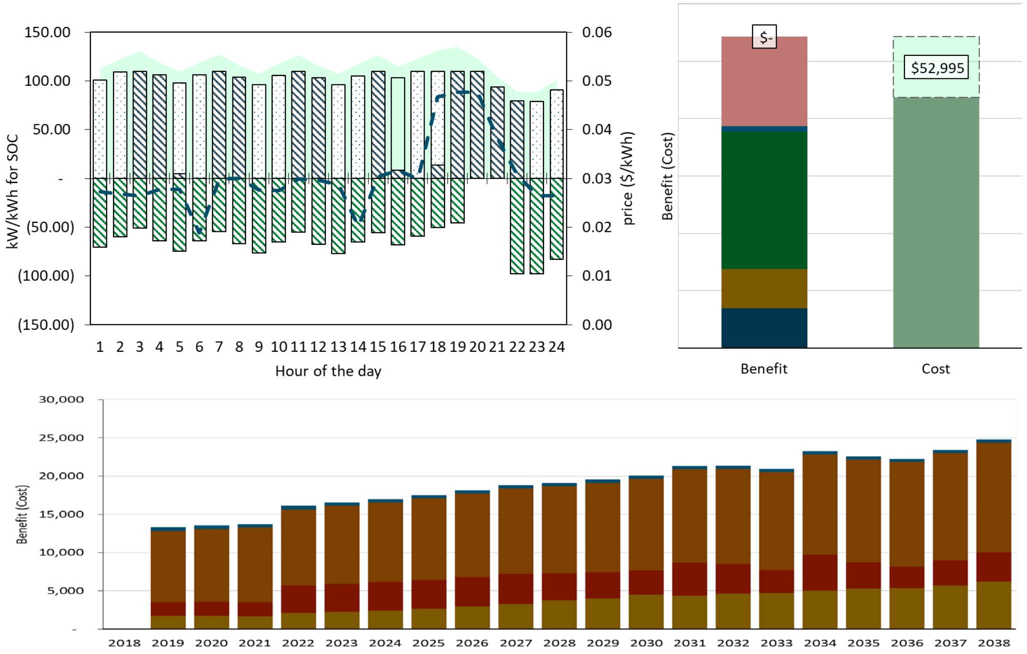
Solar + Storage Tool Overview

+ A DER valuation tool with an optimization engine for dispatch



Results:

- NPV and annual benefits and costs
- Cost tests
- DER optimal dispatch



See CEC Docket Log 19-MISC-04 for additional information and documentation: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-MISC-04

Solar + Storage Tool Optimal Dispatch Algorithm

- **Maximizing net benefits, subject to**
  - Technology operating constraints
  - Program and market rules
- **Value-stacking and customizable benefits selection**
- **Co-optimization among DER technologies**
  - PV, storage, and other generators can “work” together to maximize net benefits
- **Flexible optimization window (Daily, Monthly, Annual) and Intervals (Hourly, 15mins, 5mins)**

Customers Control

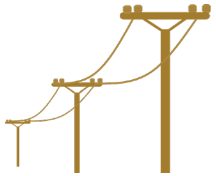
- Bill savings
- Utility program revenues (e.g. DR)
- Back-up power

Utility Control

- System avoided costs *or* wholesale energy and capacity market
- Transmission and distribution deferral value
- Ancillary service revenue
- Avoided GHG costs

Joint Control

- Joint optimization
- Bill savings + Avoided system costs
- Bill savings + Avoided GHG costs



See CEC Docket Log 19-MISC-04 for additional information and documentation: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-MISC-04

Solar + Storage Tool Capabilities

+ Dispatchable

- Objective function: minimizing net costs
- Subject to technology, market, and incentive (e.g. ITC) constraints
- Co-optimization across multiple technologies with perfect foresight
- Price taker

+ Partial Dispatchable

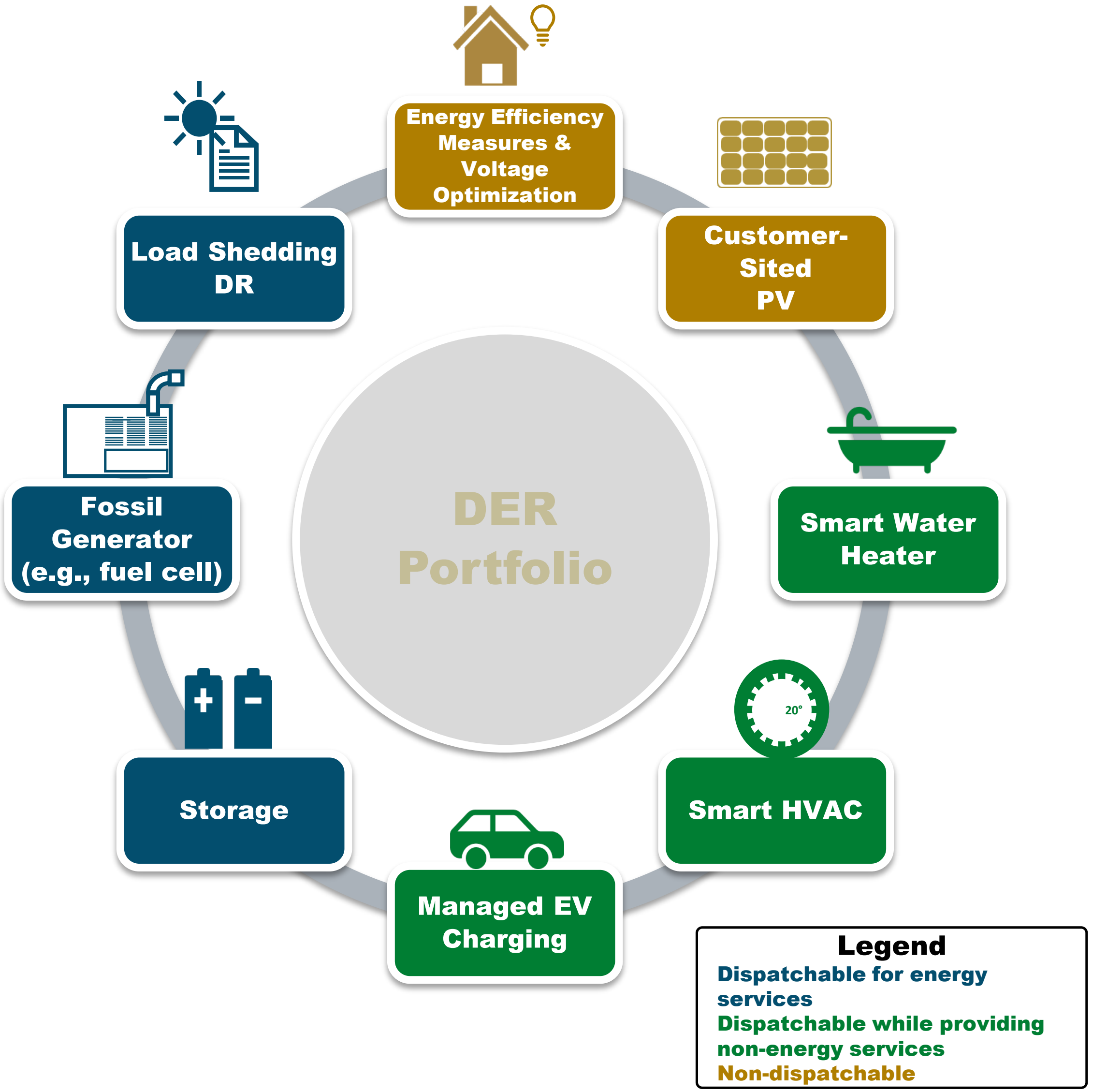
- Dispatch with the consideration of customer comfort level
- Co-optimize with both dispatchable and partial dispatchable technologies

+ Fixed shapes

- User input based on the specific project or customer
- Default PV shapes pre-loaded for each climate zone

Other highlights

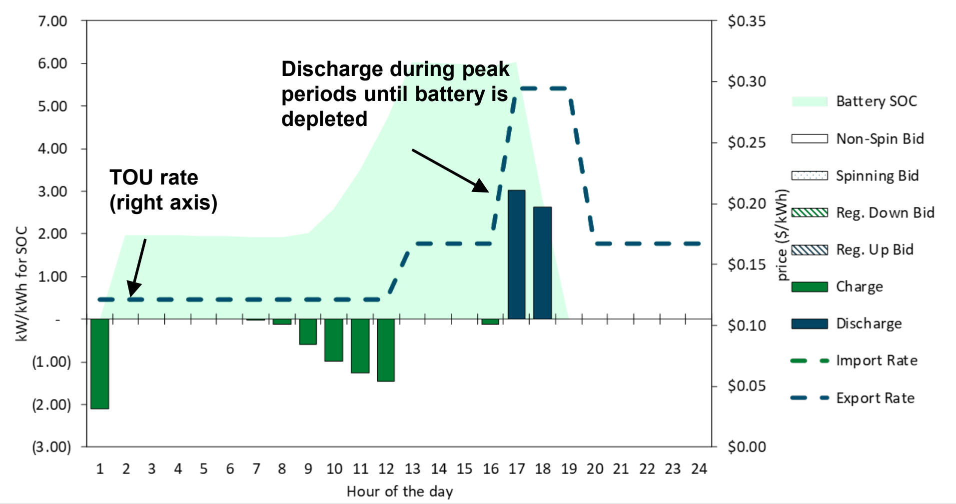
- Temperature-based day mapping
- Flexible Optimization Window (Daily, Monthly, Annual) and Intervals (Hourly, 15mins, 5mins)



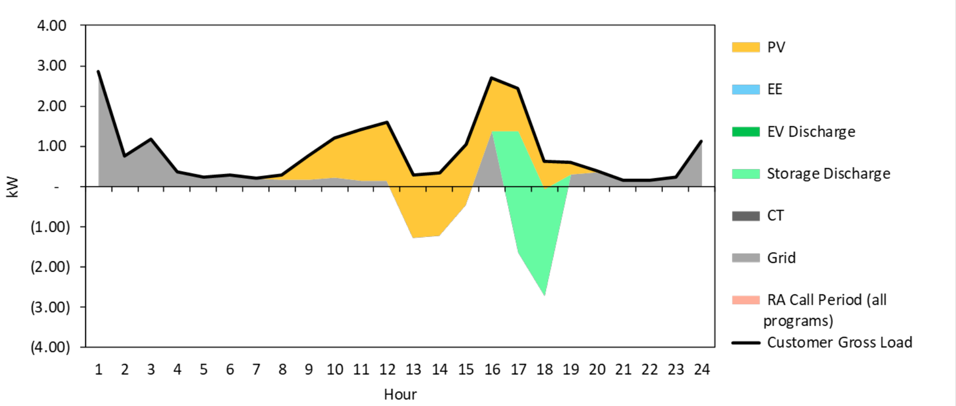
Example Dispatch – PV + Storage

Storage dispatch under a TOU rate

Storage Dispatch for July 28, 2020

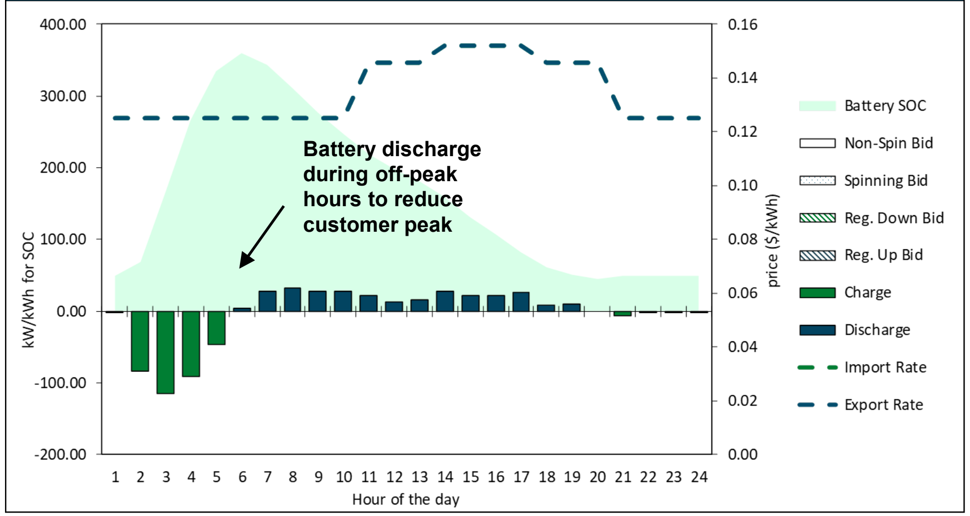


Energy Supply for July 28, 2020

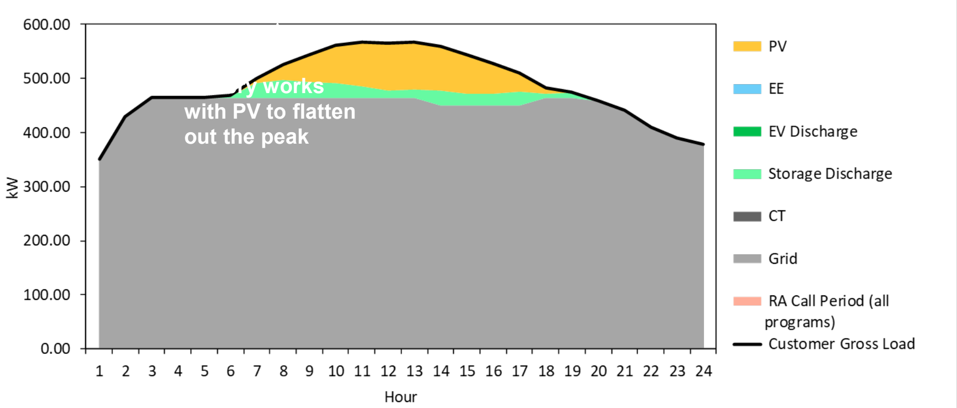


Storage dispatched to reduce demand charges

Storage Dispatch for September 5, 2020



Energy Supply for September 5, 2020



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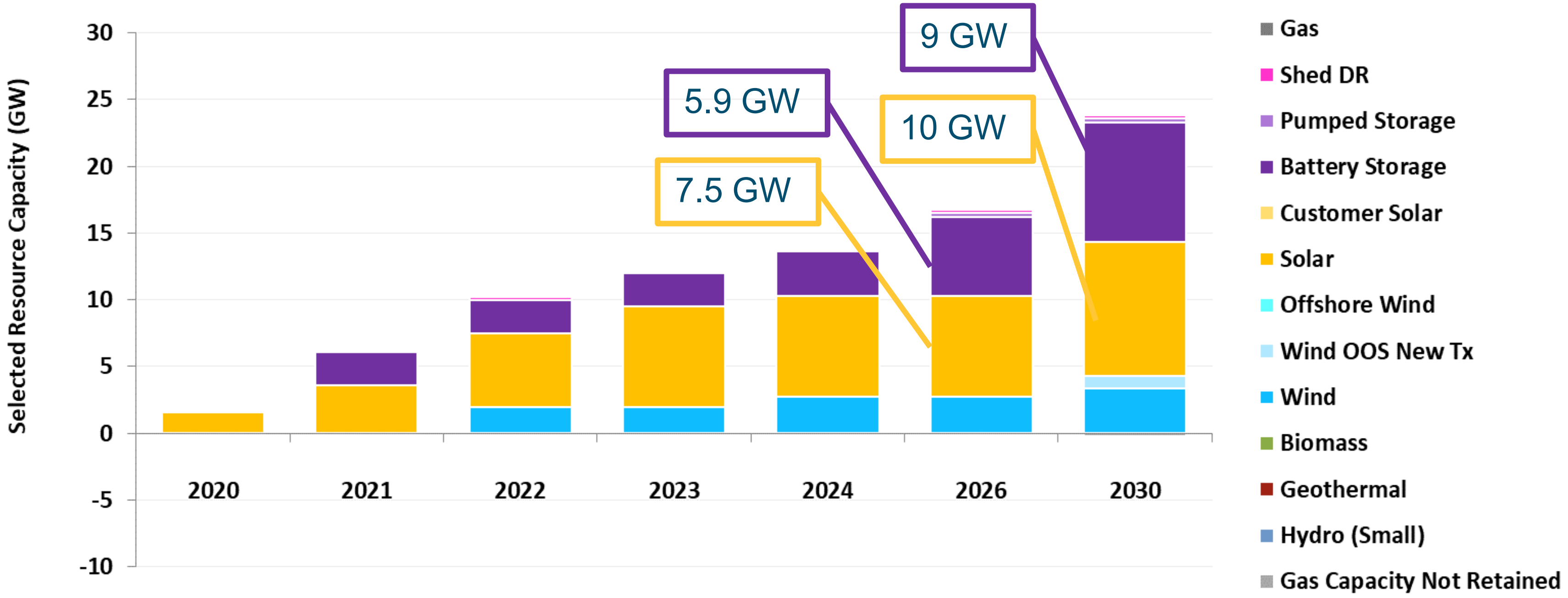
Appendix - IRP Reference System Plan for Context of First-Year Statewide Impacts

Impacts - Statewide PV and Storage Capacity

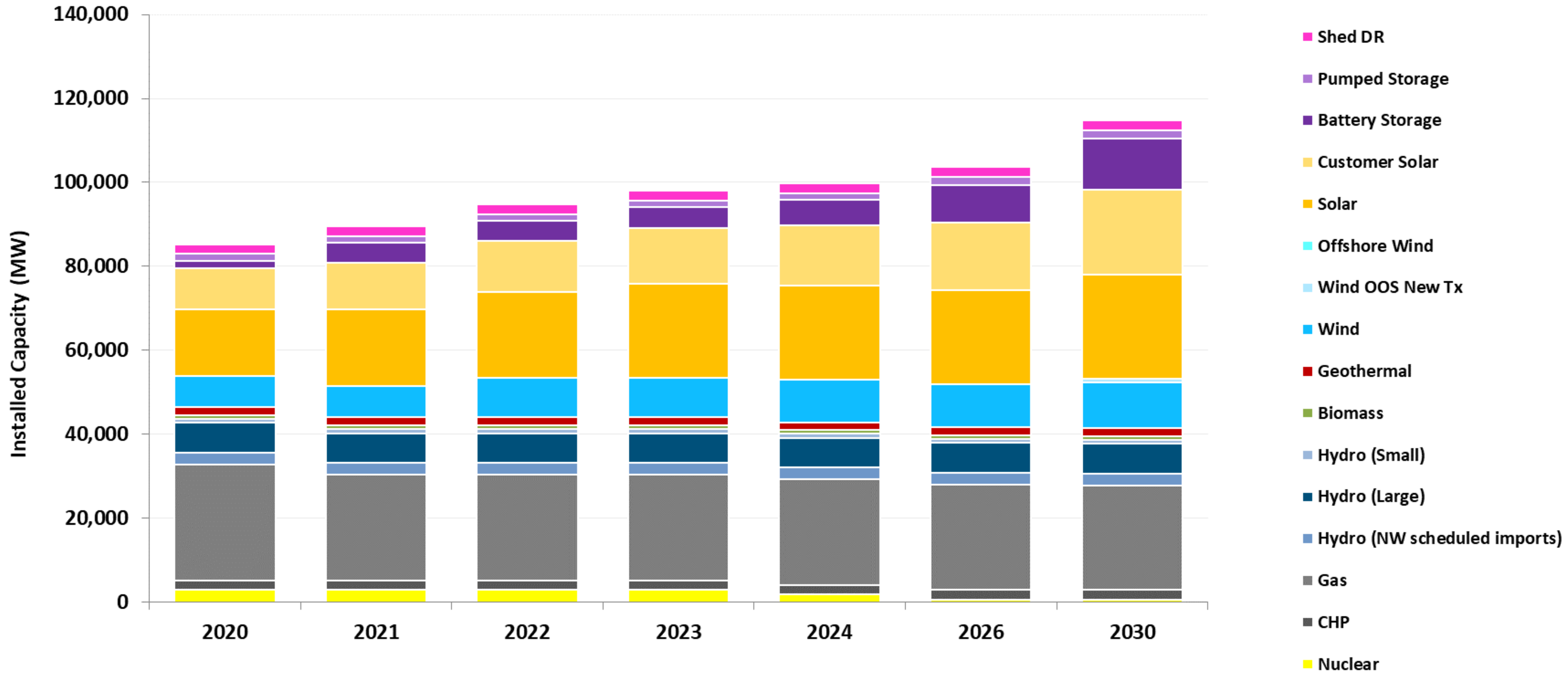
- **First year forecasted installed capacity (2023)**
  - PV – 280 MW/yr
  - Battery Storage – 100 MW, 400MWh/yr
- **CPUC IRP Reference System Plan (Incremental Installed Capacity)**



CPUC IRP Incremental Installed Capacity

Selected Resources (New Build)	*Unit*	2020	2021	2022	2023	2024	2026	2030
Gas	*MW*	-	-	-	-	-	-	-
Biomass	*MW*	-	-	-	-	-	-	-
Geothermal	*MW*	-	-	-	-	-	-	-
Hydro (Small)	*MW*	-	-	-	-	-	-	-
Wind	*MW*	-	34	1,950	1,950	2,737	2,737	3,367
Wind OOS New Tx	*MW*	-	-	-	-	-	-	892
Offshore Wind	*MW*	-	-	-	-	-	-	-
Solar	*MW*	**1,551**	**3,551**	**5,551**	**7,551**	**7,551**	**7,551**	**10,041**
Customer Solar	*MW*	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Battery Storage	*MW*	**163**	**2,462**	**2,462**	**2,462**	**3,309**	**5,883**	**8,988**
Pumped Storage	*MW*	-	-	-	-	-	334	334
Shed DR	*MW*	-	222	222	222	222	222	222
Gas Capacity Not Retained	*MW*	-	-	-	-	-	-	*(243)*

CPUC IRP Reference System Plan Total Installed Capacity



CPUC IRP Total Installed Capacity

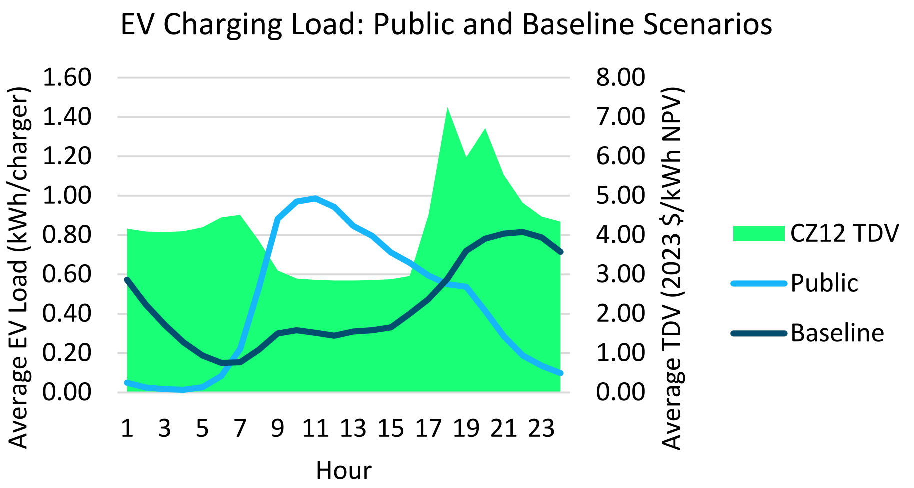
	Unit	2020	2021	2022	2023	2024	2026	2030
Nuclear	*MW*	2,935	2,935	2,935	2,935	1,785	635	635
CHP	*MW*	2,296	2,296	2,296	2,296	2,296	2,296	2,296
Gas	*MW*	27,562	25,113	25,113	25,113	25,113	25,113	24,871
Coal	*MW*	480	480	480	480	480	-	-
Hydro (Large)	*MW*	7,070	7,070	7,070	7,070	7,070	7,070	7,070
Hydro (NW scheduled imports)	*MW*	2,852	2,852	2,852	2,852	2,852	2,852	2,852
Biomass	*MW*	903	903	903	903	903	903	901
Geothermal	*MW*	1,851	1,851	1,851	1,851	1,851	1,851	1,851
Hydro (Small)	*MW*	974	974	974	974	974	974	974
Wind	*MW*	7,357	7,490	9,406	9,406	10,193	10,193	10,823
Wind OOS New Tx	*MW*	-	-	-	-	-	-	892
Offshore Wind	*MW*	-	-	-	-	-	-	-
Solar	*MW*	**15,861**	**18,317**	**20,438**	**22,438**	**22,438**	**22,438**	**24,928**
Customer Solar	*MW*	**9,827**	**11,137**	**12,284**	**13,303**	**14,288**	**16,156**	**20,066**
Battery Storage	*MW*	**1,857**	**4,624**	**4,727**	**4,895**	**6,083**	**8,821**	**12,253**
Pumped Storage	*MW*	1,599	1,599	1,599	1,599	1,599	1,934	1,934
Shed DR	*MW*	2,195	2,418	2,418	2,418	2,418	2,418	2,418
Shift DR	*MW*	-	-	-	-	-	-	-
Hydrogen Load	*MW*	-	-	-	-	-	-	-

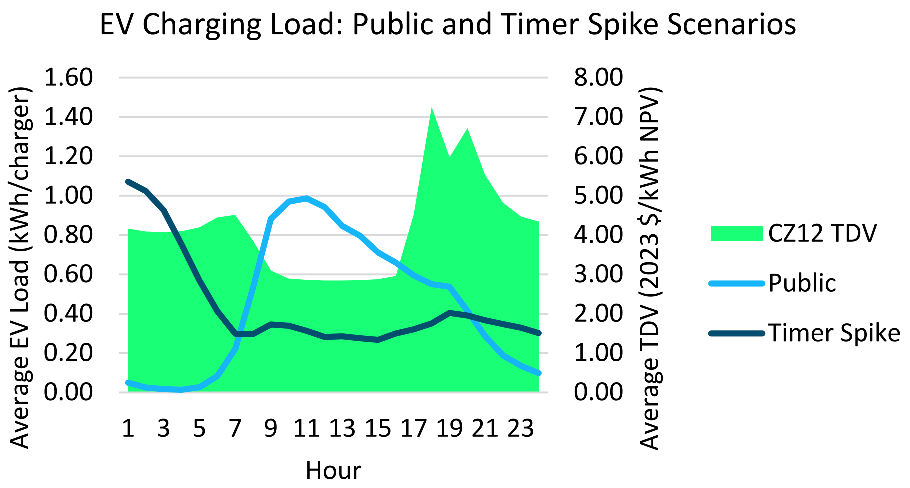
Appendix - EV Charging Compliance Option Framework

EV load profile sensitivities examine the impact of load shape and magnitude on compliance credit

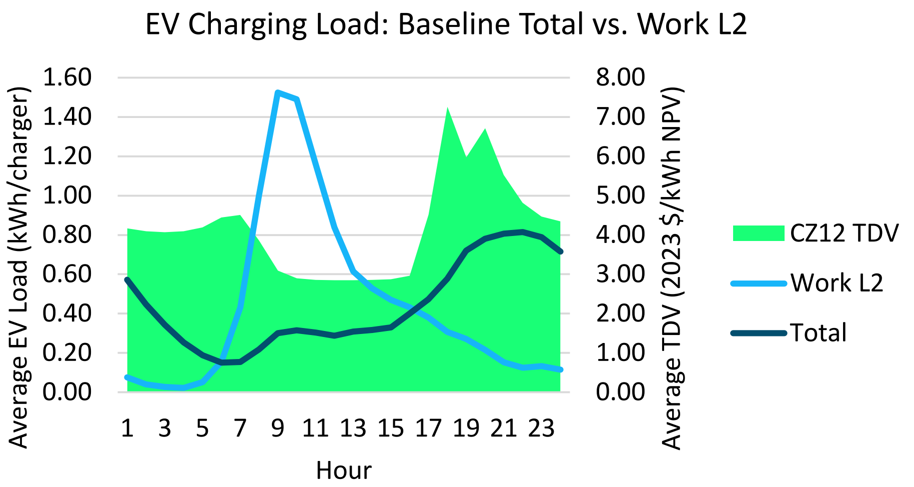
+ **CEC EVI-Pro preliminary charging profiles levelized to annual work L2 charger load**

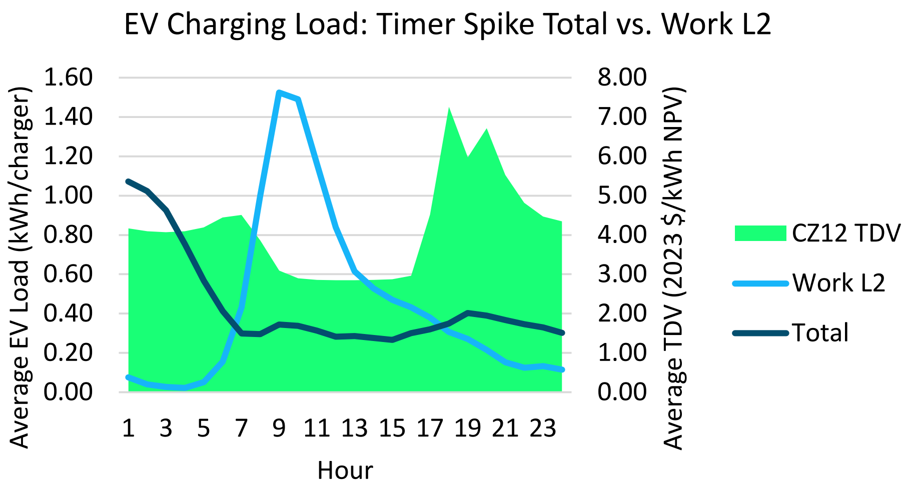
Comparison of Load Profiles Between Scenarios





Comparison of Load Profiles Within Scenarios





How significant would the credit be?

- **Compliance Credit per Charger**
  - TDV 5,000 to 22,000 kBtu per charger lifecycle in likely usage scenarios
  - Levelized Source Energy 3,000 to 5,200 kBtu per charger per year in likely usage scenarios
  - Savings of 0.11 to 0.76 Tonnes CO2-e per charger per year in likely usage scenarios
- **Figures assume EV charges on grid energy – greater savings from PV charging**

Example Credits per Charger by Profile Comparison and Annual Usage Sensitivities (kBtu)

Base Profile	Nonres Profile	Historical (2.5 MWh)	Forecast (3.9 MWh)
Baseline Total	**Public Total**	11,026	17,213
Timer Spike Total	**Public Total**	6,590	10,288
Baseline Total	**Baseline Work L2**	13,812	21,563
Timer Spike Total	**Timer Spike Work L2**	5,111	7,980

Example Credits per Charger by Profile Comparison Sensitivities and Prototype – Forecast Usage Case (% of Building Load kBtu)

HRR10 Story	MRMU5 Story	OffLrg	OffMed	OffSml	RetlLrg	RetlMed	RetlSml	SchLrg	SchSml	Whse
0.09%	0.10%	0.02%	0.17%	1.19%	0.04%	0.37%	0.69%	0.07%	0.40%	1.14%
0.06%	0.06%	0.01%	0.10%	0.71%	0.02%	0.22%	0.41%	0.04%	0.24%	0.68%
0.12%	0.13%	0.03%	0.21%	1.49%	0.05%	0.46%	0.86%	0.09%	0.50%	1.43%
0.04%	0.05%	0.01%	0.08%	0.55%	0.02%	0.17%	0.32%	0.03%	0.18%	0.53%

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Appendix - October 6 Workshop Slides

Agenda

- **Background and Context**
- **Scope of Analysis and Dimensions Considered**
- **Medium Office Deep Dive**
  - PV-only Cost Effectiveness
  - Storage-only Cost Effectiveness
  - PV + Storage Cost Effectiveness
- **Storage Duration Sensitivity**
- **Reliability and Resiliency Sensitivity**
- **EV Charging Compliance Option Framework**
- **Appendix**

Goals of this Analysis

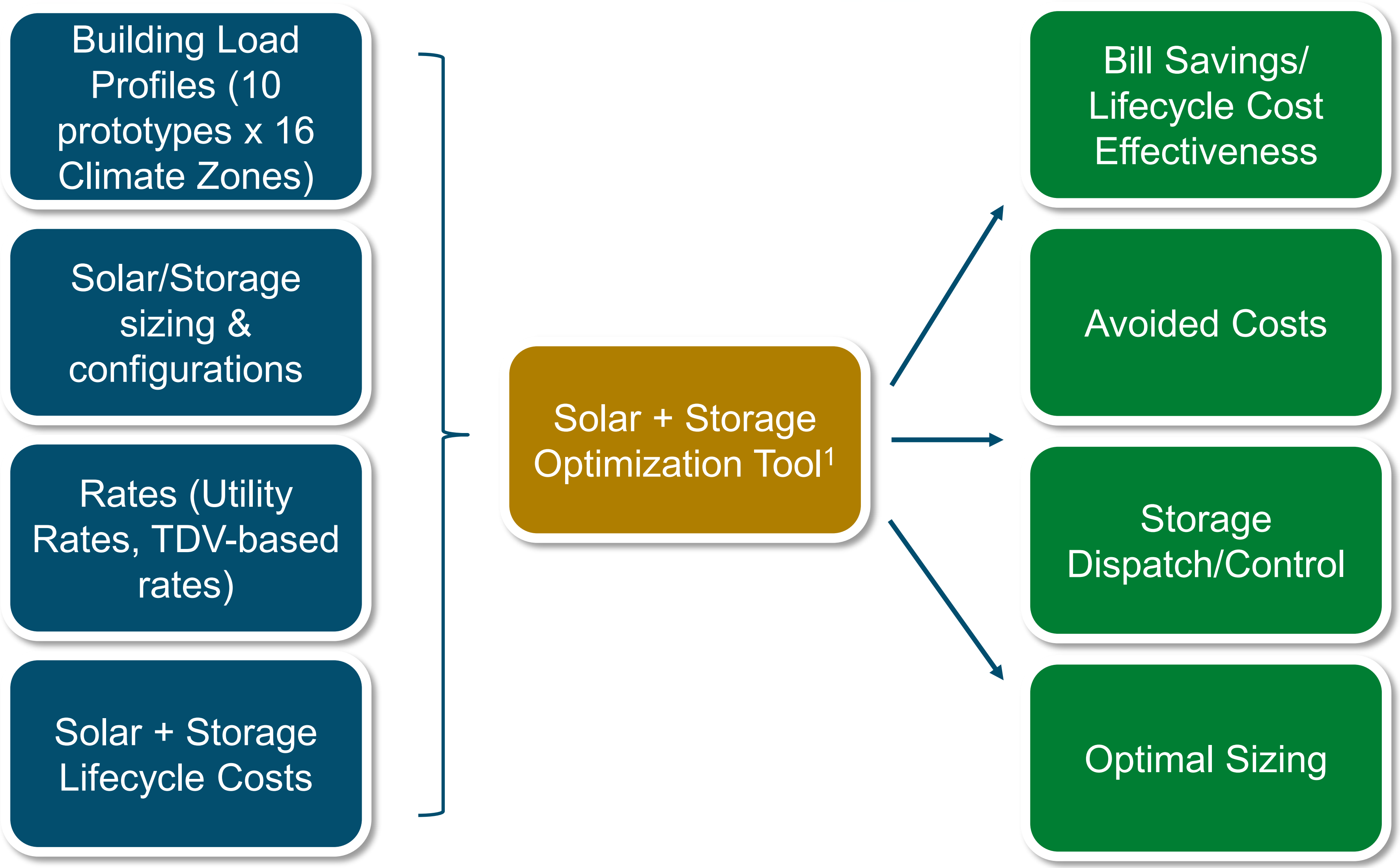
- **Evaluate participant benefits and cost effectiveness of behind the meter PV and storage in HRMF and Nonresidential new construction**
- **Study multiple configurations and sizes of PV and storage, with focus on limited grid exports**
- **Cost-effectiveness measured under both TDV-based rates and current retail rates**
  - TDV cost-effectiveness evaluated with multiple configurations to bound potential future rate design
- **Evaluation covers HRMF and nonresidential prototype buildings in each of the 16 climate zones**
- **Present data inputs and methodology in a transparent manner**
  - Open to improved data on capital costs, technology characteristics, storage control operations, future price signals, etc.

Key Findings

- **PV + Storage as a package (smaller configuration) is cost-effective for most building categories due to co-benefits of combined systems**
  - PV + Storage provides additional participant benefits, including reliability and resiliency
- **PV is cost effective across all scenarios from participant perspective, except under most significant rate reform**
  - Minimizing exports allows for significant PV benefits, while having robust cost-effectiveness in all rate sensitivities
  - Note: most significant rate reform is analogous to “buy all - sell all” on avoided cost treatment of rooftop PV
- **Storage-only presents large grid benefits, but is generally not cost-effective in this analysis**
- **Next Steps:**
  - Collect additional relevant data from stakeholders,
  - Perform additional analysis to refine optimal size and configuration in context of building codes and standards

Modeling Inputs and Dimensions

Cost-Effectiveness Modeling Framework



[1]See CEC Docket Log 19-MISC-04 for additional information and documentation: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-MISC-04

Scope of the Analysis

+ **9 major sensitivities – many combinations!**

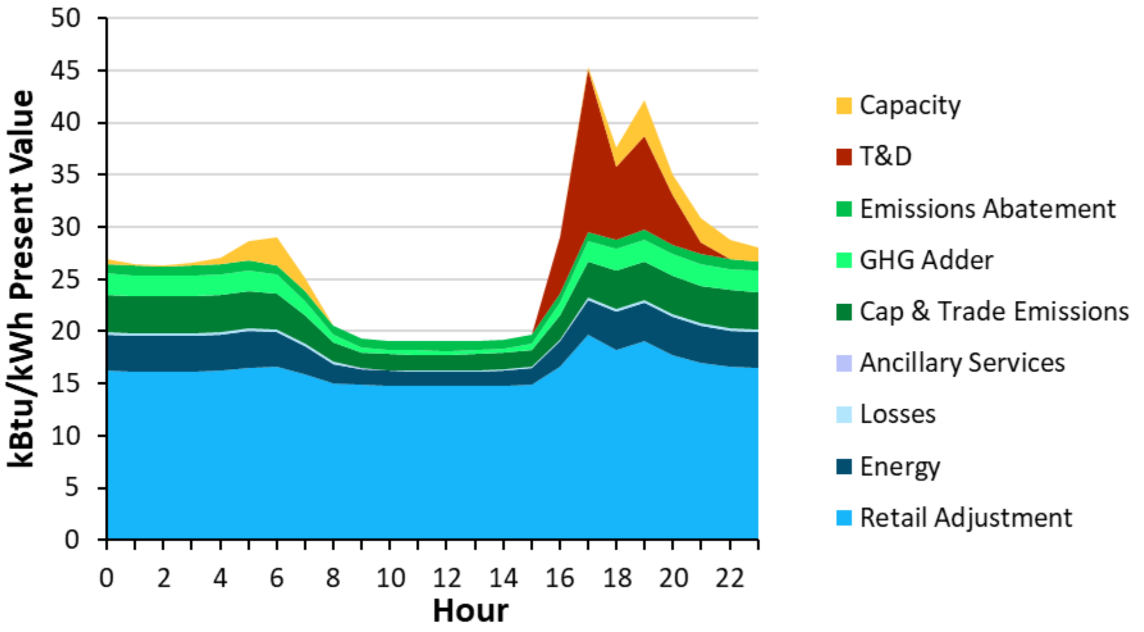
Rates	PV Size	Storage Size	Storage Dispatch	Configurations	Building Types	Building Fuels	Climate Zones	Reliability/ Resiliency
Full TDV	Full NEM	PV Capacity	Optimal	PV only	Small Office	Mixed Fuel	All CZs	Not included
Export on Avoided	Self-Util	Minimize Solar Exports	Basic	Storage Only	Medium Office	All-Electric		Included
Export on wholesale	15% Exports			PV+ storage	Large Office			
Avoided Cost for all	Roof Space				Small Retail			
Utility Rates					Medium Retail			
					Large Retail			
					Small School			
					Warehouse			
					Large School			
					High-Rise Res			

What are TDVs?

+ **The TDVs (Time Dependent Value) are a long-term forecast of hourly electricity, natural gas and propane costs to building owners and are used for cost-effectiveness activities in Title 24 Building Code**
+ **The TDVs answer the question of what is cost-effective in the long term, as required by the Warren-Alquist Act**

- Time-differentiation reflects the underlying marginal cost of producing and delivering energy
- Area-correlation reflects underlying marginal cost shapes correlated with each climate zones weather file

Sample Annual Average Electric TDV, 2022, CZ12



Rates Sensitivities Considered

Rate Name	Compensation for Self-Utilized Electricity (Imports)	Compensation for Exports
Existing Utility Retail Rates	Retail Rate + Non-bypassable charge	Retail Rate
Full TDV (NEM2.0)	Full TDV	Full TDV – Non-bypassable charges
Export on Avoided Costs	Full TDV	Avoided Costs
Export on Wholesale Costs	Full TDV	Wholesale Costs
Self-utilized/export on Avoided Costs	Avoided Costs	Avoided Costs

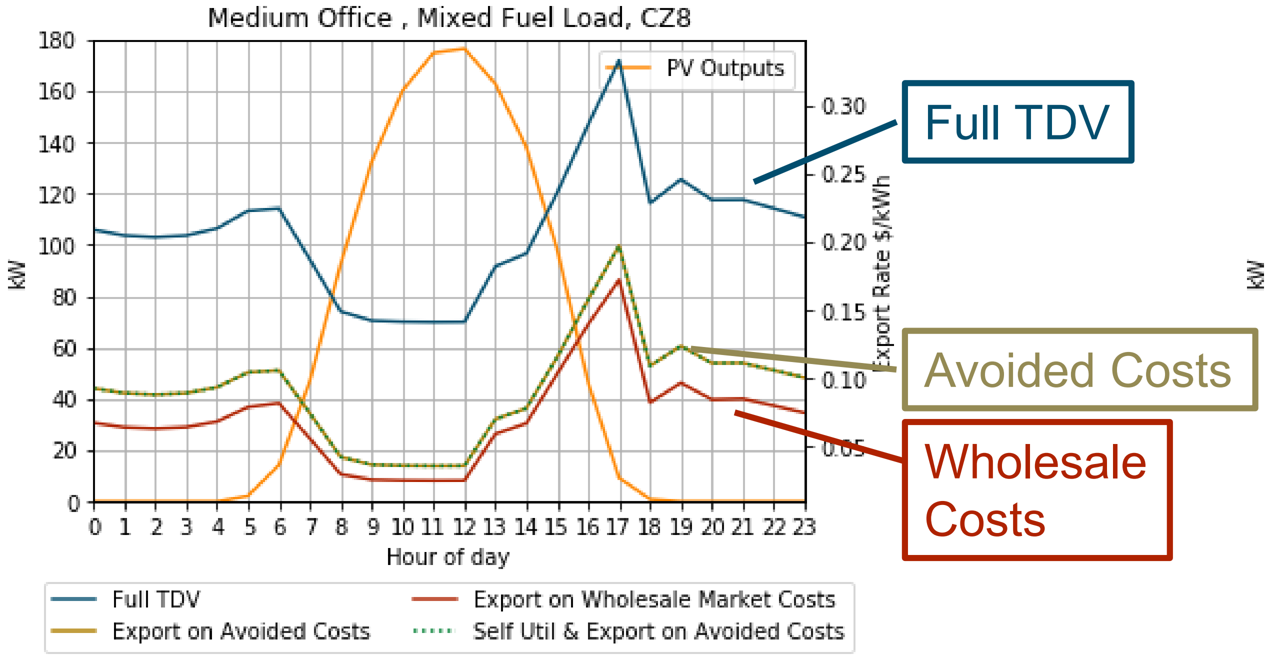
Increasing NEM rate reform (arrow pointing down the table)

- **Self-utilized electricity is generated and consumed behind the meter**
- **Imported electricity is taken from the grid to power end-use loads**
- **Exported electricity is generated behind the meter and sent to the grid**

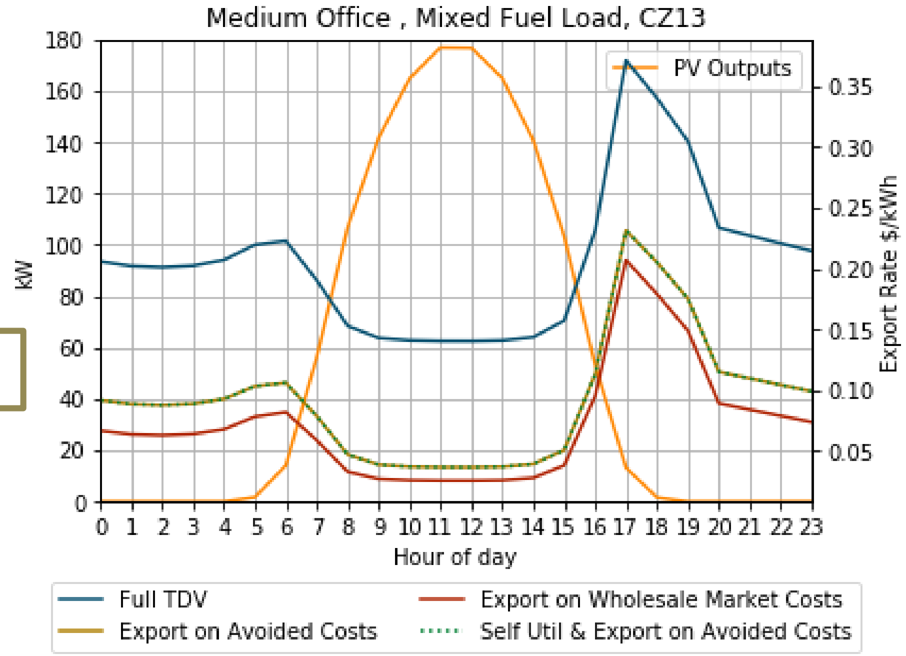
TDV Rate Sensitivities

- **Full TDV is highest, avoided costs and wholesale costs are similar in magnitude**
- **Different Climate zones have different hourly profiles due to local T&D peaks**
  - Climate zones in inland LA Basin have slightly higher midday rates

Medium Office, Mixed Fuel Load, CZ8



Medium Office, Mixed Fuel Load, CZ13



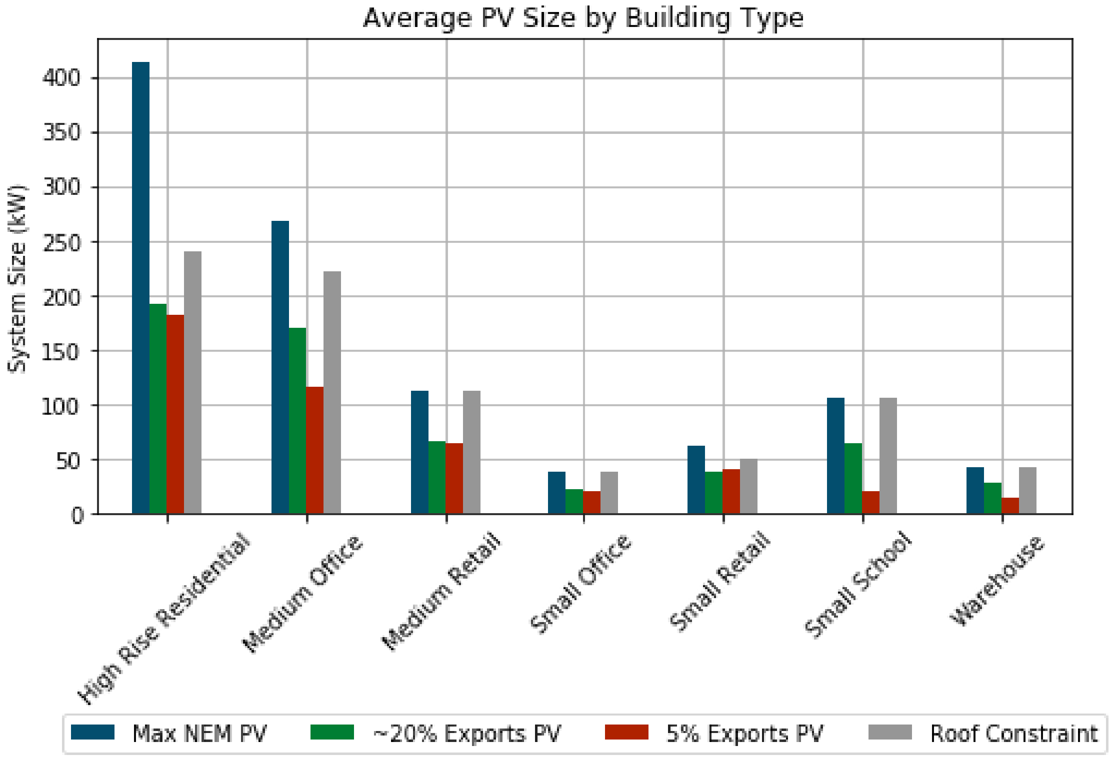
Note: TDV rate on y-axis is levelized lifetime present value

PV Sizing

+ **Three sizing options for each building type and climate zone**
  - Max NEM Complaint
    - Annual solar gen = annual total building consumption
    - ~40% of annual PV generation is exported to grid
  - Self-utilization (~20% Exports PV)
    - Sized to generate the amount of PV that is self-utilized in *Max NEM Compliant* case
    - ~20% of annual PV generation is exported to grid
  - 5% Exports
    - 5% of annual PV generation is exported to grid

+ **PV sizes compared to roof area constraints to ensure viable system size**

Average PV Size by Building Type



(See appendix for Large Office sizing)

Key PV Inputs

+ **PV Costs**
  - Considers full lifetime capital & replacement costs, fixed O&M costs, investment tax credit
  - 2% Inflation rate
  - 3% Real discount rate
+ **Fixed O&M: $11/kW$_{DC}$-yr (2018$)[1]**
+ **ITC: 10%**
+ **Lifetime: 30 years**
+ **PV Tilt: assumed zero tilt, to maximize roof utilization**
+ **PV Azimuth: South-facing**
+ **Inverter Load Ratio: 1.0**

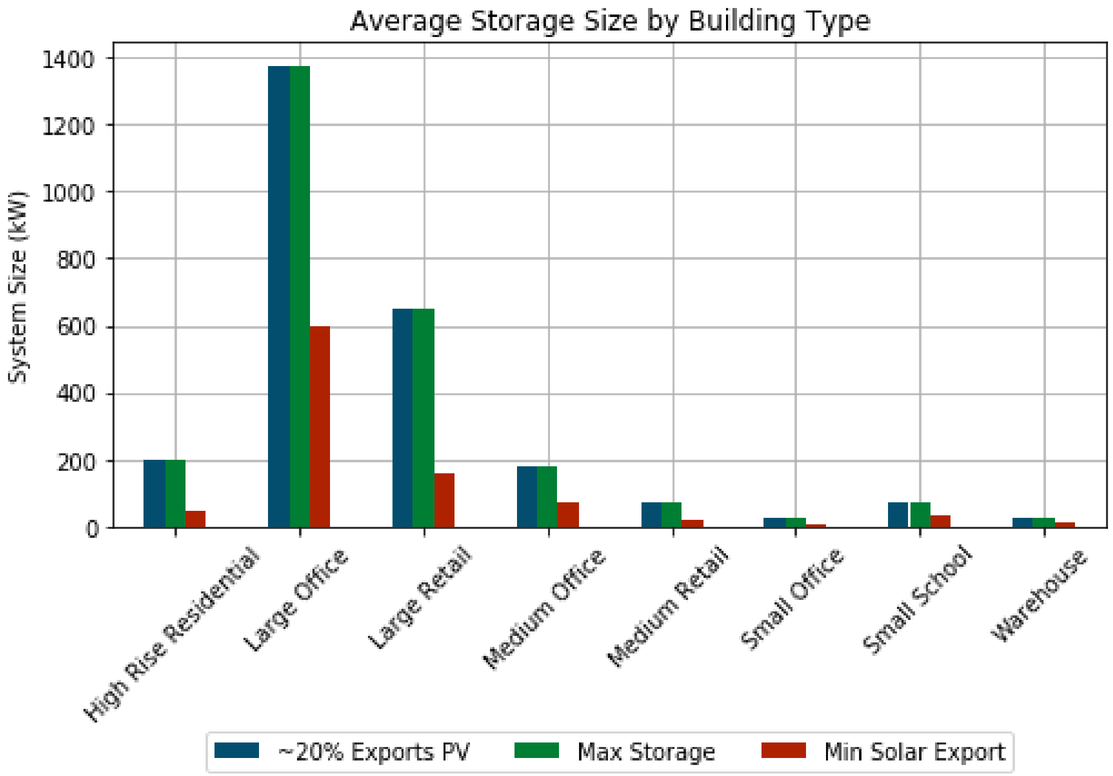
PV (kWdc)	CAPEX (2020$/W$_{DC}$)	Lifetime NPV Costs used in this analysis ($2023/kW$_{DC}$)
10	$3.16	$3,263
20	$2.84	$2,957
50	$2.46	$2,594
100	$2.21	$2,355
200	$1.99	$2,145
500	$1.73	$1,897
1000	$1.55	$1,725

[1] NREL 2020 Annual Technology Baseline https://atb.nrel.gov/electricity/2020/index.php?t=sd
*Fixed OM costs in 2020 NREL ATB include annualized large component replacement costs over technical life (e.g., inverters at 15 years)

Storage Sizing

- **Two sizing options for each building type, climate zone**
  - **Max Storage:** Sized to *Self-utilization* (~20% Exports) PV capacity
  - **Min Solar Export:** Sized to minimize net solar exports
    - Reduces PV gen exports form 20% to ~10%
- **Typical assumption is 4-hr duration**
- **Additional sensitivity with 2-hr duration**

Average Storage Size by Building Type



Key Storage Inputs

- Storage Costs
  - Considers full lifetime capital & replacement costs, fixed O&M costs, investment tax credit
- Fixed O&M: $29.61/kW_{DC}-yr (2018$)[2]
- 10% ITC
- Storage RTE: 85%
- Storage duration: 4 hours
- Storage lifetime: 10 years (cell replacement)
- AC-coupled
- Inverter Load Ratio : 1.0 - No PV generation “clipping”
- Exclude SGIP incentive in cost-effectiveness evaluation for code requirement
- Assumed only charge from solar to maximize ITC

Battery Size (kW)	Battery CAPEX (2020 $/kWh)	Battery Replacement Cost (2020$/kWh)
< 100	$800	$392 (year 10) $344 (year 20)
> 100	$600	$284 (year 10) $258 (year 20)

[2] NREL 2020 Annual Technology https://atb.nrel.gov/electricity/2020/index.php?t=st

Levels of Battery Control

- **Two major factors impact energy storage economic benefit**
  - **Controls scheme**: Commercially available energy storage does have sophisticated controls, but cannot match perfect foresight
  - **Price signal**: Current retail rates have limited alignment between participant benefits and grid benefits

	Near-term Proxy	Aspirational
Controls Scheme	Basic	Optimal Dispatch (Perfect Foresight)
Rate Signal/ Participant Benefits	Retail Rates	Full TDV-based rate signal

Less Sophisticated

More Sophisticated

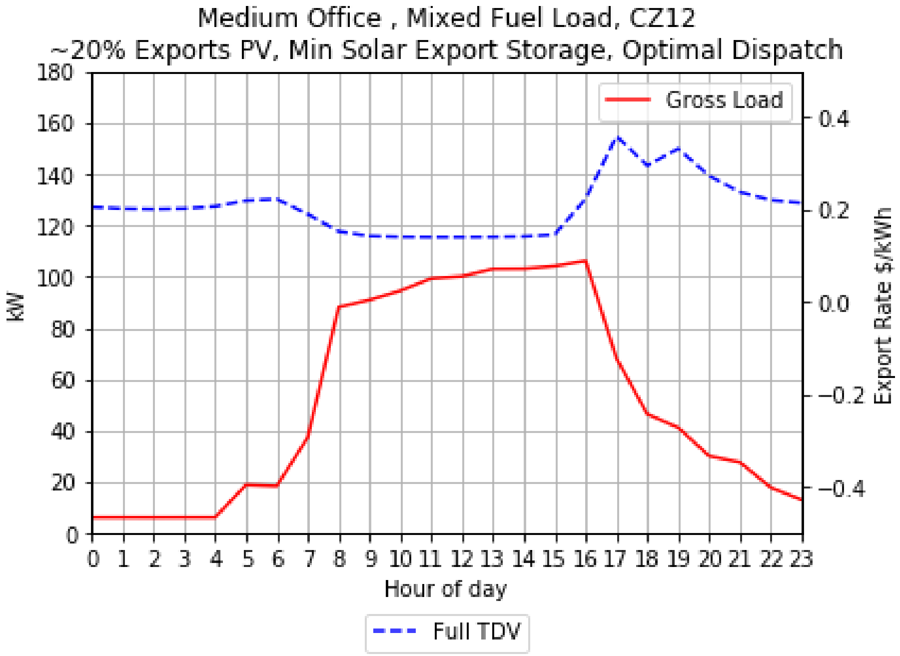
Less Alignment with Grid Benefits

Higher Grid Benefits

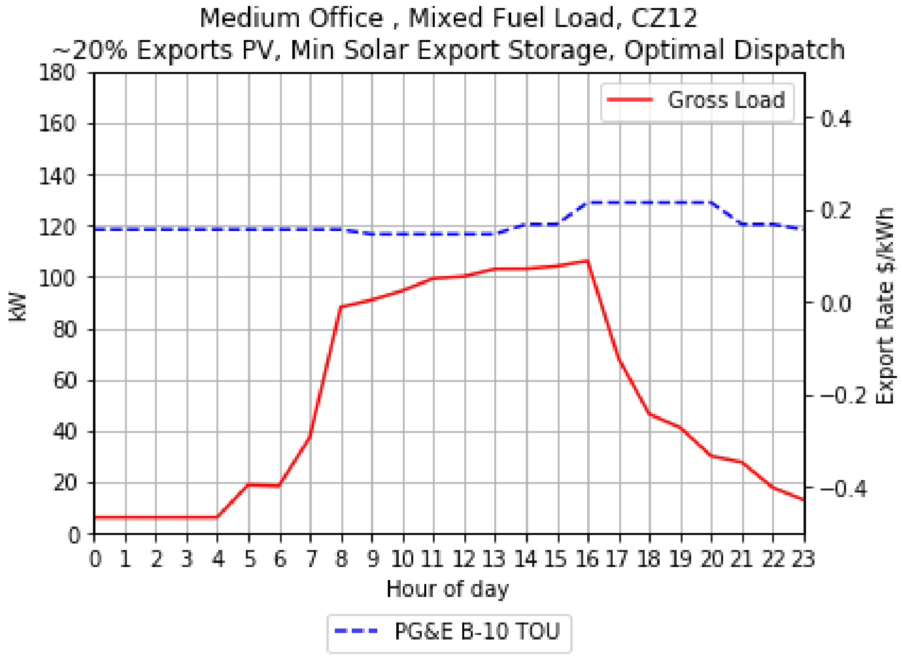
Optimal Dispatch Option

+ **Optimal dispatch responds based on customer load, PV generation, different rate signals to maximize customer benefit**
+ **These plots show annual average of rate signals**
+ **TOU rate also includes demand charges (not shown)**

Full TDV



PG&E B-10 TOU



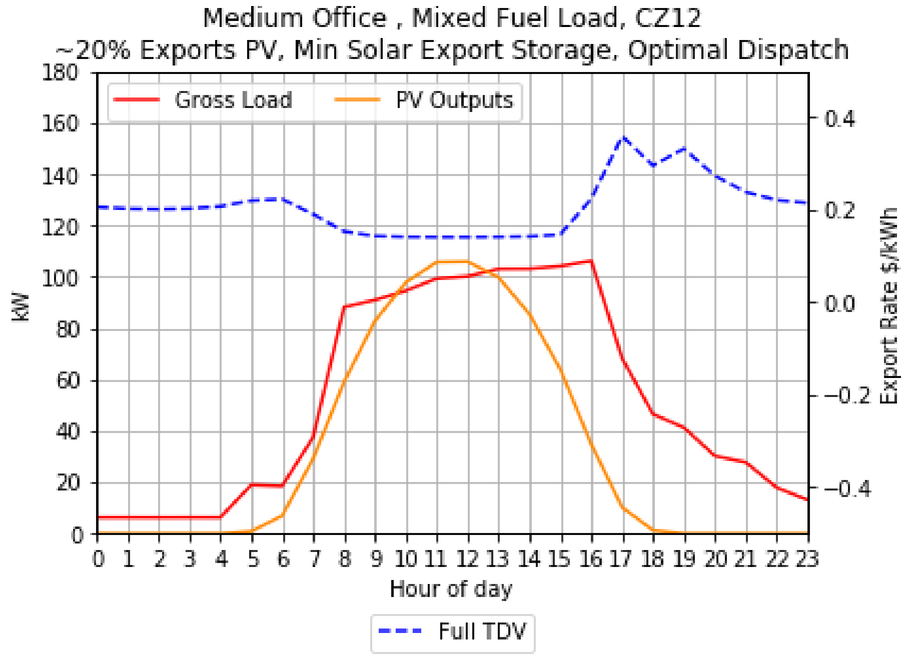
TDV and retail rates are both in levelized lifetime present value

Optimal Dispatch Option

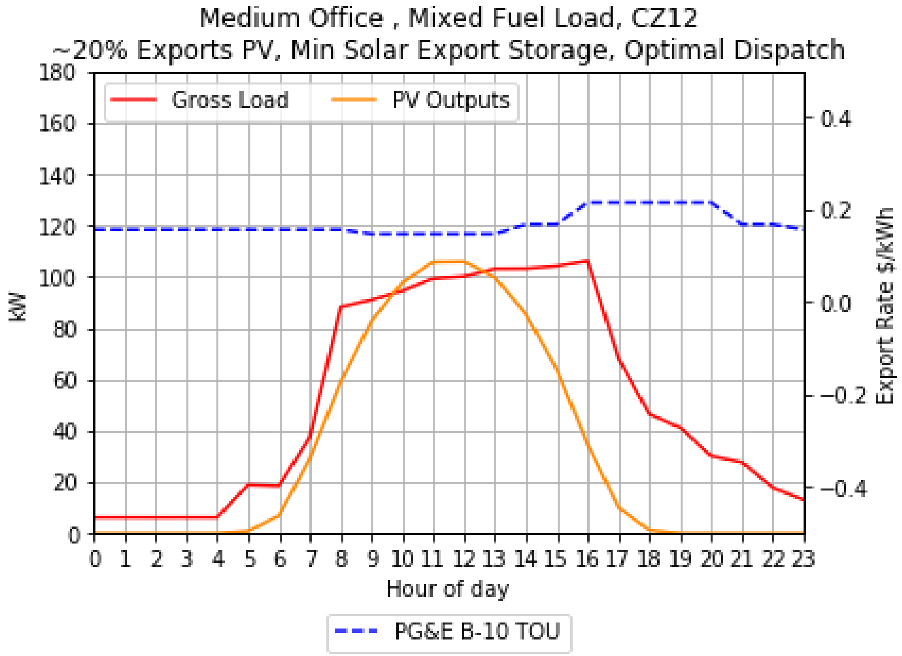
+ Behind the meter PV largely coincides with Medium office load profile

- Some continued load after PV gen decreases, contributing to duck curve

Full TDV



PG&E B-10 TOU

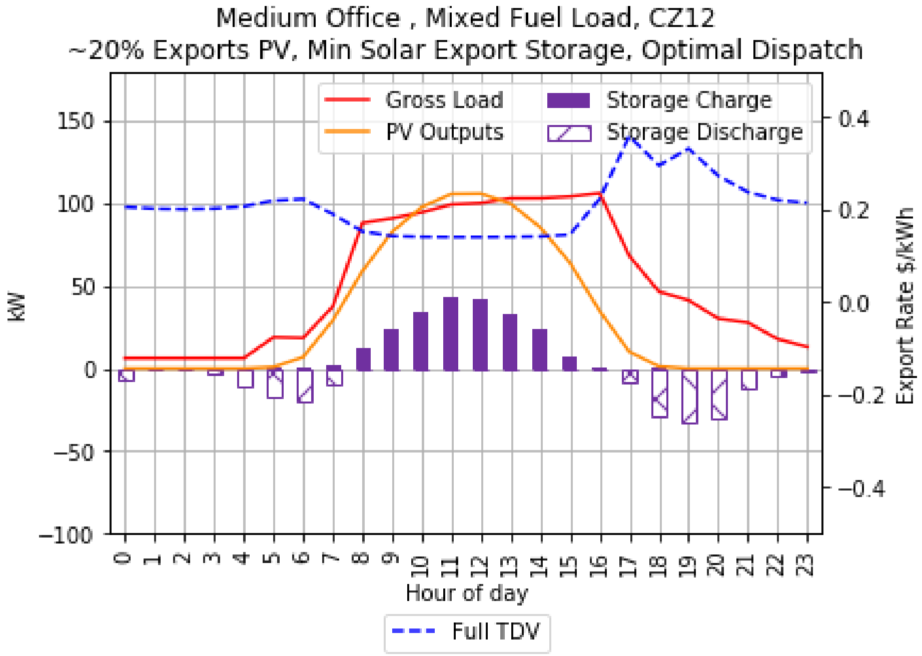


TDV and retail rates are both in levelized lifetime present value

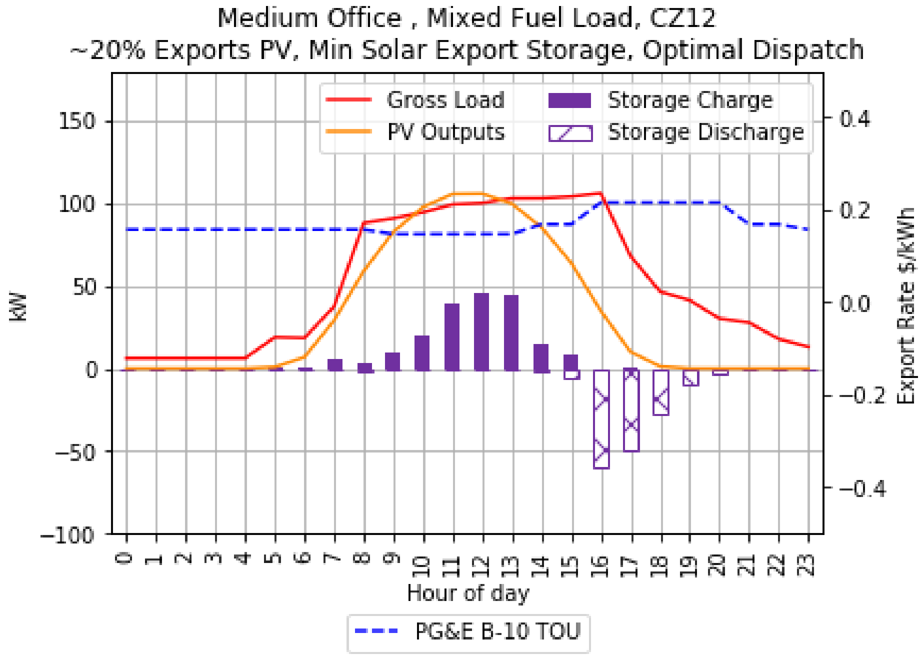
Optimal Dispatch Option – Rate Signals

- Under TDV based rate, optimal storage charging is mid-day, and discharges in evening (spring, summer, fall) and morning (winter), matching grid marginal costs
- Commercial retail rates are dominated by demand charges, and optimal dispatch focuses on more lucrative demand charge clipping

Full TDV



PG&E B-10 TOU

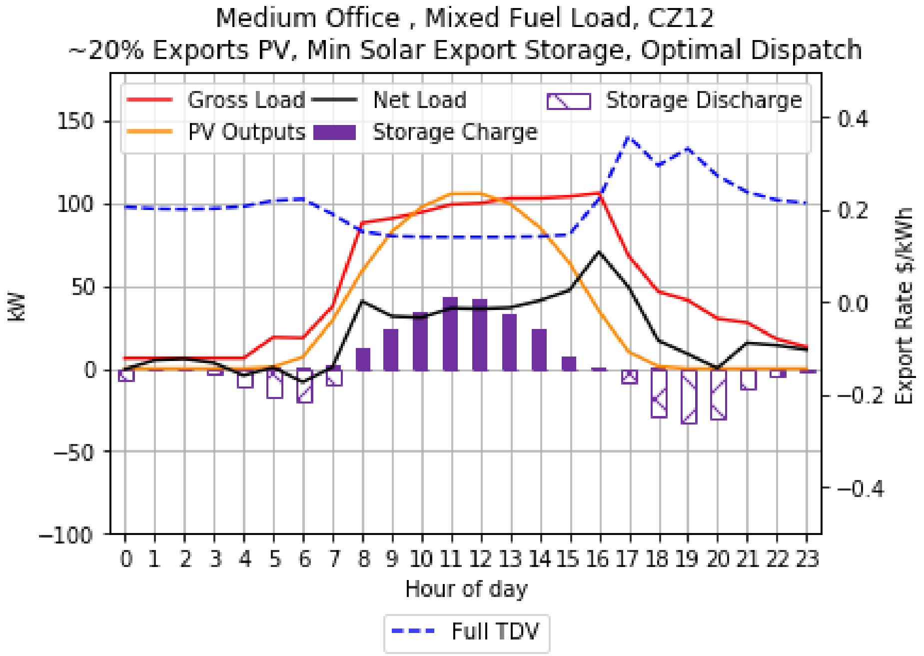


TDV and retail rates are both in levelized lifetime present value

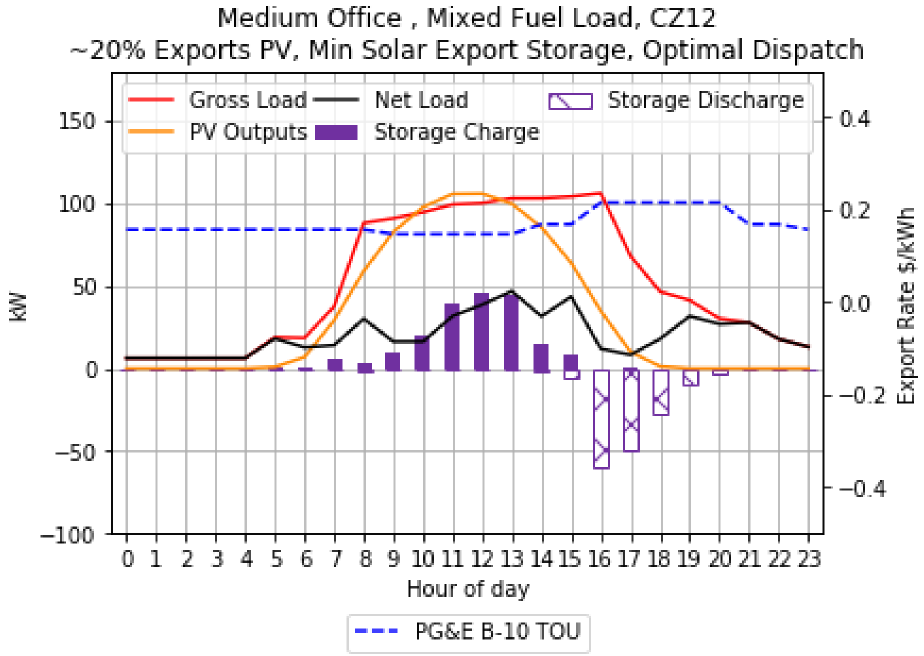
Optimal Dispatch Option – Rate Signals

- Under TDV based rate, net load is increased mid-day to take advantage of cheap electricity, decreased in late evening to avoid expensive grid power
- Under retail rate signal, net demand is minimized, even though it does not necessarily align with grid peak

Full TDV



PG&E B-10 TOU

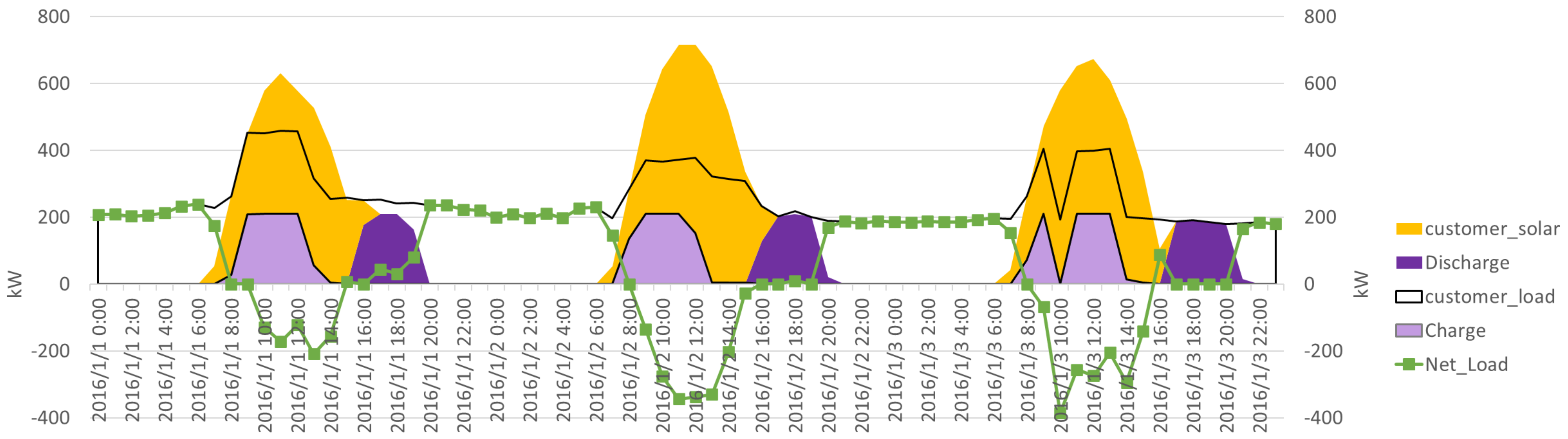


TDV and retail rates are both in levelized lifetime present value

Basic Dispatch Option

- Battery charges on PV net exports and discharges when load again exceeds PV production
- Demonstrates simple “maximize solar consumption” control scheme

Example PV & Storage Dispatch under “Basic Dispatch”



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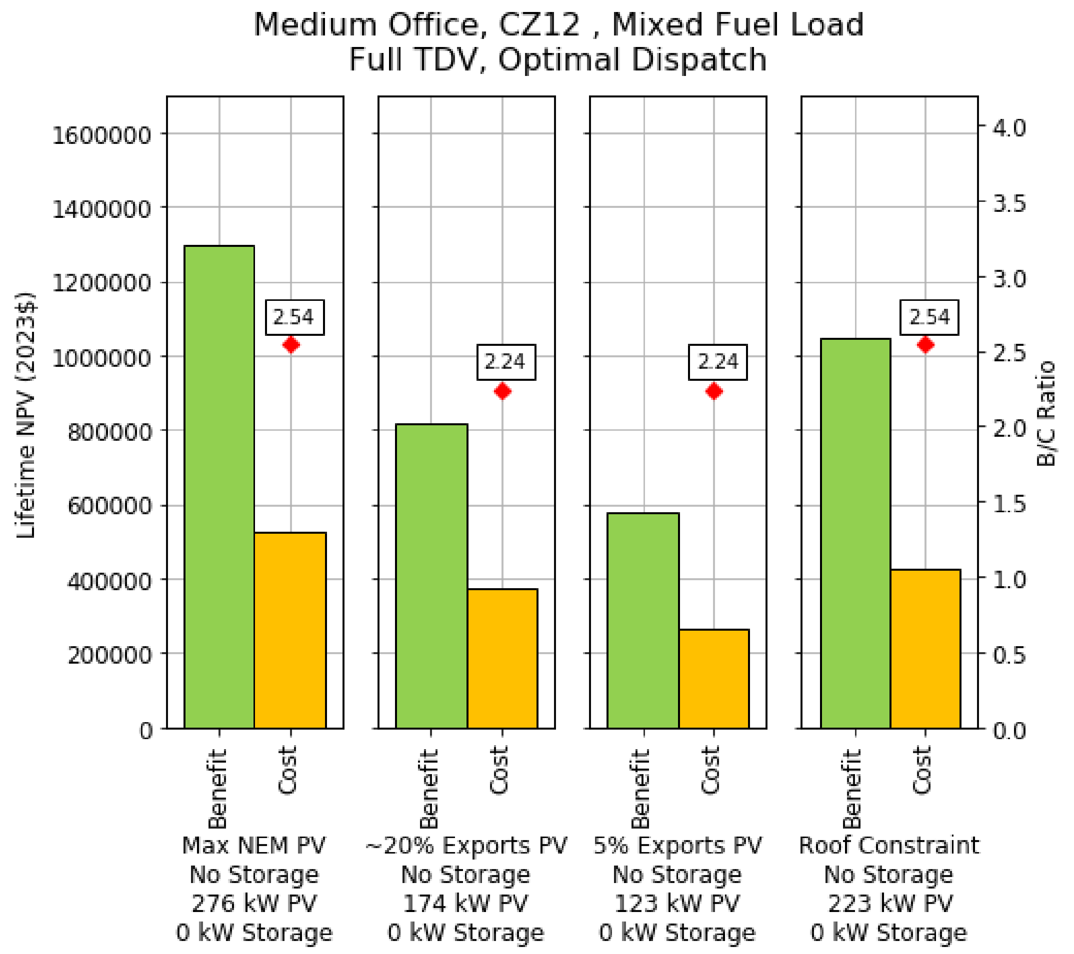
PV-Only Cost-Effectiveness

PV Cost-Effectiveness with Full TDV Rate

+ Under Full TDV rate, self-utilized electricity generation is compensated nearly the same the same as exported electricity
+ Benefit/Cost ratio stays largely the same, regardless of PV size (except in case of PV cost reductions due to economies of scale)
+ No added incentive for limited exports
+ PV is cost-effective for all sizes

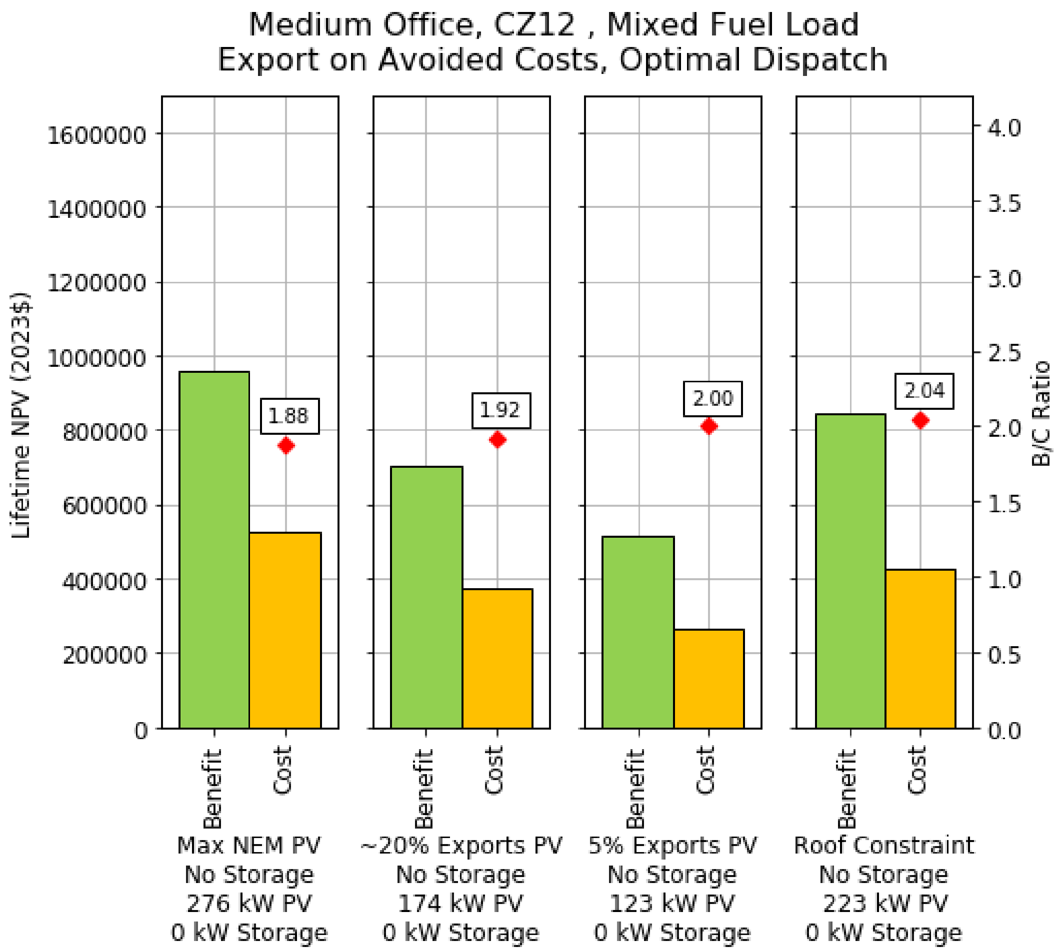
Cost Effectiveness



PV Cost-Effectiveness with Export on Avoided Costs

- "Export on Avoided Costs" and "Export on Wholesale Costs" rates have higher compensation for self-utilized PV generation than exports
- Benefit/Cost ratio increases with smaller PV size
- Increased incentive to self-utilize PV generation
- PV cost effective for all sizes

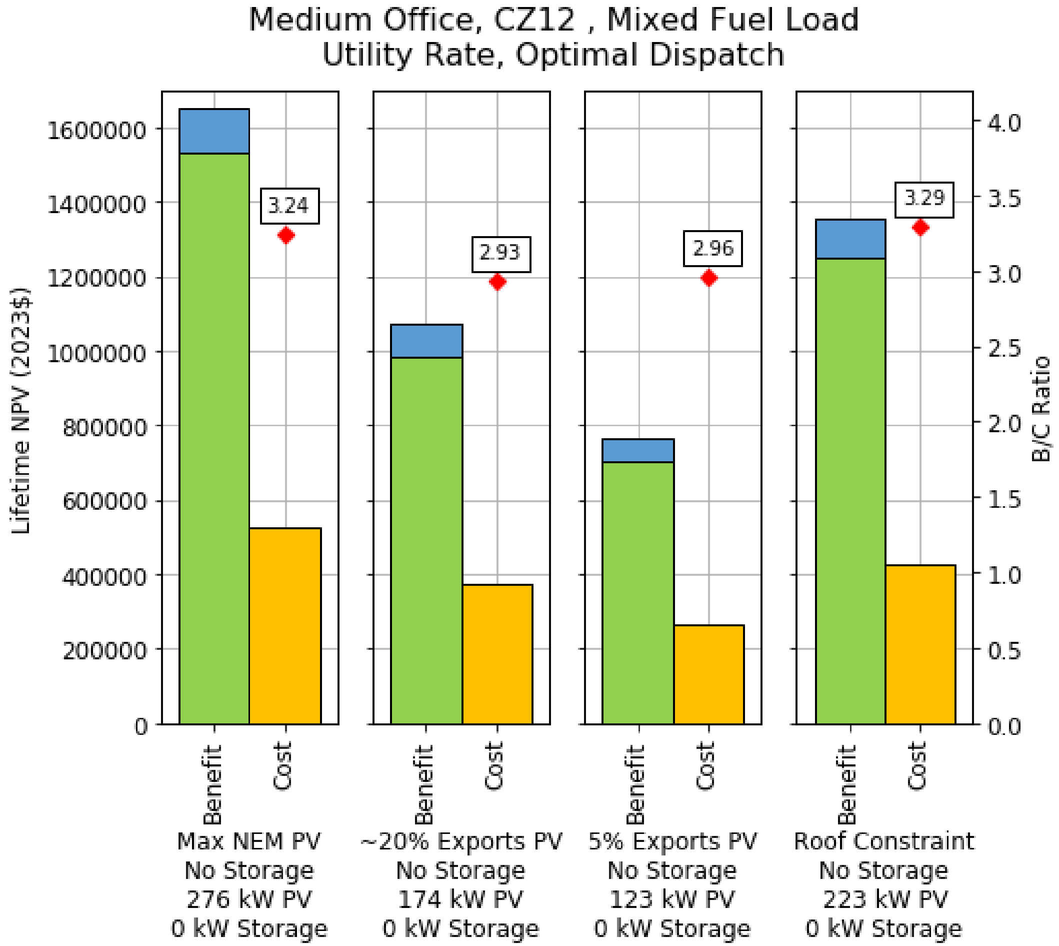
Cost Effectiveness



Utility Rates Increase PV cost-Effectiveness

- PV more cost-effective under existing retail rates than all TDV-based rates
- Current utility retail rates compensate exports at nearly the same rate as self-utilized generation (with the exception of "Non-Bypassable Charges")
- Higher mid-day prices during behind the meter PV generation drive higher cost-effectiveness
- Little incentive to limit exports

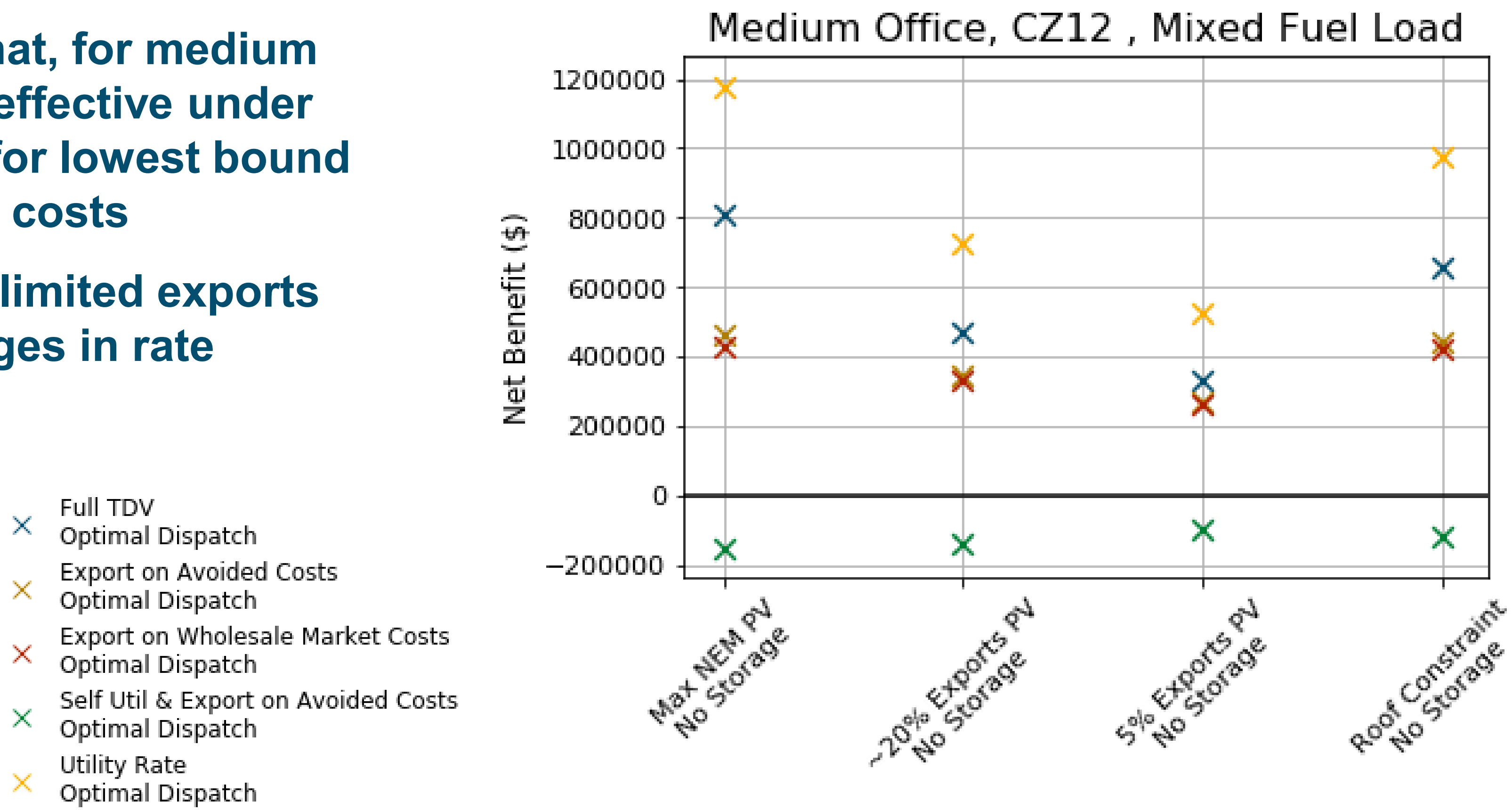
Cost Effectiveness – B10-TOU Rate



PV System Net Benefits

- Below chart summarizes preceding benefit/cost charts
- Map of Net Benefit shows that, for medium office, all PV sizes are cost effective under all rate sensitivities except for lowest bound of import/export on avoided costs
- Smaller sized systems with limited exports are insulated to major changes in rate design

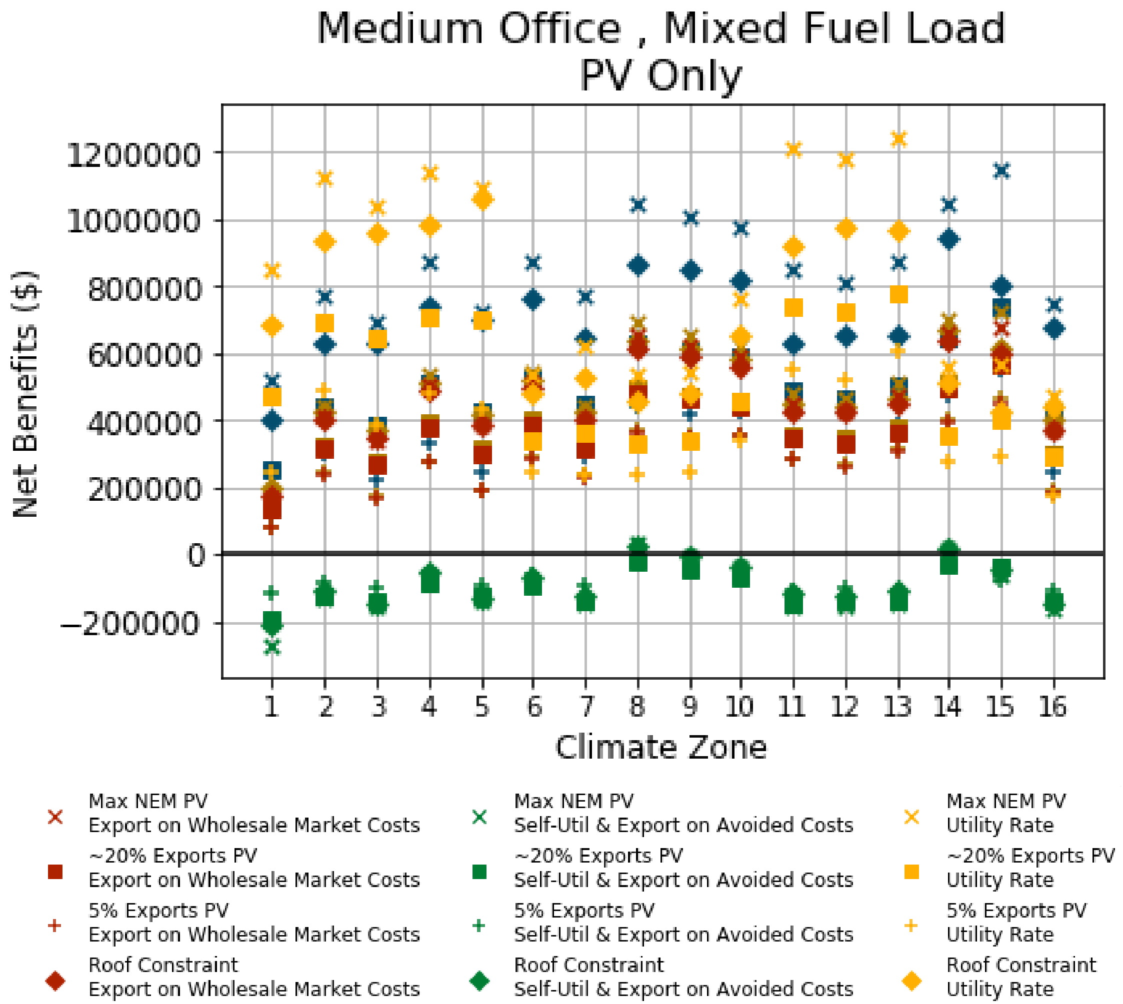
Cost Effectiveness, All Sizes, All Rates



PV System Net Benefits

- Expanding to Medium office, all climate zones, general trend stays consistent
- Climate zone 1, 16 are less cost-effective than other climate zones due to limited PV output
- Rate sensitivity of import/export under avoided costs are on the brink of cost-effectiveness

Cost Effectiveness, All Sizes, Rates, Climate Zones



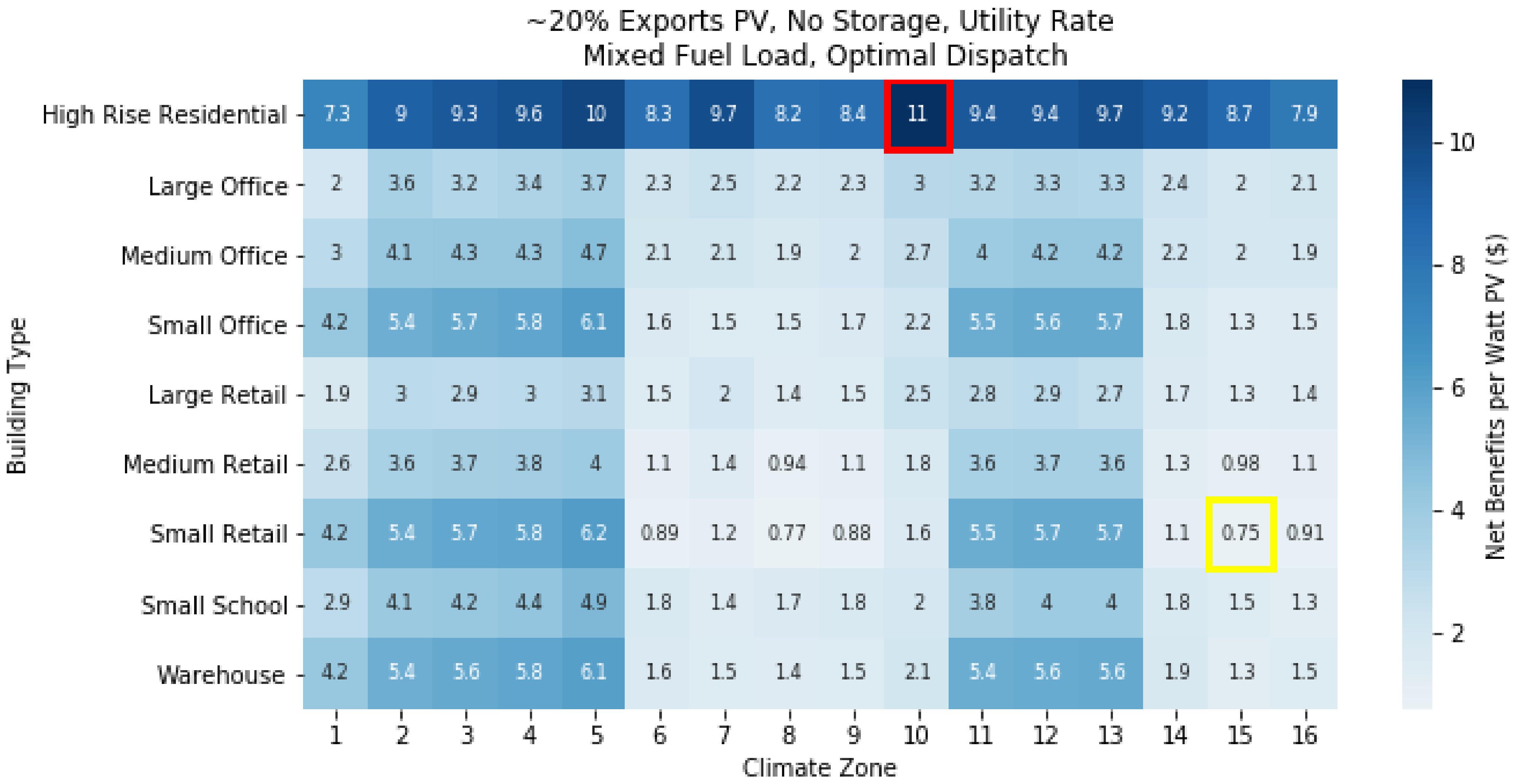
PV Only Net Benefit on TDV/Exported on Avoided Costs Building Types

~20% Exports PV, No Storage, Export on Avoided Costs
Mixed Fuel Load, Optimal Dispatch

Net Benefits per Watt PV ($)

Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	0.95	2	1.9	2.5	2.2	2.6	2.1	3.3	3	3.1	2.3	2.1	2.4	3.2	3	2.1
Large Office	1.3	2.4	2.3	2.8	2.5	2.9	2.3	3.3	3.2	3.1	2.3	2.4	2.5	3.6	3.1	2.4
Medium Office	0.93	1.9	1.8	2.4	2.1	2.4	1.9	2.9	2.8	2.7	1.9	2	2	3.1	2.9	2
Small Office	0.57	1.6	1.5	2.1	1.8	2.1	1.6	2.5	2.5	2.3	1.6	1.6	1.7	2.8	2.3	1.7
Large Retail	1.5	2.5	2.5	3	2.8	3.1	2.5	3.5	3.4	3.2	2.5	2.5	2.6	3.7	3.1	2.6
Medium Retail	0.88	1.9	1.8	2.4	2.1	2.5	1.9	2.9	2.8	2.6	1.9	1.9	2	3.1	2.5	2
Small Retail	0.68	1.7	1.7	2.2	2	2.3	1.7	2.7	2.7	2.5	1.7	1.8	1.8	3	2.4	1.9
Small School	0.67	1.6	1.5	2	1.8	2.1	1.6	2.5	2.5	2.3	1.6	1.6	1.7	2.8	2.3	1.7
Warehouse	0.47	1.4	1.4	1.9	1.6	1.9	1.4	2.4	2.3	2.2	1.4	1.5	1.6	2.7	2.2	1.5

PV Only Net Benefit on Utility Rates Across Building Types



CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV Cost Effectiveness Across Building Types

- **With exception of some edge cases, PV is cost effective across building types and climate zones, even under conservative compensation assumptions (TDV rate with exports on avoided costs)**
- **Larger buildings have improved cost effectiveness due to lower PV costs**
- **Under TDV rates, some further variation in cost effectiveness between building types, likely driven by coincidence of building loads and PV generation**
- **Utility rates impact cost-effectiveness of PV, depending on utility, selected rate tariff**
  - Note: Some utilities have options for alternative rate tariffs for customers within a given customer class (Ex. one tariff option with high demand charges and low volumetric charges, and one tariff option with low demand charges and high volumetric charges). This analysis did not attempt to optimize rate design for PV customers

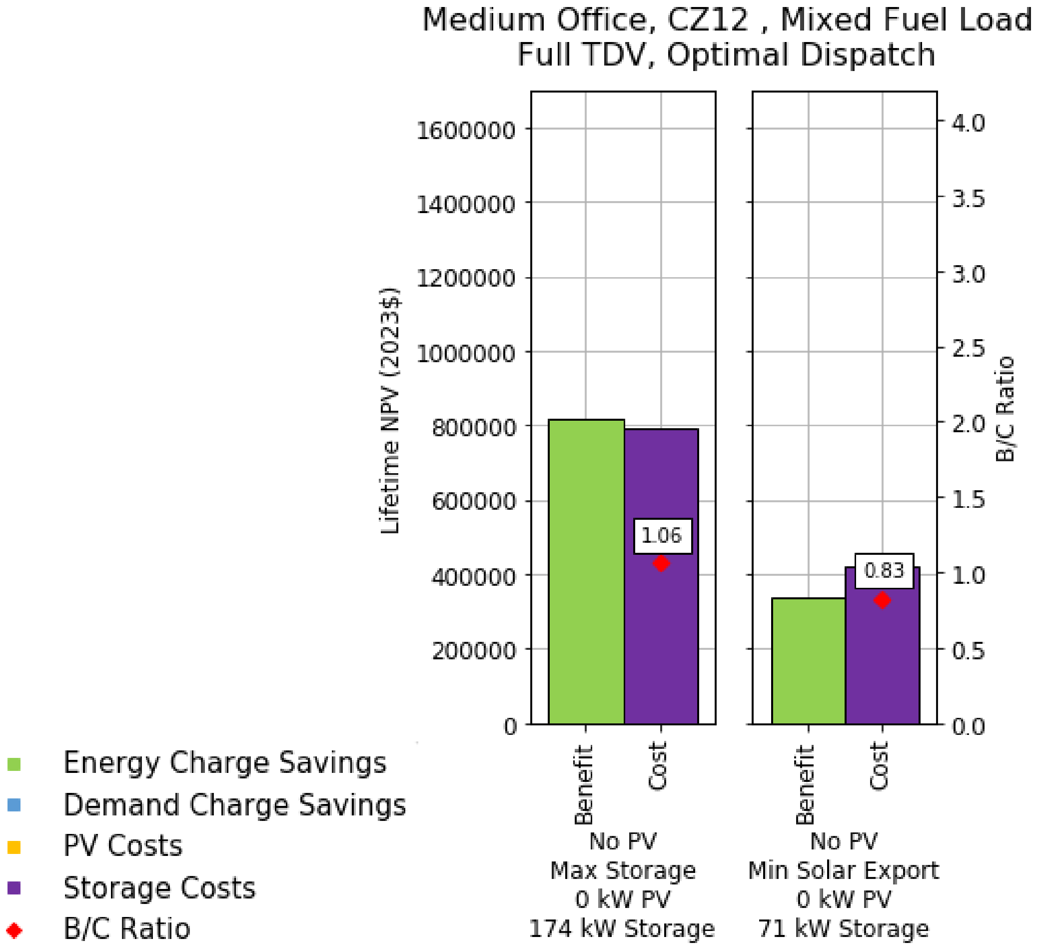
Energy+Environmental Economics

Storage-Only Cost-Effectiveness

Storage Cost-Effectiveness with Full TDV Rate

- Storage-only is borderline cost-effective under Full TDV Rate
- With Full TDV rate, storage imports energy from the grid, to reduce load in high cost hours, arbitraging high and low price signals
- Larger battery has higher BC ratio due to proportionally lower battery cost ($/kWh)
- Note: basic dispatch defined by charging on solar, so only optimal dispatch tested for storage-only

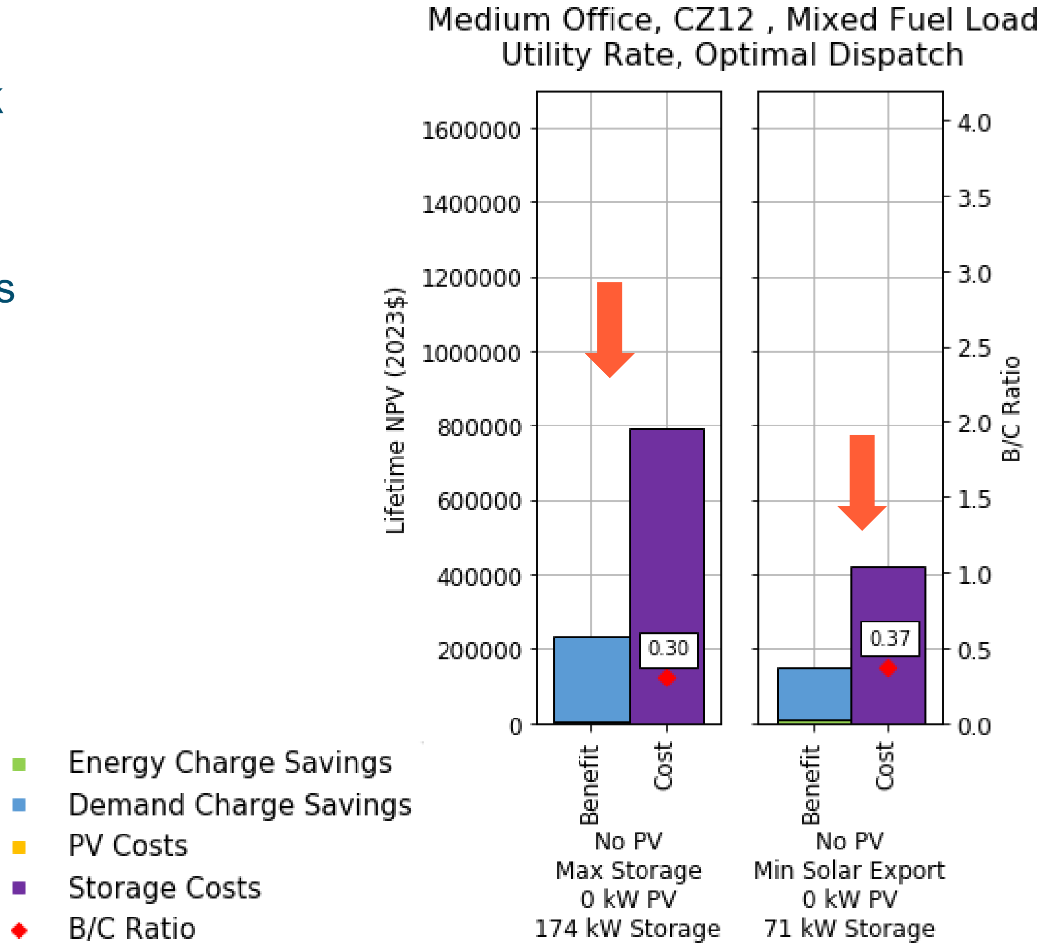
Cost Effectiveness



Utility rates Affect Cost-effectiveness

- **Storage generally less cost-effective under existing utility rates**
- **Storage benefit is largely comprised of peak demand clipping of monthly demand charges**
  - This specific utility rate has lower demand charges than other examined rates
  - Energy arbitrage opportunity is limited
- **Note that prototype buildings may have flatter load profiles than actual buildings, limiting opportunity for demand charge reduction**
  - Many real-world scenarios where BTM energy storage is cost-effective for participants

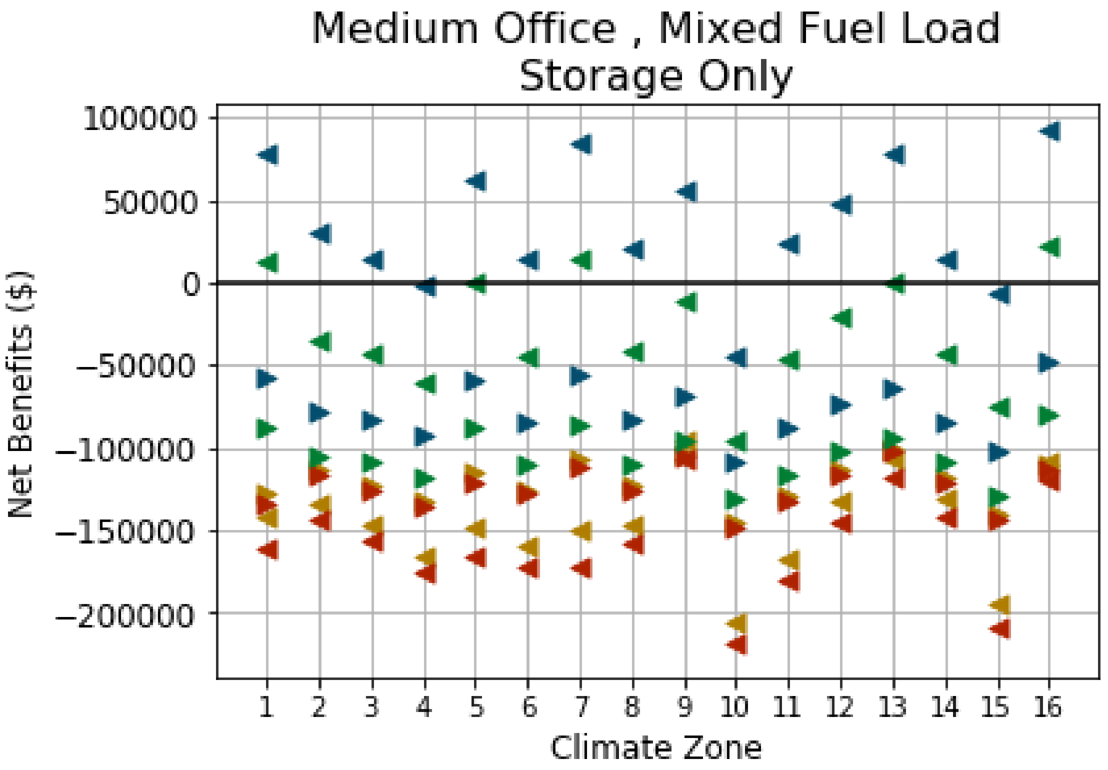
Cost Effectiveness – B10-TOU Rate



Storage System Net Benefits

- Expanding to medium office, all climate zones, cost-effectiveness does not change dramatically based on climate zone for storage-only systems
- Largely not cost-effective, but could change based on storage cost projections, and potential cost declines

Cost Effectiveness, All Sizes, Rates, Climate Zones



◀ Max Storage, Optimal Dispatch Full TDV
▶ Min Solar Export Storage, Optimal Dispatch Full TDV
◀ Max Storage, Optimal Dispatch Export on Wholesale Market Costs
▶ Min Solar Export Storage, Optimal Dispatch Export on Wholesale Market Costs
◀ Max Storage, Optimal Dispatch Export on Avoided Costs
▶ Min Solar Export Storage, Optimal Dispatch Export on Avoided Costs
◀ Max Storage, Optimal Dispatch Self-Util & Export on Avoided Costs
▶ Min Solar Export Storage, Optimal Dispatch Self-Util & Export on Avoided Costs

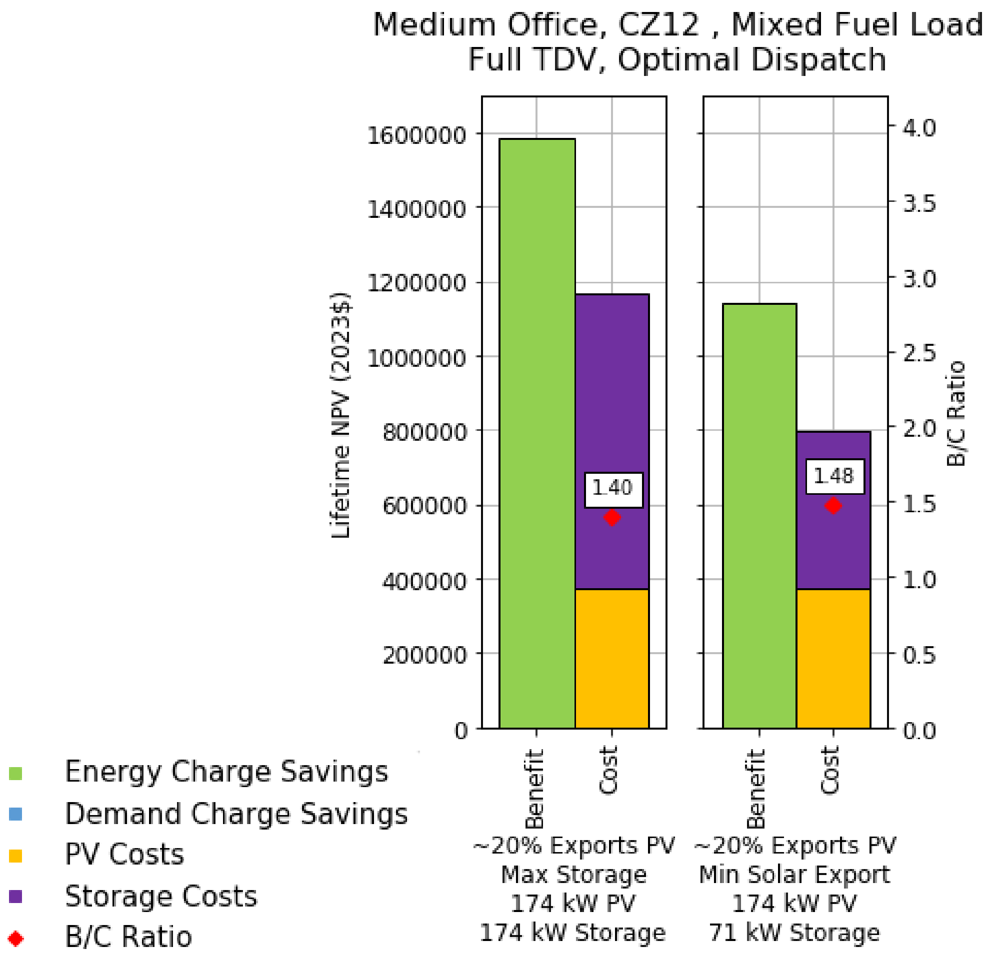
(without utility retail rate sensitivity)

PV+Storage Cost-Effectiveness

PV+Storage Cost-Effectiveness with Full TDV Rate

- Focused on Self-utilization (~20% Exports) PV size with larger and smaller storage sizes
- PV+Storage combined as a package has a lifetime net benefit under Full TDV rate
- Smaller storage system has higher Benefit-cost ratio due to diminishing returns in benefits of storage sizing

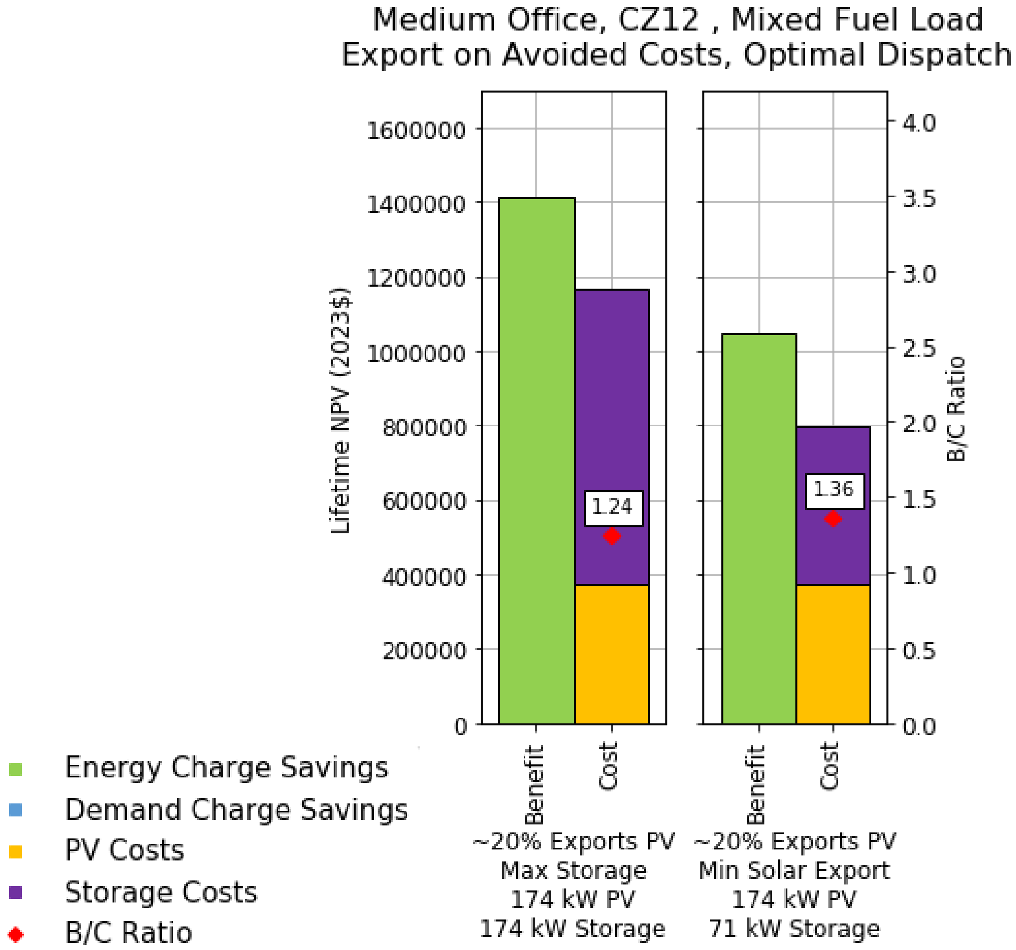
Cost Effectiveness



PV+Storage Cost-Effectiveness with Exports on Avoided Costs

- On Export on Avoided Costs rate, smaller system has higher net benefit than larger storage system
- Smaller system size is more insulated to potential NEM rate reforms

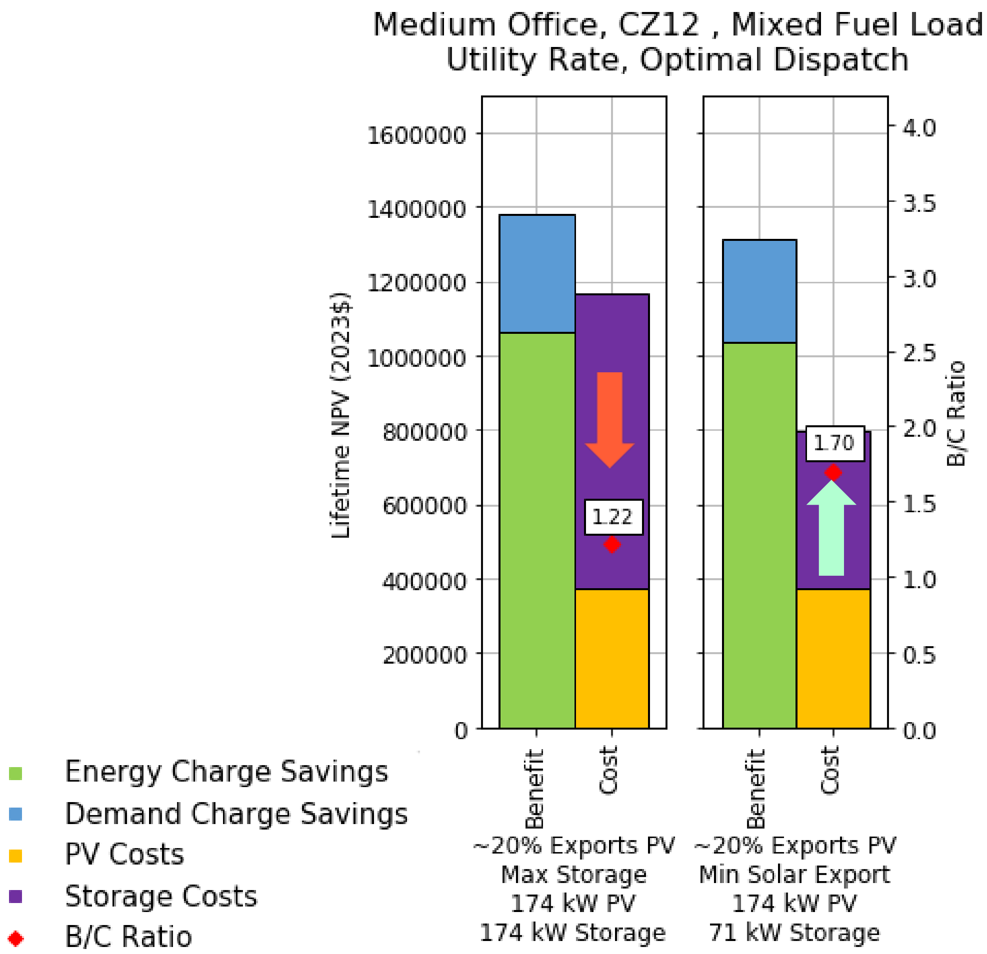
Cost Effectiveness



Utility rates affect cost-effectiveness

- Utility retail rate increases on cost-effectiveness for PV+Storage for smaller battery size, due to strong cost-effectiveness of PV, potential for large demand charge reduction opportunities
- Net benefit with smaller storage size notably higher than larger storage configuration

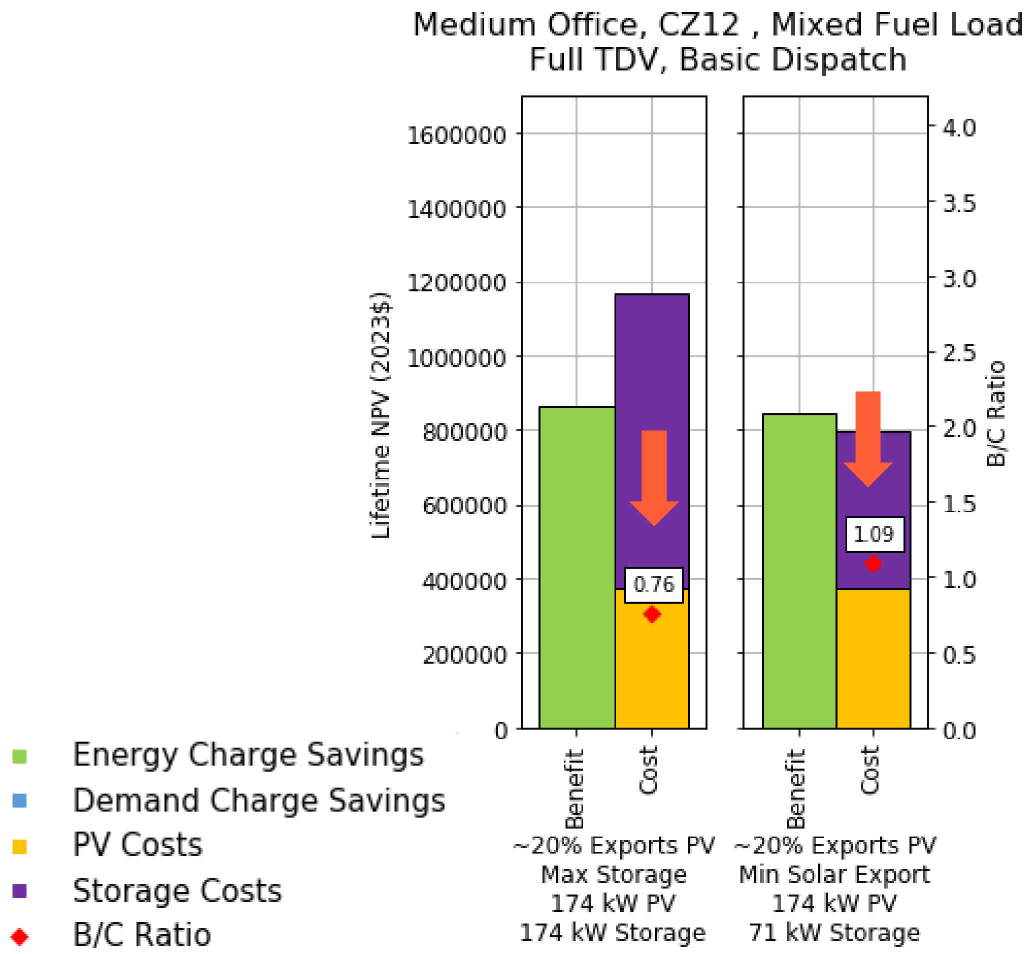
Cost Effectiveness – B10-TOU Rate



Basic dispatch limits cost-effectiveness

- **Smaller PV+Storage configuration still cost-effective with Basic dispatch under Full TDV rate scenario**
  - Battery only charges on PV net exports and discharges when load again exceeds PV production
- **Due to diminishing returns, smaller storage size is cost-effective while large storage size is not**
- **This case represents a low-booked value for PV+storage cost-effectiveness**

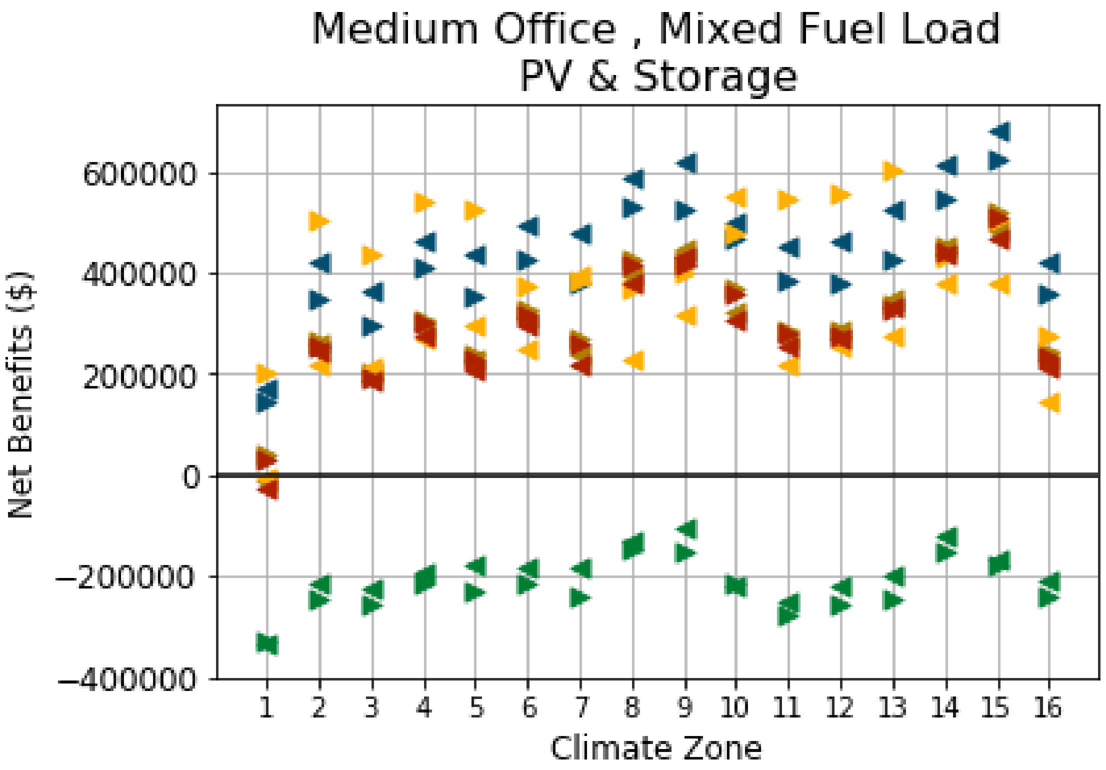
Cost Effectiveness – Basic Dispatch



PV+Storage System Net Benefits, Optimal Dispatch

- Expanding to medium office, all climate zones, general trend stays consistent
- Climate zone 1, 16 are less cost-effective than other climate zones due to limited PV output
- Rate sensitivity of import/export under avoided costs is not cost-effective
- Utility rate has mixed impacts on cost-effectiveness

Cost Effectiveness, All Rates & Climate Zones



PV + Storage Optimal Dispatch on TDV/Exported on Avoided Costs Across Building Types

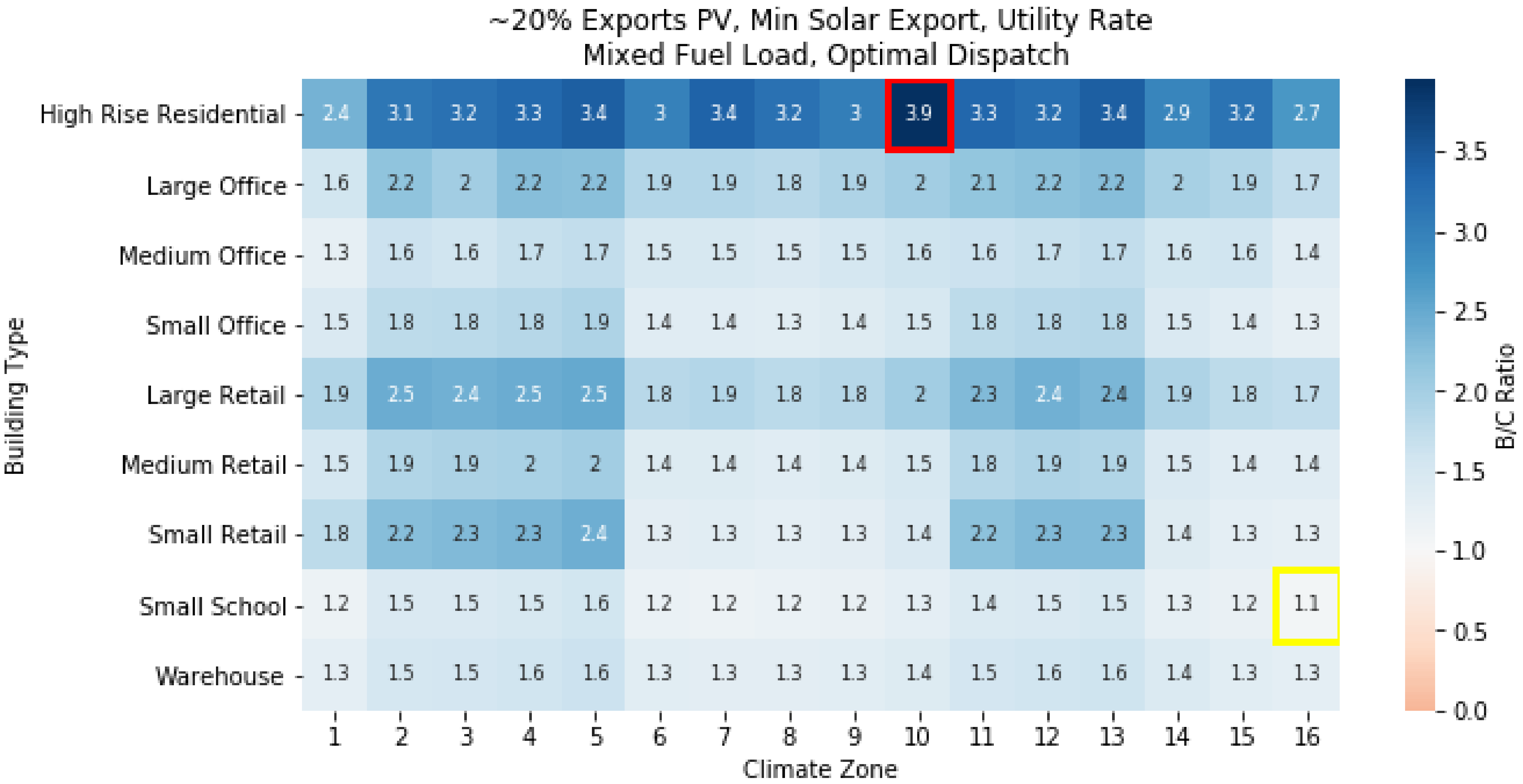
~20% Exports PV, Min Solar Export, Export on Avoided Costs
Mixed Fuel Load, Optimal Dispatch

Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	1.3	1.6	1.6	1.8	1.7	1.8	1.7	2.1	2	2	1.7	1.7	1.8	1.9	2	1.7
Large Office	1.3	1.7	1.6	1.8	1.7	1.8	1.7	2	2	1.9	1.7	1.7	1.8	2	1.9	1.7
Medium Office	1.1	1.3	1.3	1.4	1.3	1.4	1.3	1.5	1.6	1.5	1.3	1.4	1.4	1.6	1.6	1.3
Small Office	1	1.3	1.3	1.4	1.3	1.4	1.3	1.5	1.5	1.4	1.3	1.3	1.3	1.5	1.4	1.3
Large Retail	1.6	2	2	2.2	2.1	2.2	2.1	2.4	2.4	2.3	2	2	2.1	2.4	2.2	2.1
Medium Retail	1.2	1.5	1.5	1.6	1.6	1.7	1.5	1.8	1.8	1.7	1.5	1.5	1.5	1.8	1.6	1.6
Small Retail	1.2	1.5	1.5	1.6	1.6	1.6	1.5	1.8	1.7	1.7	1.5	1.5	1.5	1.8	1.6	1.5
Small School	1	1.2	1.2	1.3	1.3	1.3	1.2	1.4	1.4	1.3	1.2	1.2	1.3	1.4	1.4	1.2
Warehouse	0.89	1.1	1.1	1.2	1.1	1.2	1.1	1.3	1.3	1.2	1.1	1.2	1.2	1.4	1.3	1.2

Climate Zone

B/C Ratio: 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

PV + Storage Optimal Dispatch on Utility Rates Across Building Types



Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	2.4	3.1	3.2	3.3	3.4	3	3.4	3.2	3	3.9	3.3	3.2	3.4	2.9	3.2	2.7
Large Office	1.6	2.2	2	2.2	2.2	1.9	1.9	1.8	1.9	2	2.1	2.2	2.2	2	1.9	1.7
Medium Office	1.3	1.6	1.6	1.7	1.7	1.5	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.6	1.6	1.4
Small Office	1.5	1.8	1.8	1.8	1.9	1.4	1.4	1.3	1.4	1.5	1.8	1.8	1.8	1.5	1.4	1.3
Large Retail	1.9	2.5	2.4	2.5	2.5	1.8	1.9	1.8	1.8	2	2.3	2.4	2.4	1.9	1.8	1.7
Medium Retail	1.5	1.9	1.9	2	2	1.4	1.4	1.4	1.4	1.5	1.8	1.9	1.9	1.5	1.4	1.4
Small Retail	1.8	2.2	2.3	2.3	2.4	1.3	1.3	1.3	1.3	1.4	2.2	2.3	2.3	1.4	1.3	1.3
Small School	1.2	1.5	1.5	1.5	1.6	1.2	1.2	1.2	1.2	1.3	1.4	1.5	1.5	1.3	1.2	1.1
Warehouse	1.3	1.5	1.5	1.6	1.6	1.3	1.3	1.3	1.3	1.4	1.5	1.6	1.6	1.4	1.3	1.3

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	SCE
7	SDG&E
8	SCE
9	SCE
10	SCE
11	PG&E
12	PG&E
13	PG&E
14	SCE
15	SCE
16	SCE

PV+Storage Cost Effectiveness Across Building Types

- With exception of some edge cases, PV+storage with the smaller sizing configuration is cost effective across building types and climate zones, even under conservative compensation assumptions (TDV rate with exports on avoided costs)
- Basic dispatch diminishes cost effectiveness across building types, yielding some non-cost-effective combinations
- Cost-effectiveness by building type largely driven by cost declines for larger systems
- Under TDV rates, some further variation in cost effectiveness between building types, likely driven by building load profile and ability for PV+storage to impact net load
- Using selected utility rates, co-benefits of PV and storage yields a generally cost-effective solution for prototype buildings

Energy+Environmental Economics

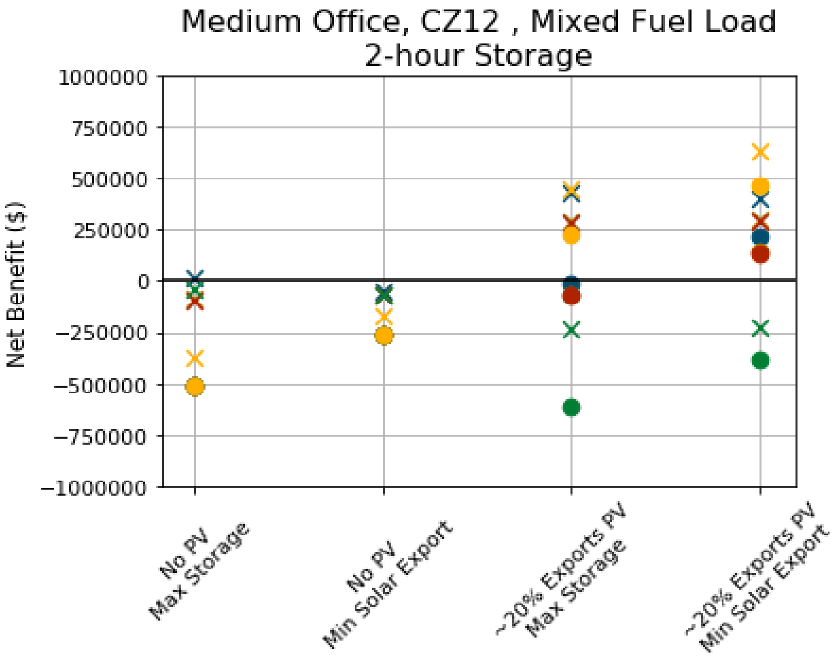
Storage Duration & Size Sensitivity

Storage Duration Sensitivity

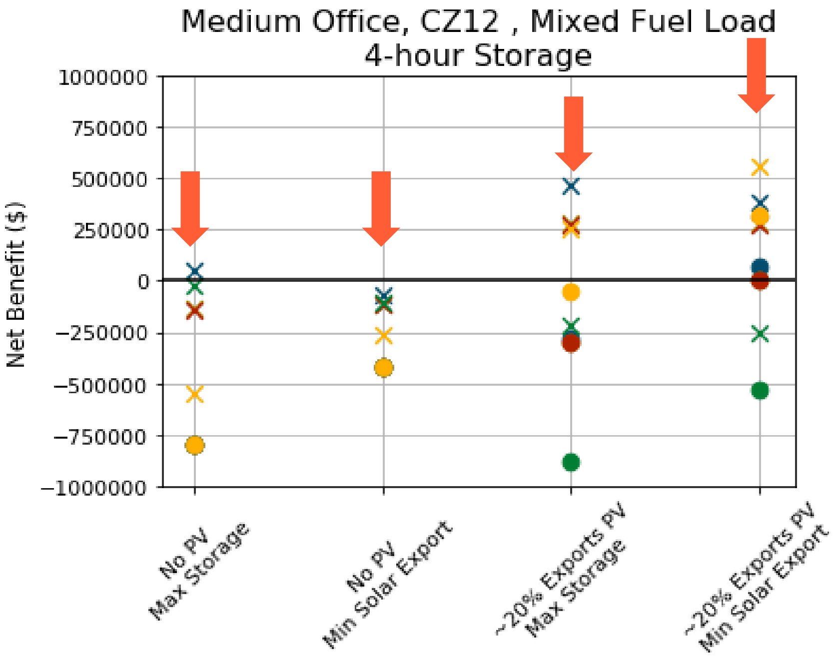
+ 2-hour duration improves cost-effectiveness

Full TDV Basic Dispatch
Export on Avoided Costs Basic Dispatch
Export on Wholesale Market Costs Basic Dispatch
Self Util & Export on Avoided Costs Basic Dispatch
Utility Rate Basic Dispatch
Full TDV Optimal Dispatch
Export on Avoided Costs Optimal Dispatch
Export on Wholesale Market Costs Optimal Dispatch
Self Util & Export on Avoided Costs Optimal Dispatch
Utility Rate Optimal Dispatch

2-hour Storage



4-hour Storage



Energy+Environmental Economics

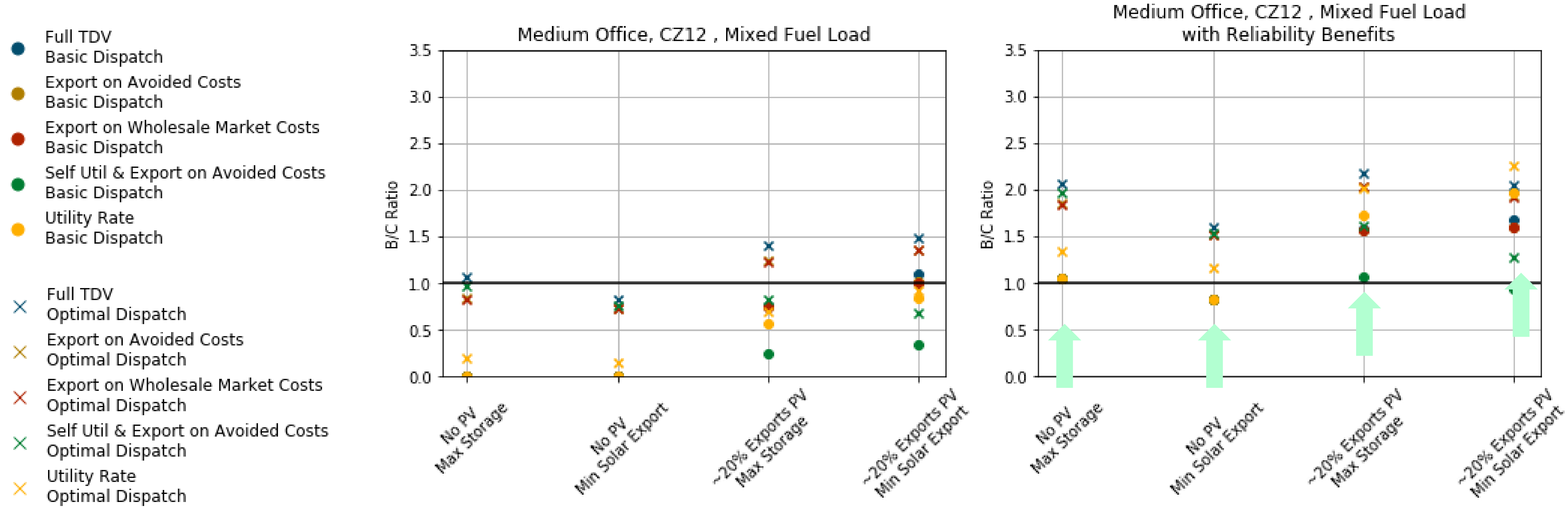
Reliability & Resiliency Value Sensitivity

Reliability Benefit Improves Cost-Effectiveness

+ If considered, reliability value can largely improve cost-effectiveness

- Reliability benefit comes from having PV generation or reserving storage energy for unplanned short T&D power interruptions

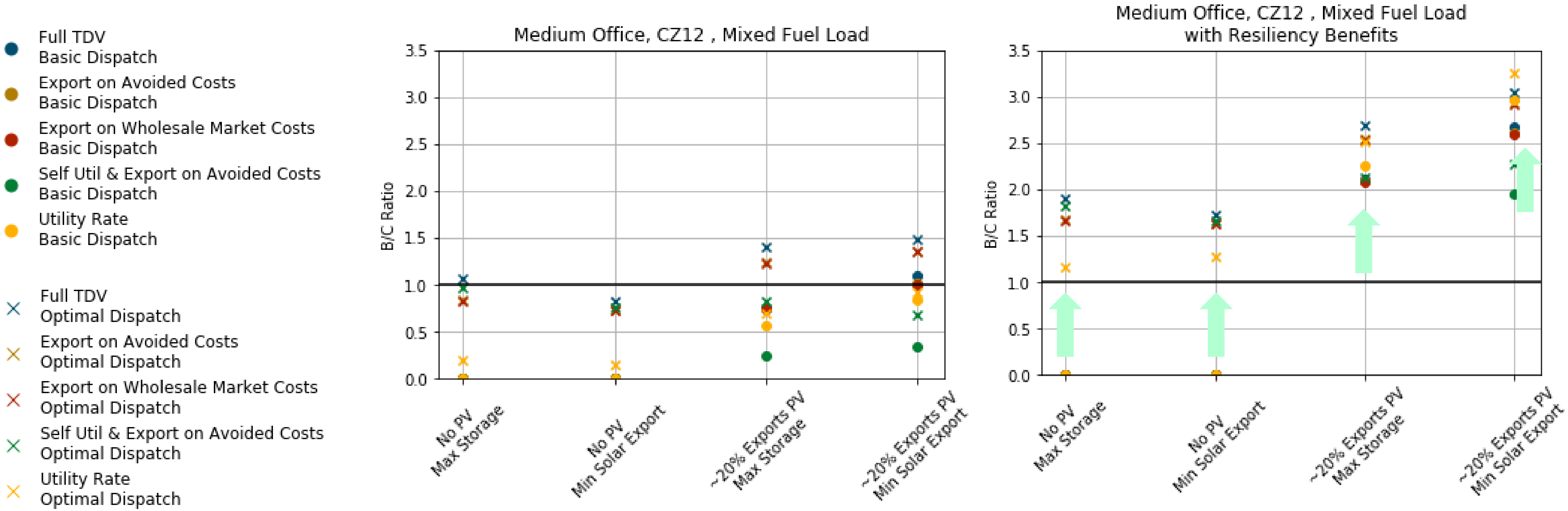
Without Reliability, Resiliency Value | **With Reliability Value Only**



Resiliency Benefit Improves Cost-Effectiveness

+ **If considered, resiliency value can largely improve cost-effectiveness**
  - Resiliency benefit comes from covering critical load during planned outage days (ex. Public Safety Power Shutoff)

Without Reliability, Resiliency Value | **With Resiliency Value Only**



Energy+Environmental Economics

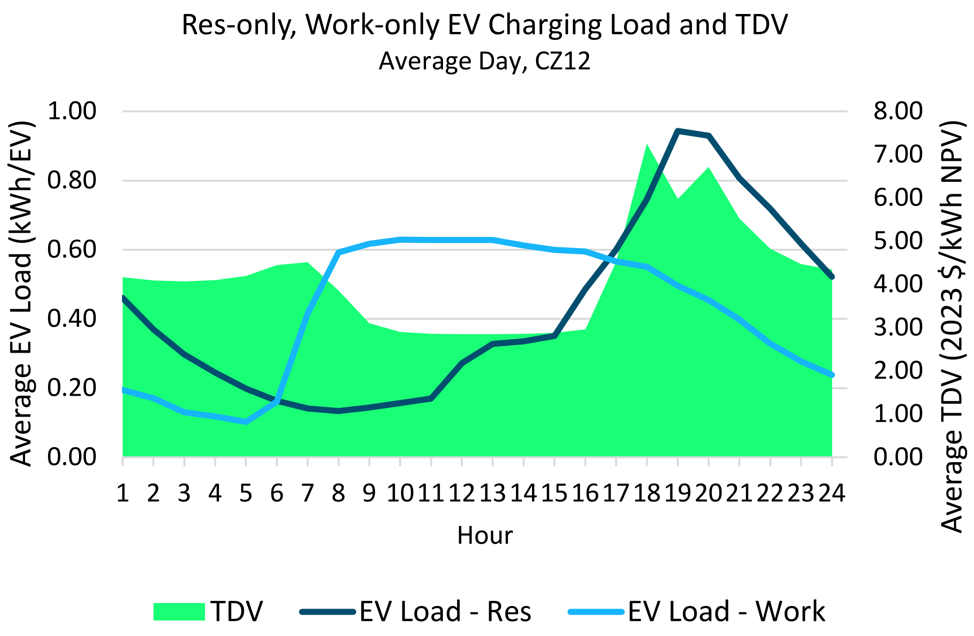
EV Charging Compliance Option Framework

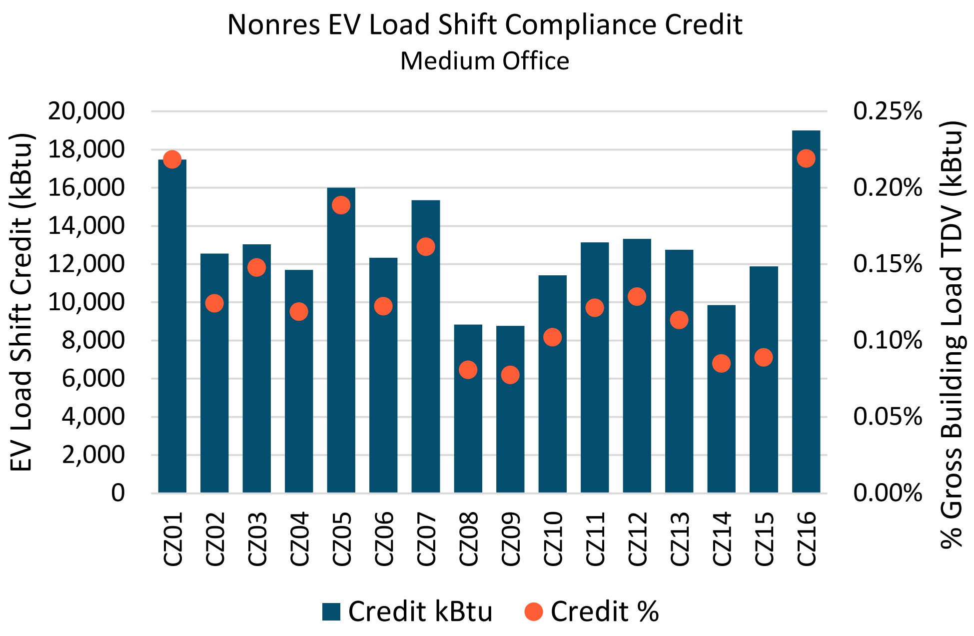
Proposed framework for nonresidential EV compliance credit and initial example

- **In order to meet California's 2025 ZEV goals, CARB estimates an additional need of 8,000-76,000 public/workplace level 2 (L2, ~7 kW) EV chargers, beyond those forecast under current building codes and incentives**
- **Title 24, Part 11 (CALGreen) requires ~6% of a building's parking spaces be "EV Capable" – cable raceway and sufficient panel capacity to support Electric Vehicle Supply Equipment (EVSE) – but does not require installation of the charger equipment itself**
- **Granting Title 24, Part 6 compliance credit for EVSE installation in non-residential buildings could help fill this gap**
- **Designing proposal so that it does not double count with LCFS**
- **This compliance credit is based on chargers in daytime charging locations that provide grid benefits:**
  - TDV value of shifting EV charging load from a typical residential charging shape (during peak or evening hours) to a more solar-aligned workplace charging shape

How significant would the credit be?

+ **Compliance Credit per Charger**
  - TDV 8,777 to 19,000 kBtu per charger lifecycle
  - Levelized Source Energy 3,172 to 3,194 kBtu per charger per year
  - Savings of at least 0.2 Tonnes CO2-e per charger per year
+ **Figures assume EV charges on grid energy – greater savings from PV charging**





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Conclusions and Next Steps

Key Findings

- **PV + Storage as a package (smaller configuration) is cost-effective for most building categories due to co-benefits of combined systems**
  - PV + Storage provides additional participant benefits, including reliability and resiliency
- **PV is cost effective across all scenarios from participant perspective, except under most significant rate reform**
  - Minimizing exports allows for significant PV benefits, while having robust cost-effectiveness in all rate sensitivities
  - Note: most significant rate reform is analogous to “buy all - sell all” on avoided cost treatment of rooftop PV
- **Storage-only presents large grid benefits, but is generally not cost-effective in this analysis**

Next Steps

+ **Refine sizing and configuration**
+ **Calculate source energy, emissions impacts of selected configurations**
+ **Refine battery controls**
  - Optimal dispatch is an upper bound
  - Basic dispatch is likely too conservative
  - Explore more realistic controls, or heuristic for benefit captured in real world vs optimal dispatch
+ **Collect real-world data from interested stakeholders**
  - Capital and operating costs
  - Technology characteristics
  - Battery control schemes
  - Typical storage duration
  - Future rate design

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Thank you!

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Appendix

Appendix Contents

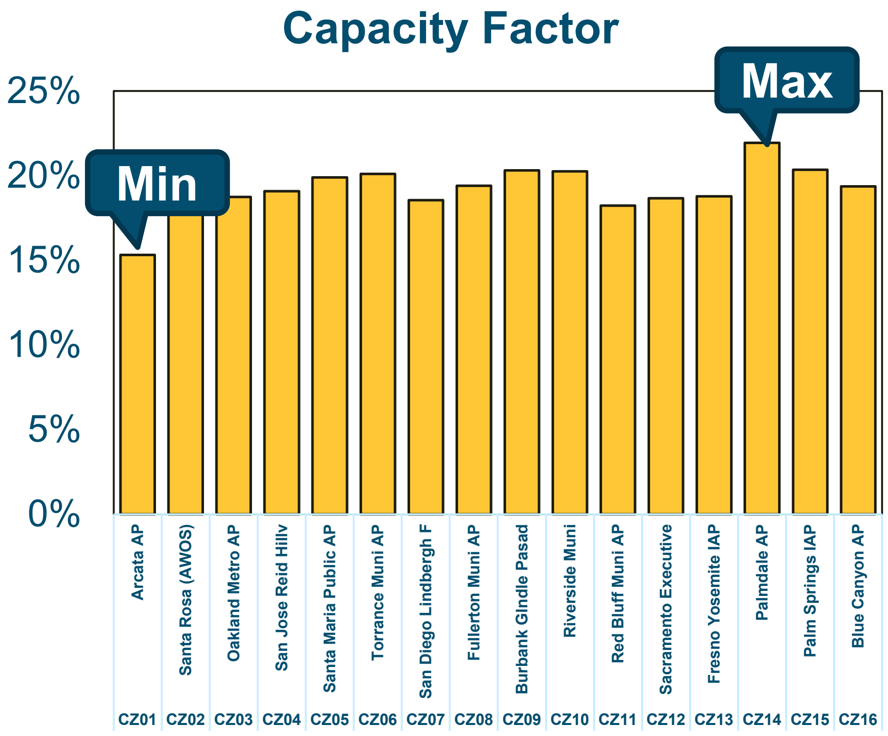
Energy+Environmental Economics

Appendix – Additional PV-Only and Storage-Only Results

PV Capacity Factor

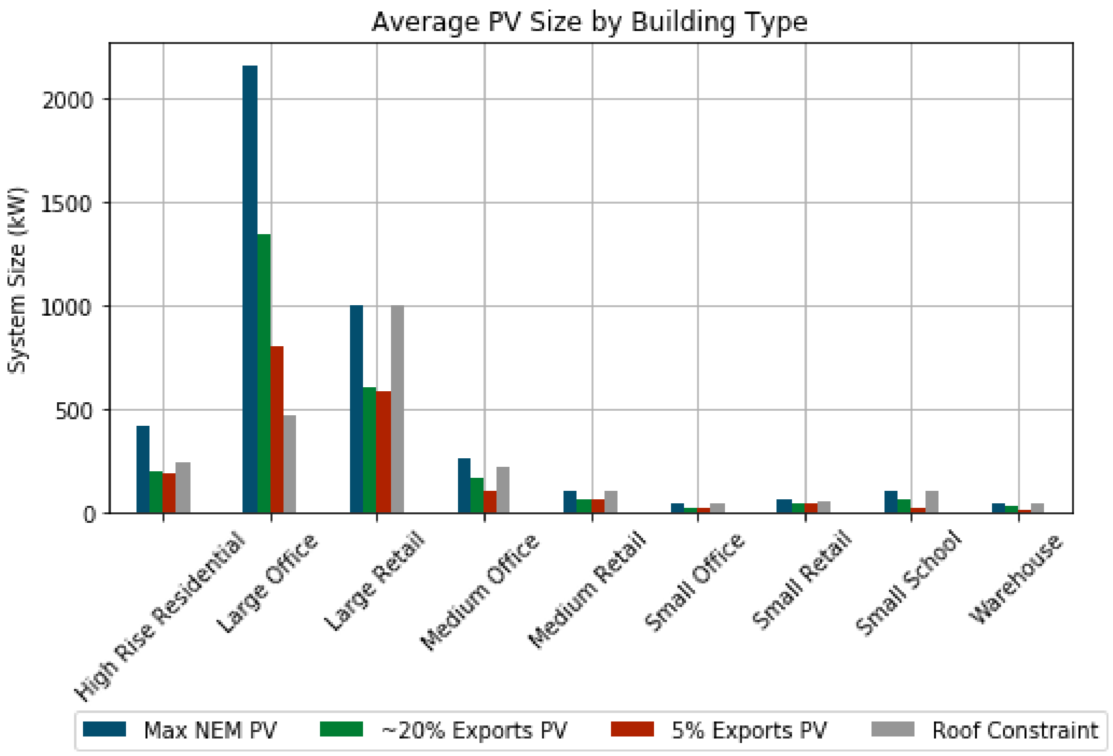
+ **CZ01 has much lower PV output (les cost-effective), CZ14 has much higher PV output (more cost-effective)**

Climate Zone	Weather Station Name	Capacity Factor
CZ01	Arcata AP	15.3%
CZ02	Santa Rosa (AWOS)	18.1%
CZ03	Oakland Metro AP	18.7%
CZ04	San Jose Reid Hillv	19.1%
CZ05	Santa Maria Public AP	19.9%
CZ06	Torrance Muni AP	20.1%
CZ07	San Diego Lindbergh F	18.6%
CZ08	Fullerton Muni AP	19.4%
CZ09	Burbank Glndle Pasad	20.3%
CZ10	Riverside Muni	20.3%
CZ11	Red Bluff Muni AP	18.2%
CZ12	Sacramento Executive	18.7%
CZ13	Fresno Yosemite IAP	18.8%
CZ14	Palmdale AP	21.9%
CZ15	Palm Springs IAP	20.3%
CZ16	Blue Canyon AP	19.4%



PV Sizing

Average PV Size by Building Type



- **Three sizing options for each building type and climate zone**
  - Max NEM Complaint
    - Annual solar gen = annual total building consumption
    - ~40% of annual PV generation is exported to grid
  - Self-utilization (~20% Exports PV)
    - Sized to generate the amount of PV that is self-utilized in *Max NEM Compliant* case
    - ~20% of annual PV generation is exported to grid
  - 5% Exports
    - 5% of annual PV generation is exported to grid

- **PV sizes compared to roof area constraints to ensure viable system size**

PV Only Net Benefit on Utility Rates Across Building Types w/ LADWP & SMUD

~20% Exports PV, No Storage, Utility Rate
Mixed Fuel Load, Optimal Dispatch

Net Benefits per Watt PV ($)

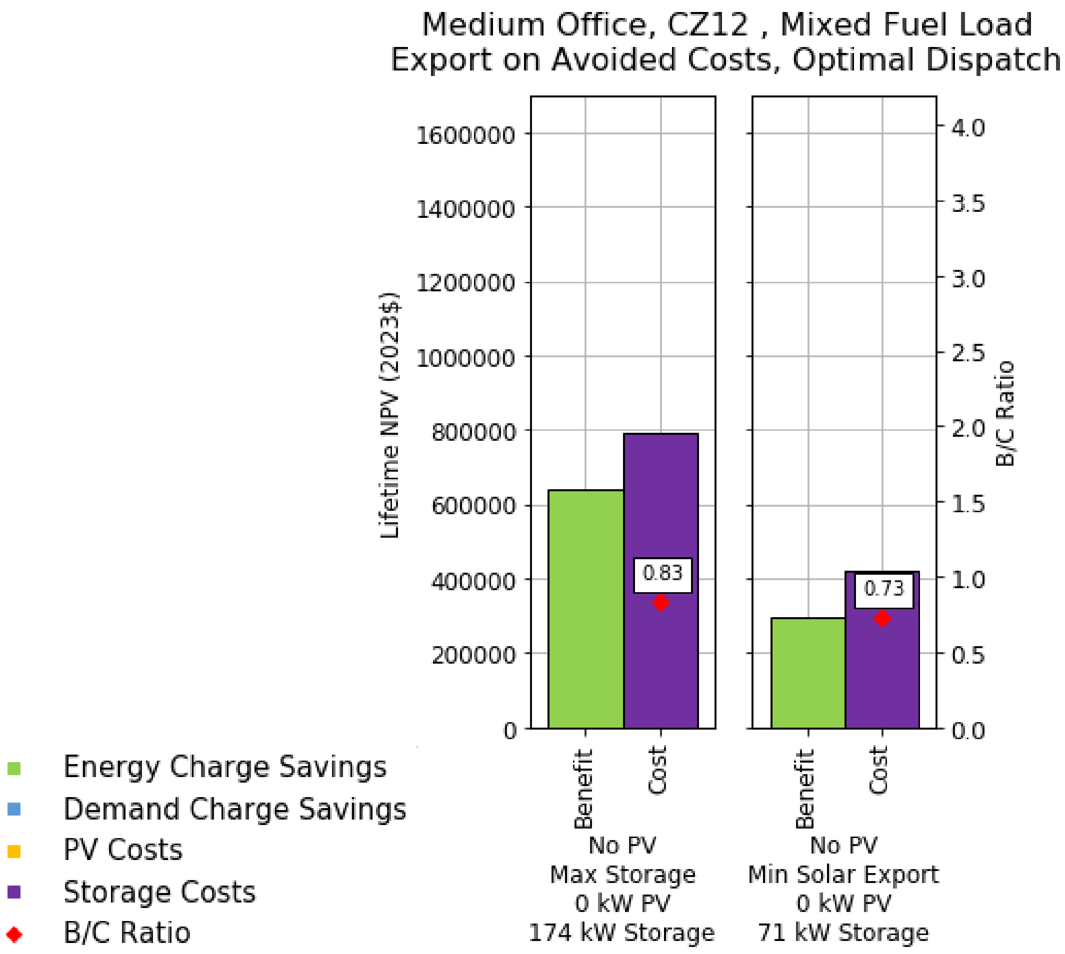
Building Type \ Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	7.3	9	9.3	9.6	10	5.5	9.7	5.5	5.5	11	9.4	2	9.7	9.2	8.7	7.9
Large Office	2	3.6	3.2	3.4	3.7	2.9	2.5	2.7	3	3	3.2	2.2	3.3	2.4	2	2.1
Medium Office	3	4.1	4.3	4.3	4.7	2.5	2.1	2.4	2.4	2.7	4	1.7	4.2	2.2	2	1.9
Small Office	4.2	5.4	5.7	5.8	6.1	4.8	1.5	4.6	4.7	2.2	5.5	1.3	5.7	1.8	1.3	1.5
Large Retail	1.9	3	2.9	3	3.1	5.3	2	5.1	5.4	2.5	2.8	2.2	2.7	1.7	1.3	1.4
Medium Retail	2.6	3.6	3.7	3.8	4	4.7	1.4	4.4	4.7	1.8	3.6	1.5	3.6	1.3	0.98	1.1
Small Retail	4.2	5.4	5.7	5.8	6.2	4.5	1.2	4.3	4.5	1.6	5.5	1.3	5.7	1.1	0.75	0.91
Small School	2.9	4.1	4.2	4.4	4.9	5.4	1.4	5.3	5.3	2	3.8	1.5	4	1.8	1.5	1.3
Warehouse	4.2	5.4	5.6	5.8	6.1	4.4	1.5	4.2	4.5	2.1	5.4	1.3	5.6	1.9	1.3	1.5

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	**SMUD**
13	PG&E
14	SCE
15	SCE
16	SCE

Storage Cost-Effectiveness with Export on Avoided Costs

+ **Storage-only is slightly less cost-effective under Export on Avoided Costs**
+ **Larger battery has higher BC ratio due to proportionally lower battery cost ($/kWh)**
+ **Significant benefits, but benefits do not out-weigh costs**

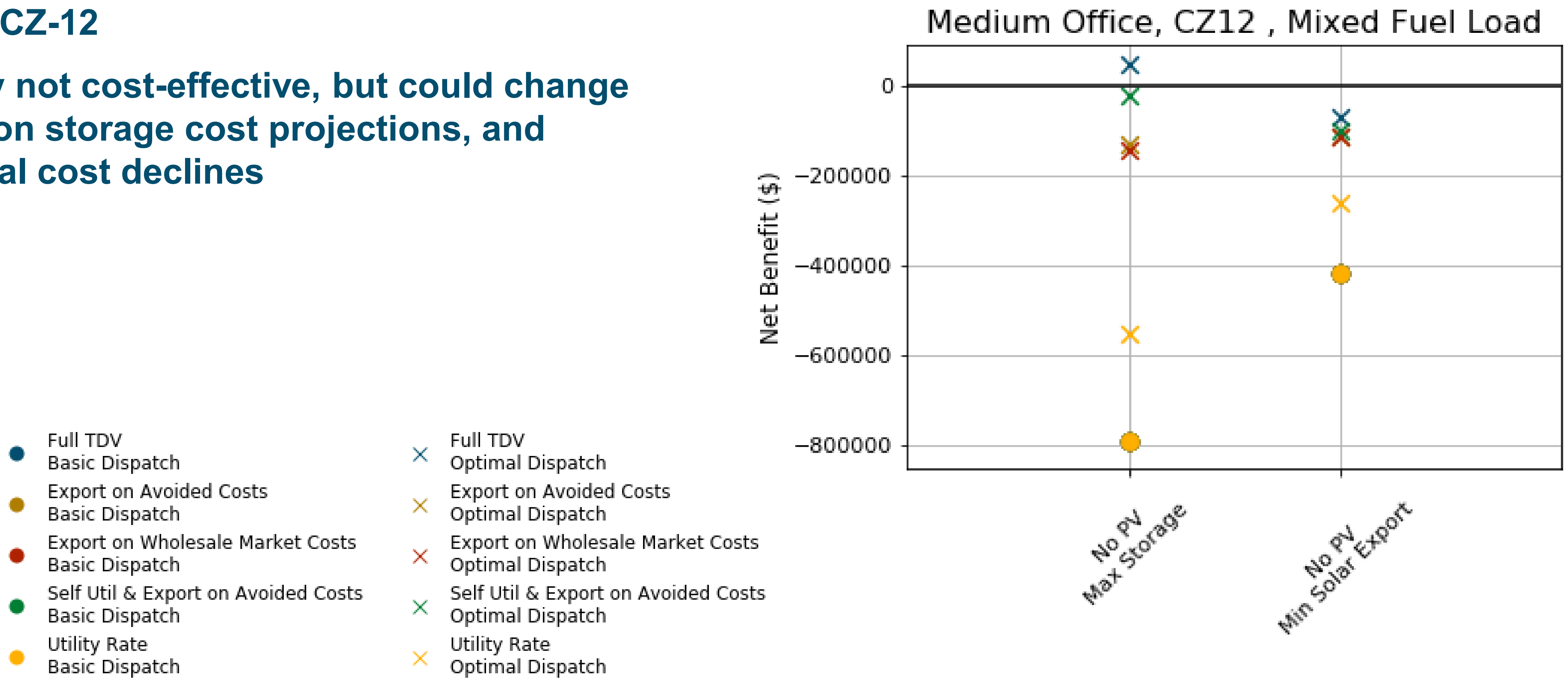
Cost Effectiveness



Storage System Net Benefits

- The chart aggregates previous storage only charts, with all rate sensitivities for Medium Office, CZ-12
- Largely not cost-effective, but could change based on storage cost projections, and potential cost declines

Cost Effectiveness, All Sizes, All Rates

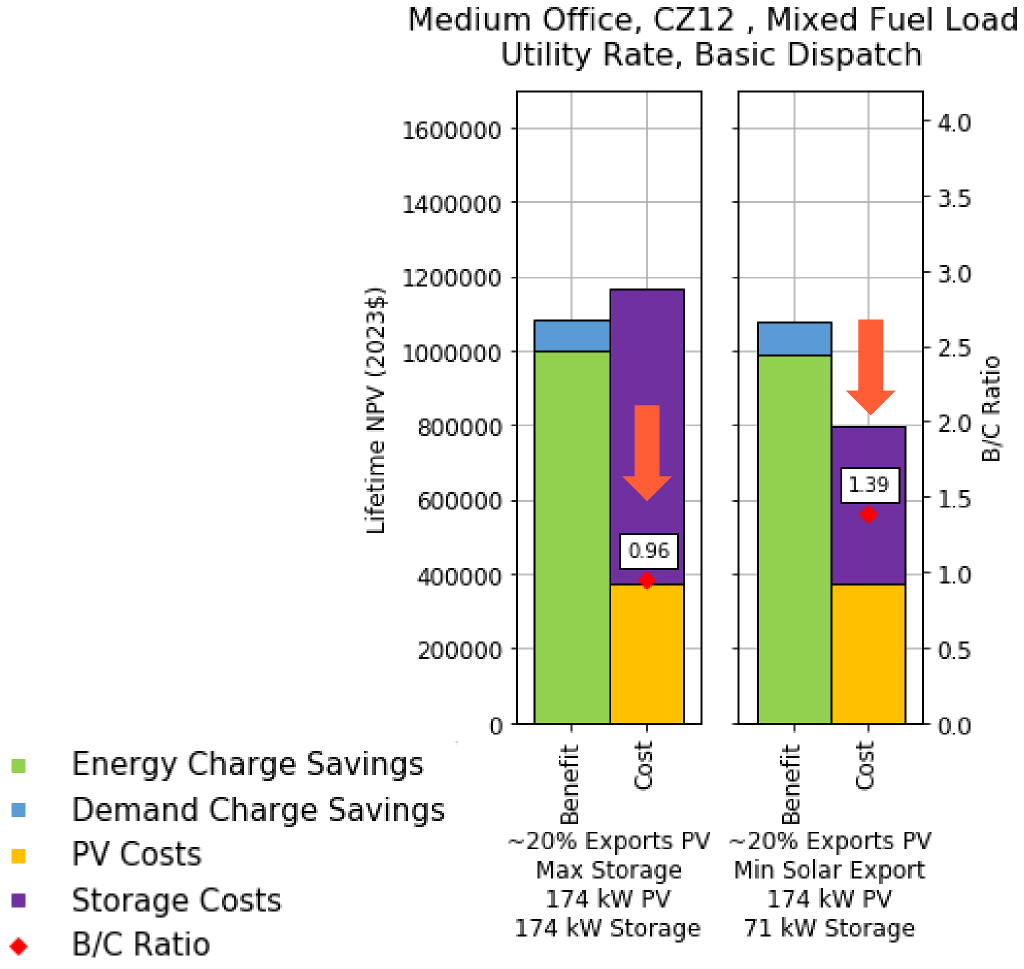


Appendix – PV+Storage Additional Results

Basic dispatch limits cost-effectiveness

+ **PV+Storage still cost-effective with Basic dispatch under utility rates**
  - Battery charges on PV net exports and discharges when load again exceeds PV production
+ **Basic dispatch matches TOU-periods, and building load profile reasonably well, to reduce energy costs and demand charges**

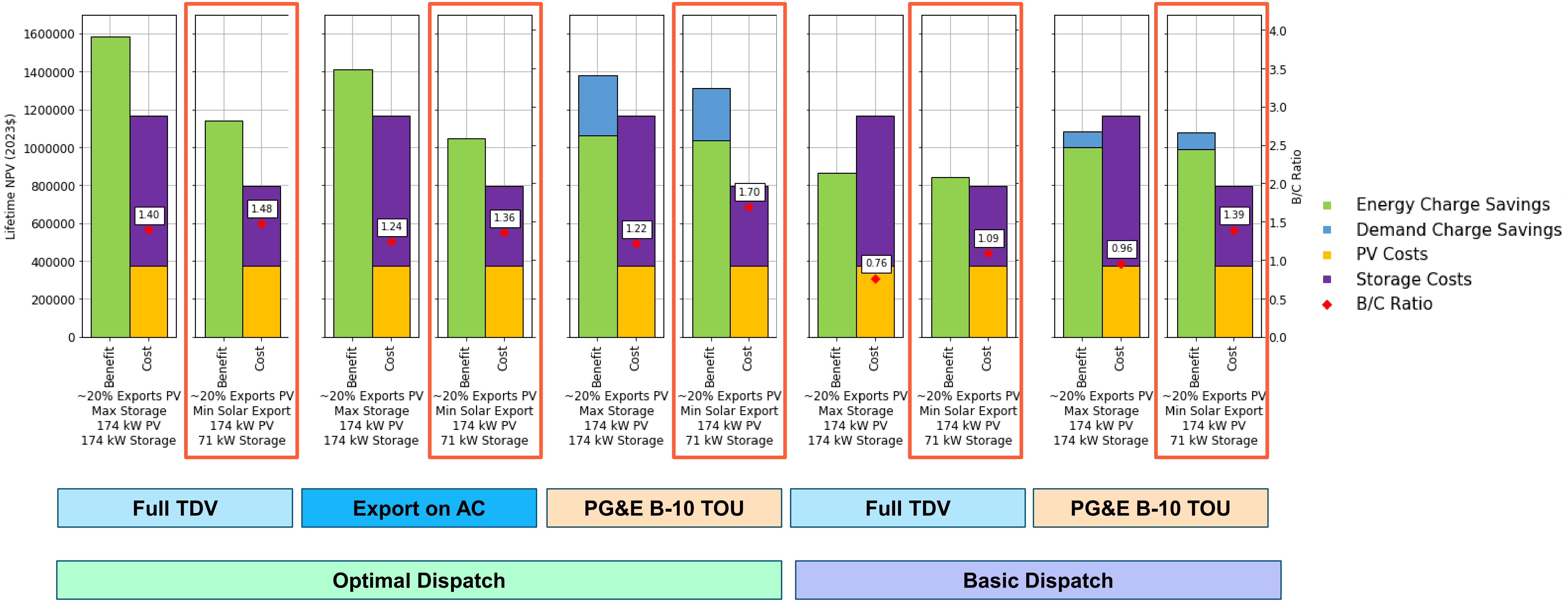
Cost Effectiveness – B10-TOU Rate, Basic Dispatch



PV+Storage Cost Effectiveness Summary

+ For smaller storage size, cost effective across all configurations

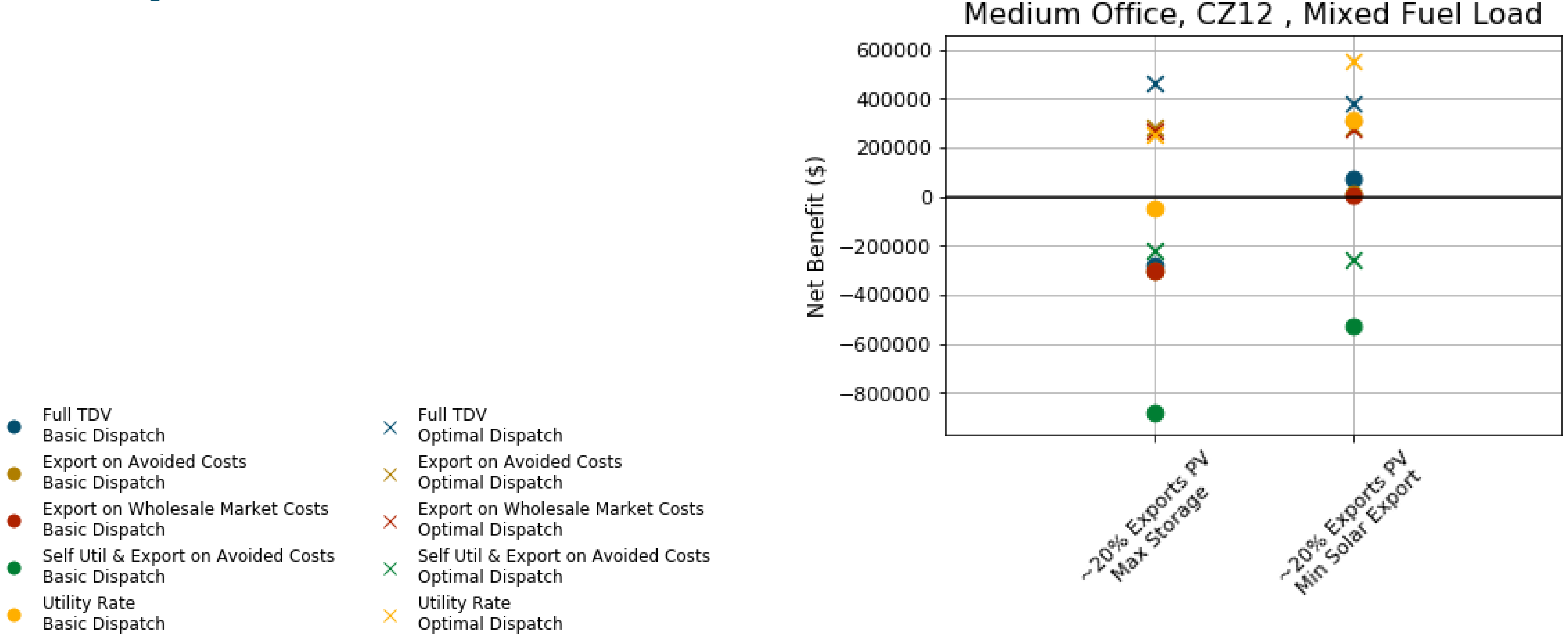
Medium Office, CZ 12, Mixed Fuel



PV+Storage System Net Benefits

- Basic dispatch limits cost-effectiveness, but PV+Storage is still cost-effective

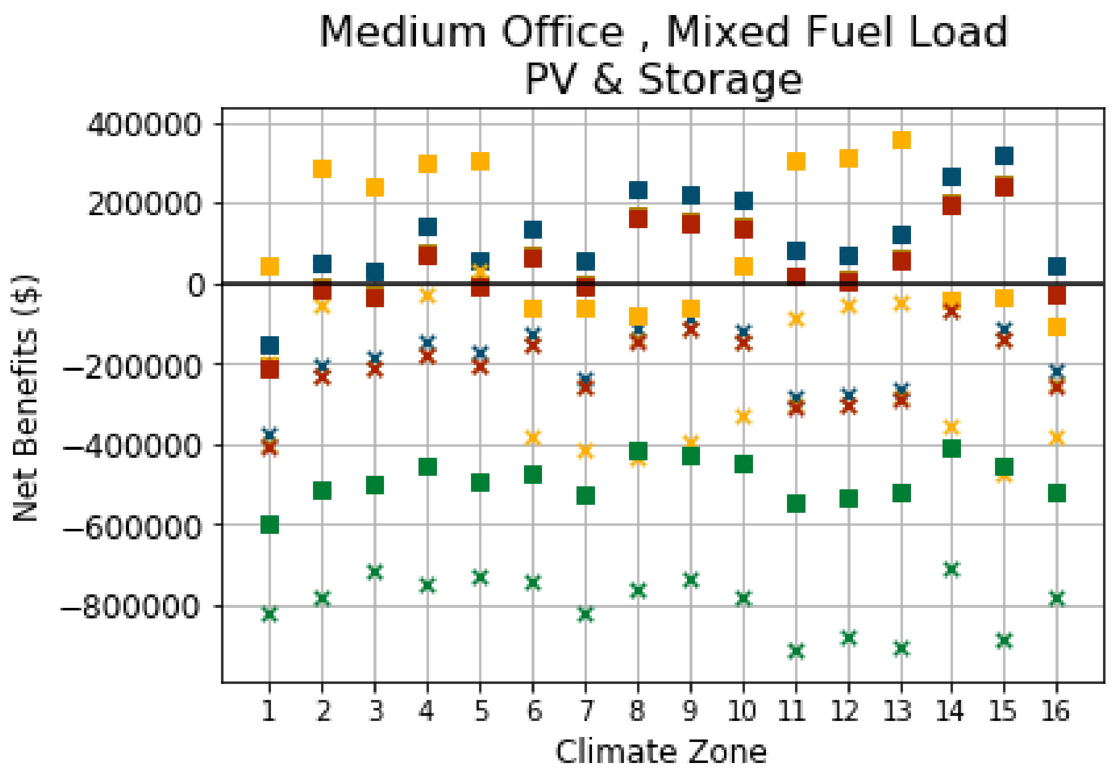
Cost Effectiveness, All Sizes, All Rates



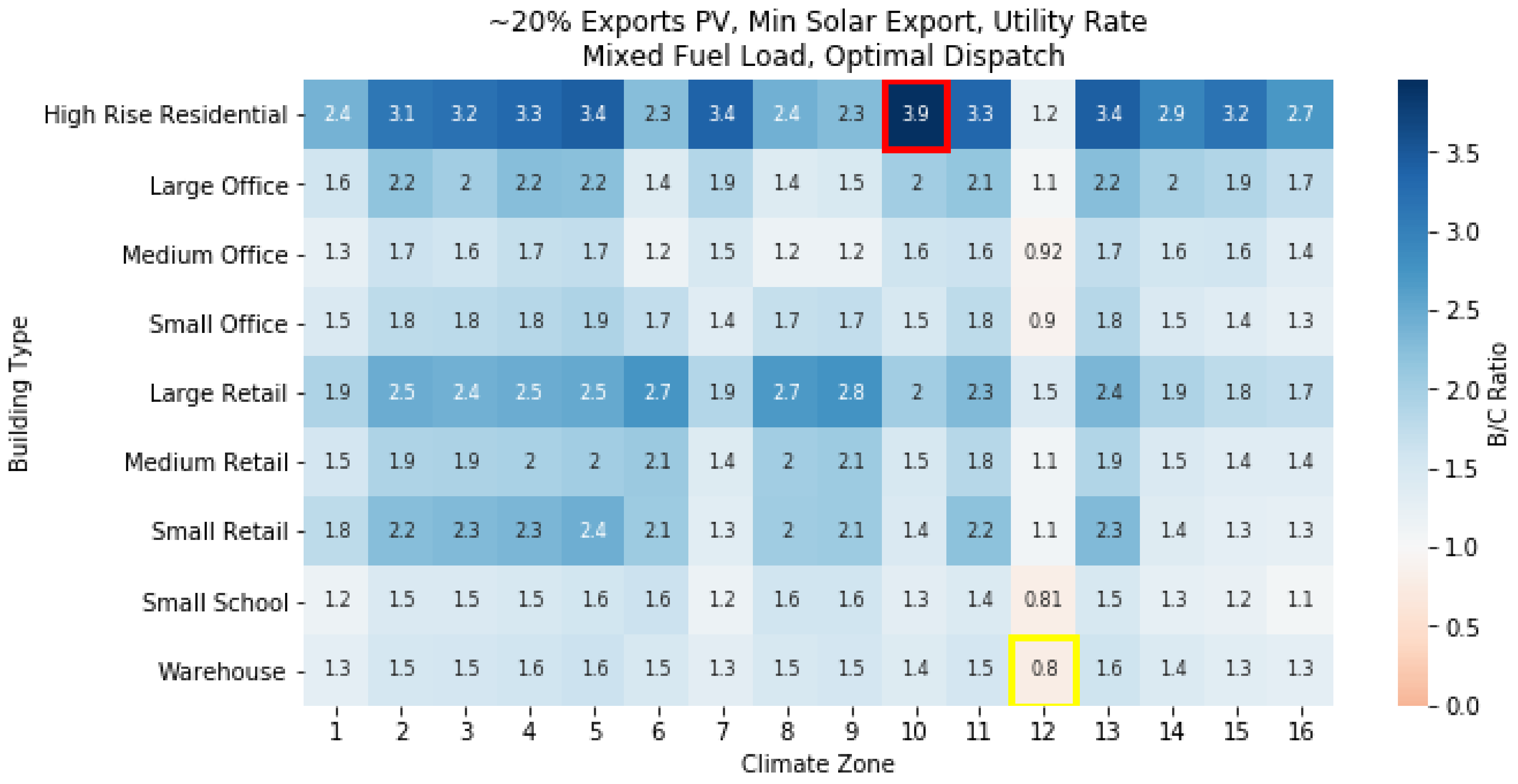
PV+Storage System Net Benefits, Basic Dispatch

- Expanding to medium office, all climate zones, general trend stays consistent
- Basic dispatch limits cost-effectiveness, but smaller PV+Storage is still cost-effective in most climate zones
- Rate sensitivity of import/export under avoided costs is not cost-effective
- Utility rate has mixed impacts on cost-effectiveness

Cost Effectiveness, All Rates & Climate Zones



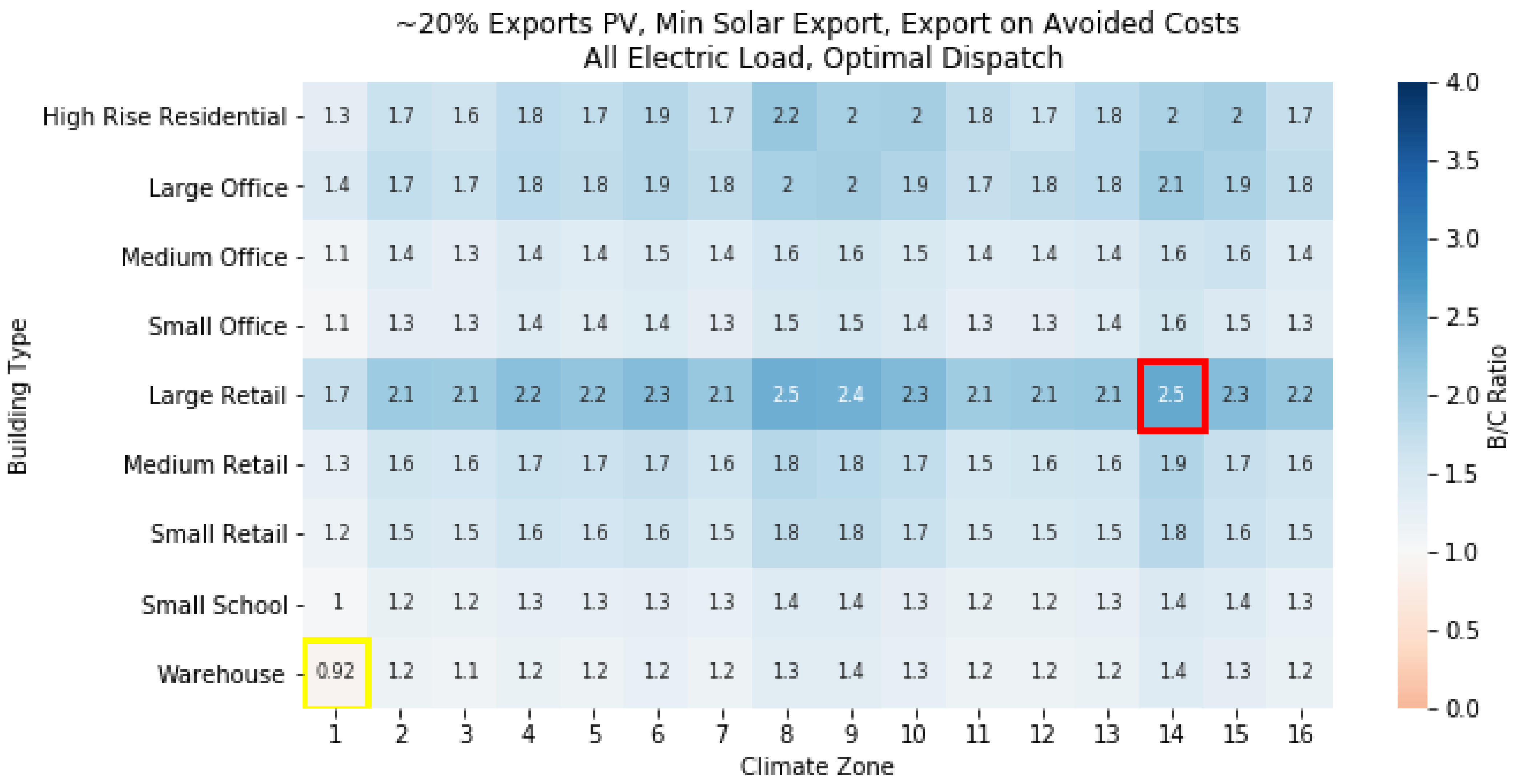
PV + Storage Optimal Dispatch on Utility Rates Across Building Types w/ LADWP & SMUD



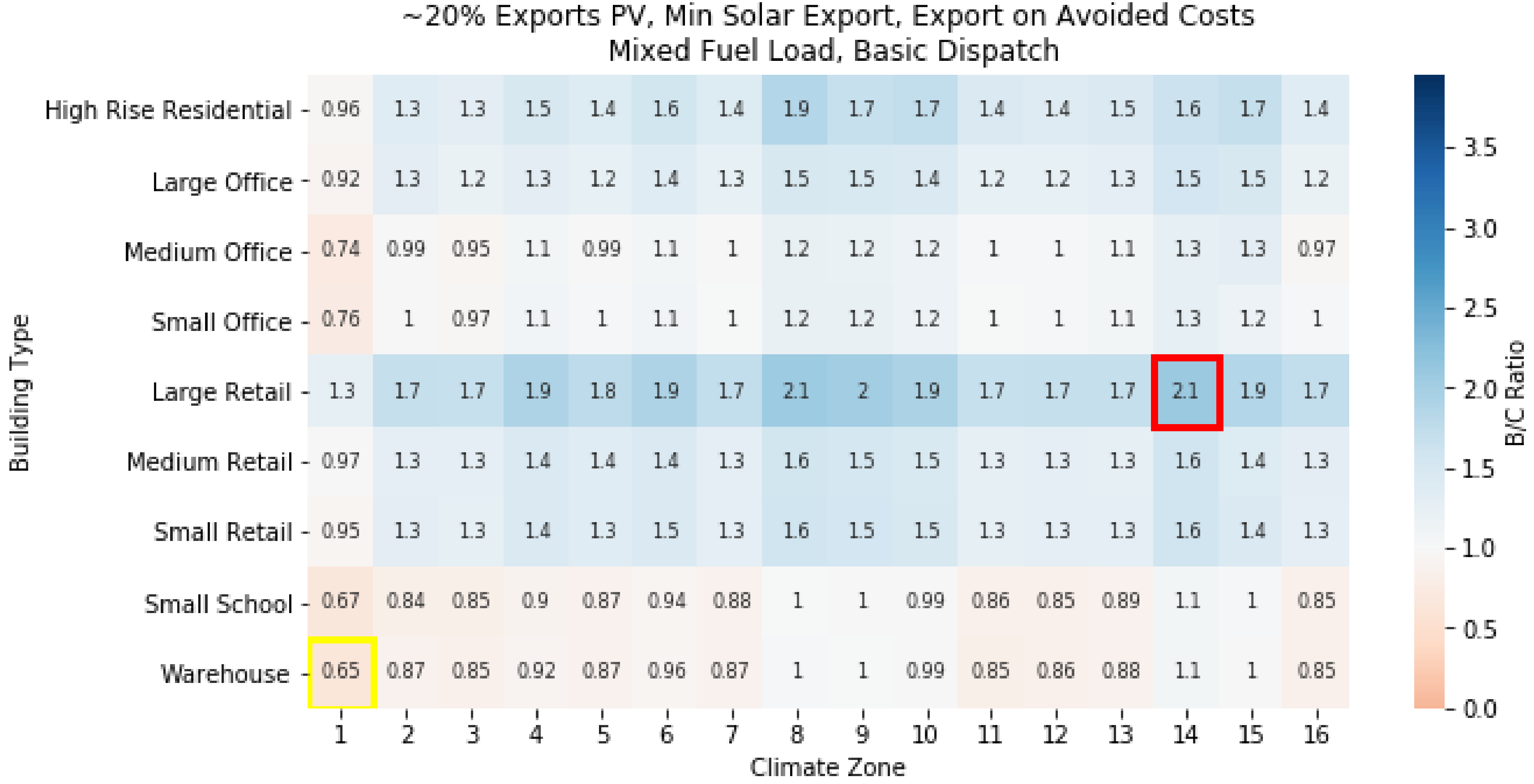
Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	2.4	3.1	3.2	3.3	3.4	2.3	3.4	2.4	2.3	3.9	3.3	1.2	3.4	2.9	3.2	2.7
Large Office	1.6	2.2	2	2.2	2.2	1.4	1.9	1.4	1.5	2	2.1	1.1	2.2	2	1.9	1.7
Medium Office	1.3	1.7	1.6	1.7	1.7	1.2	1.5	1.2	1.2	1.6	1.6	0.92	1.7	1.6	1.6	1.4
Small Office	1.5	1.8	1.8	1.8	1.9	1.7	1.4	1.7	1.7	1.5	1.8	0.9	1.8	1.5	1.4	1.3
Large Retail	1.9	2.5	2.4	2.5	2.5	2.7	1.9	2.7	2.8	2	2.3	1.5	2.4	1.9	1.8	1.7
Medium Retail	1.5	1.9	1.9	2	2	2.1	1.4	2	2.1	1.5	1.8	1.1	1.9	1.5	1.4	1.4
Small Retail	1.8	2.2	2.3	2.3	2.4	2.1	1.3	2	2.1	1.4	2.2	1.1	2.3	1.4	1.3	1.3
Small School	1.2	1.5	1.5	1.5	1.6	1.6	1.2	1.6	1.6	1.3	1.4	0.81	1.5	1.3	1.2	1.1
Warehouse	1.3	1.5	1.5	1.6	1.6	1.5	1.3	1.5	1.5	1.4	1.5	0.8	1.6	1.4	1.3	1.3

CZ	Utility
1	PG&E
2	PG&E
3	PG&E
4	PG&E
5	PG&E
6	**LADWP**
7	SDG&E
8	**LADWP**
9	**LADWP**
10	SCE
11	PG&E
12	SMUD
13	PG&E
14	SCE
15	SCE
16	SCE

PV + Storage Optimal Dispatch on TDV/Exported on Avoided Costs Across Building Types – All-Electric



PV + Storage Basic Dispatch on TDV/Exported on Avoided Costs Across Building Types



Building Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
High Rise Residential	0.96	1.3	1.3	1.5	1.4	1.6	1.4	1.9	1.7	1.7	1.4	1.4	1.5	1.6	1.7	1.4
Large Office	0.92	1.3	1.2	1.3	1.2	1.4	1.3	1.5	1.5	1.4	1.2	1.2	1.3	1.5	1.5	1.2
Medium Office	0.74	0.99	0.95	1.1	0.99	1.1	1	1.2	1.2	1.2	1	1	1.1	1.3	1.3	0.97
Small Office	0.76	1	0.97	1.1	1	1.1	1	1.2	1.2	1.2	1	1	1.1	1.3	1.2	1
Large Retail	1.3	1.7	1.7	1.9	1.8	1.9	1.7	2.1	2	1.9	1.7	1.7	1.7	2.1	1.9	1.7
Medium Retail	0.97	1.3	1.3	1.4	1.4	1.4	1.3	1.6	1.5	1.5	1.3	1.3	1.3	1.6	1.4	1.3
Small Retail	0.95	1.3	1.3	1.4	1.3	1.5	1.3	1.6	1.5	1.5	1.3	1.3	1.3	1.6	1.4	1.3
Small School	0.67	0.84	0.85	0.9	0.87	0.94	0.88	1	1	0.99	0.86	0.85	0.89	1.1	1	0.85
Warehouse	0.65	0.87	0.85	0.92	0.87	0.96	0.87	1	1	0.99	0.85	0.86	0.88	1.1	1	0.85

Energy+Environmental Economics

Appendix - Reliability & Resiliency Inputs

Key Reliability & Resiliency Assumptions

+ Benefit calculation methodology

- Reliability (ability to cover short-duration unplanned T&D power interruptions)
  - average T&D interruption probability * energy availability in PV and storage * interruption costs (VoLL)
- Resiliency (ability to cover long-duration multi-day planned outage events)
  - covered critical load by PV and storage during outage days * interruption costs (VoLL) + covered non-critical load * VoLL * 50%

+ Reliability metrics

- From PGE 2019 Reliability Report
- SAIDI – 117.7
- SAIFI – 1.010
- CAIDI – 116.5

+ Interruption costs (VoLL)

- From LBNL Interruption Cost Estimate (ICE)
- By building type
  - Medium Office: 85.39 2016$/kWh

+ Outage events

- A 3-day outage event within the first week of November

+ Critical load

- Assume 10% of building load

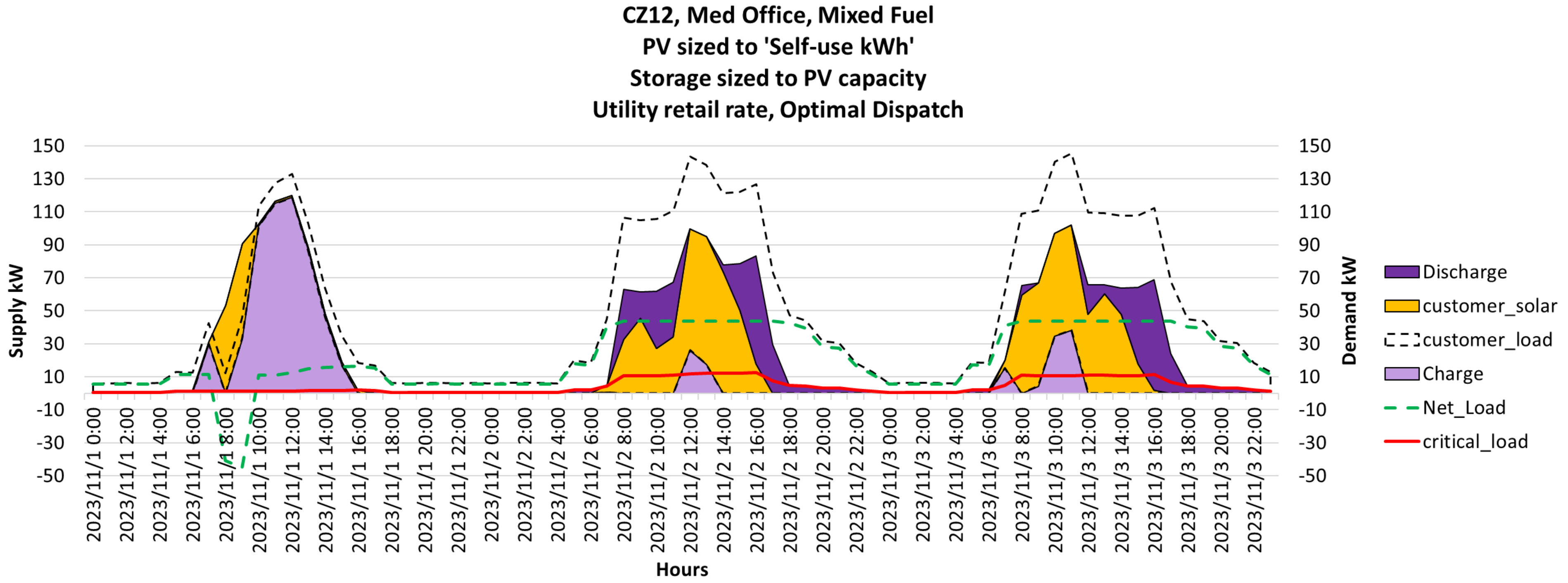
Storage will be encouraged to cover critical load during planned outage days to obtain resiliency benefits

VoLL Assumptions by Building Type

Building Type	Load Type	MWh	Sector	VoLL 2016 $/kWh
High-rise Res	Mixed-fuel	691	Medium and Large C&I	69.86
Large Office	Mixed-fuel	3609	Medium and Large C&I	31.63
Medium Office	**Mixed-fuel**	**453**	**Medium and Large C&I**	**85.39**
Small Office	Mixed-fuel	62	Small C&I	223.41
Large Office	Mixed-fuel	1754	Medium and Large C&I	44.75
Medium Retail	Mixed-fuel	188	Medium and Large C&I	129.44
Medium Retail	Mixed-fuel	103	Small C&I	145.65
Small School	Mixed-fuel	179	Small C&I	91.17
Warehouse	Mixed-fuel	73	Small C&I	194.73

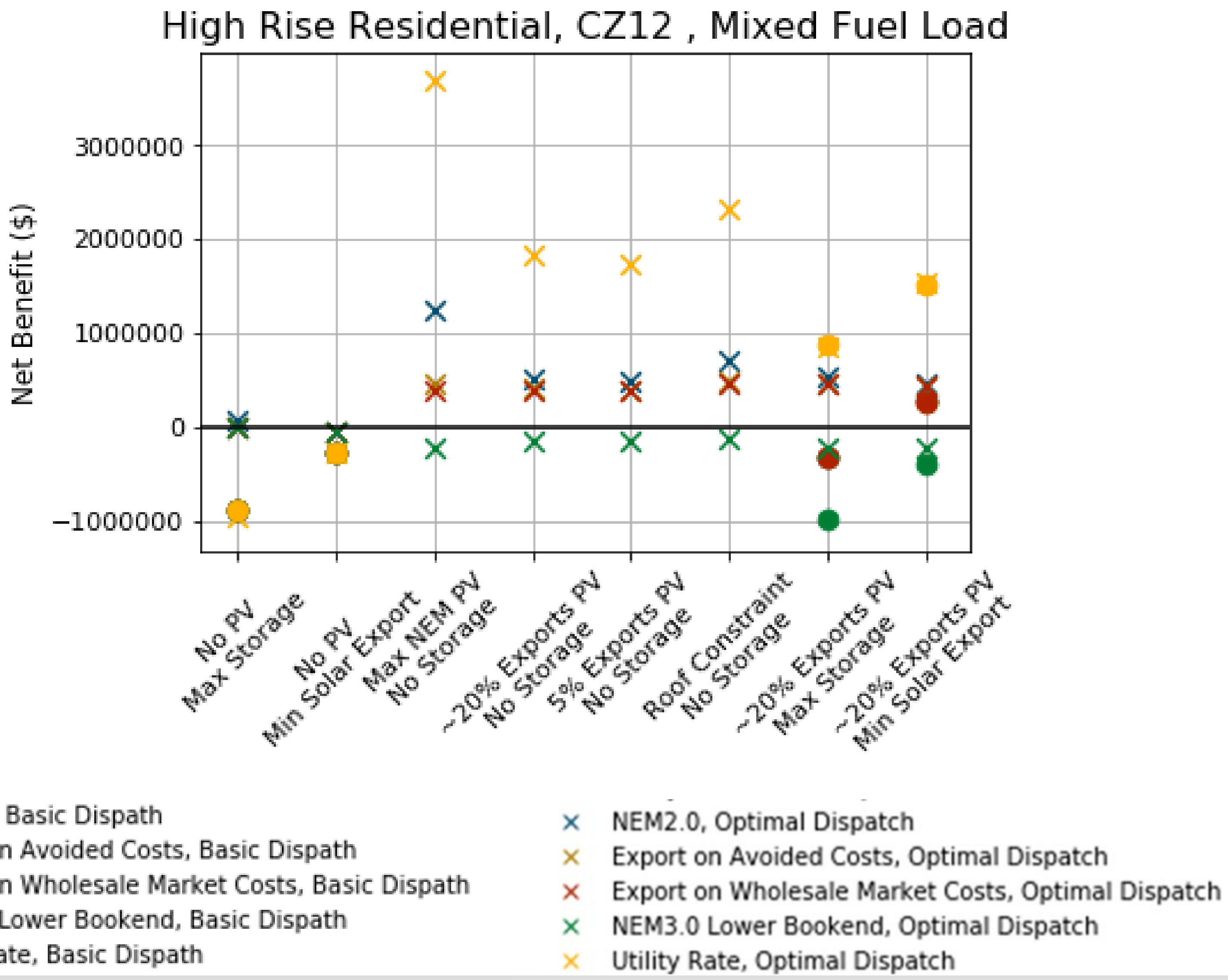
Detailed Operation – Outage Days

+ Optimal storage dispatch under utility retail rate
+ Storage discharges conservatively during non-solar hours to make sure it covers critical loads during these outage days as much as possible
+ Storage still discharges to reduce customer peak demand to minimize demand charges

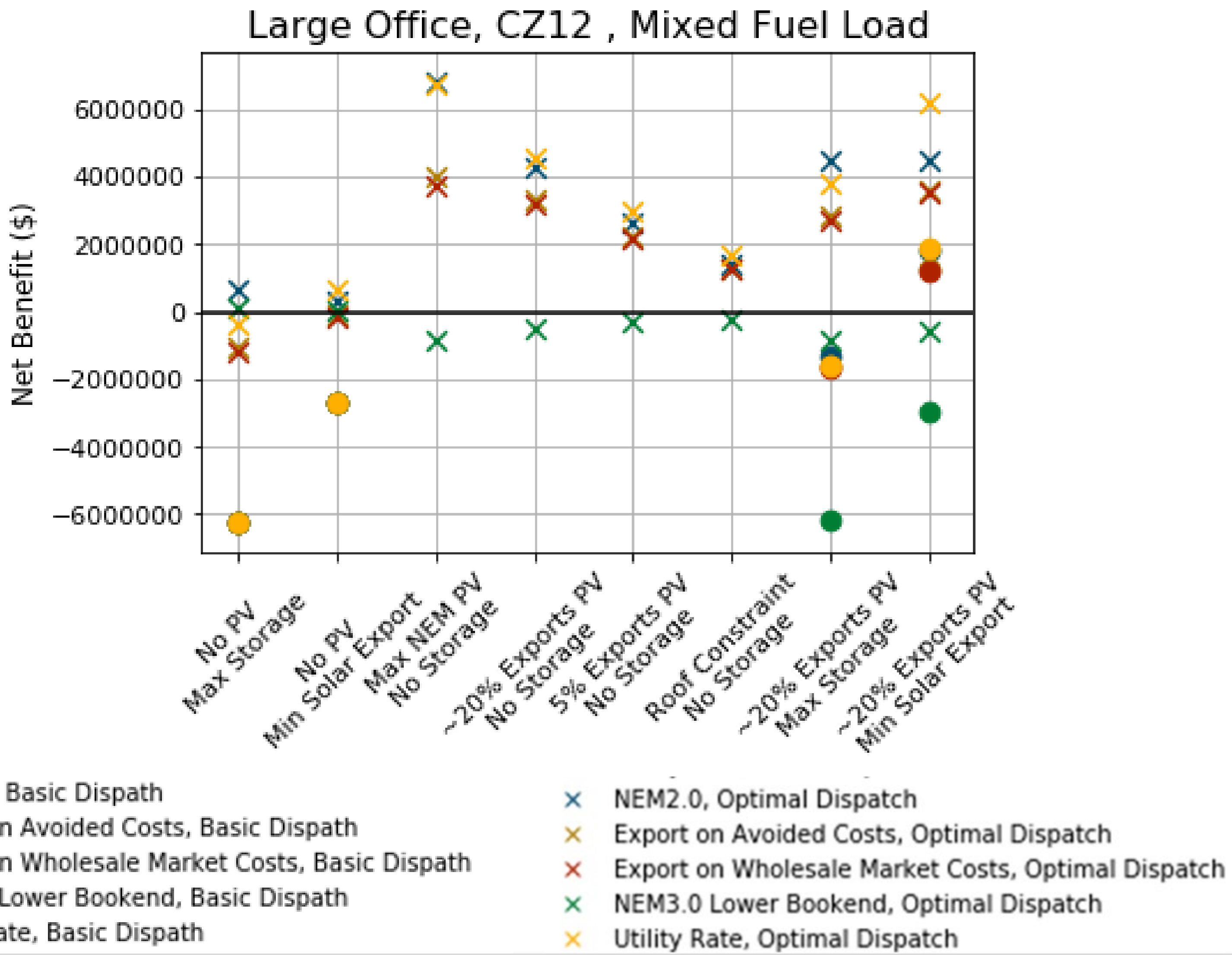


Appendix - Net Benefit Results By Building Type (CZ 12)

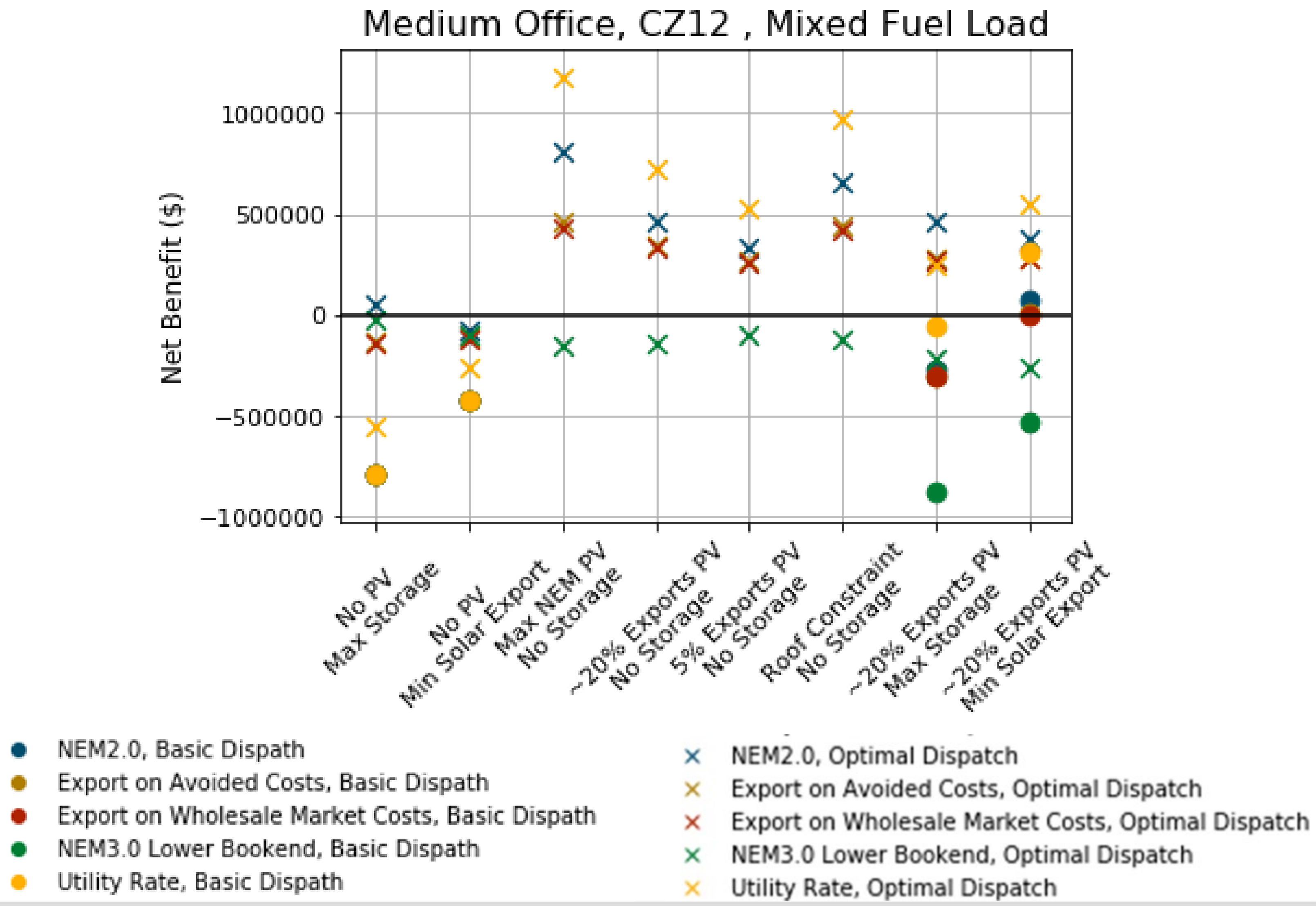
High Rise Residential



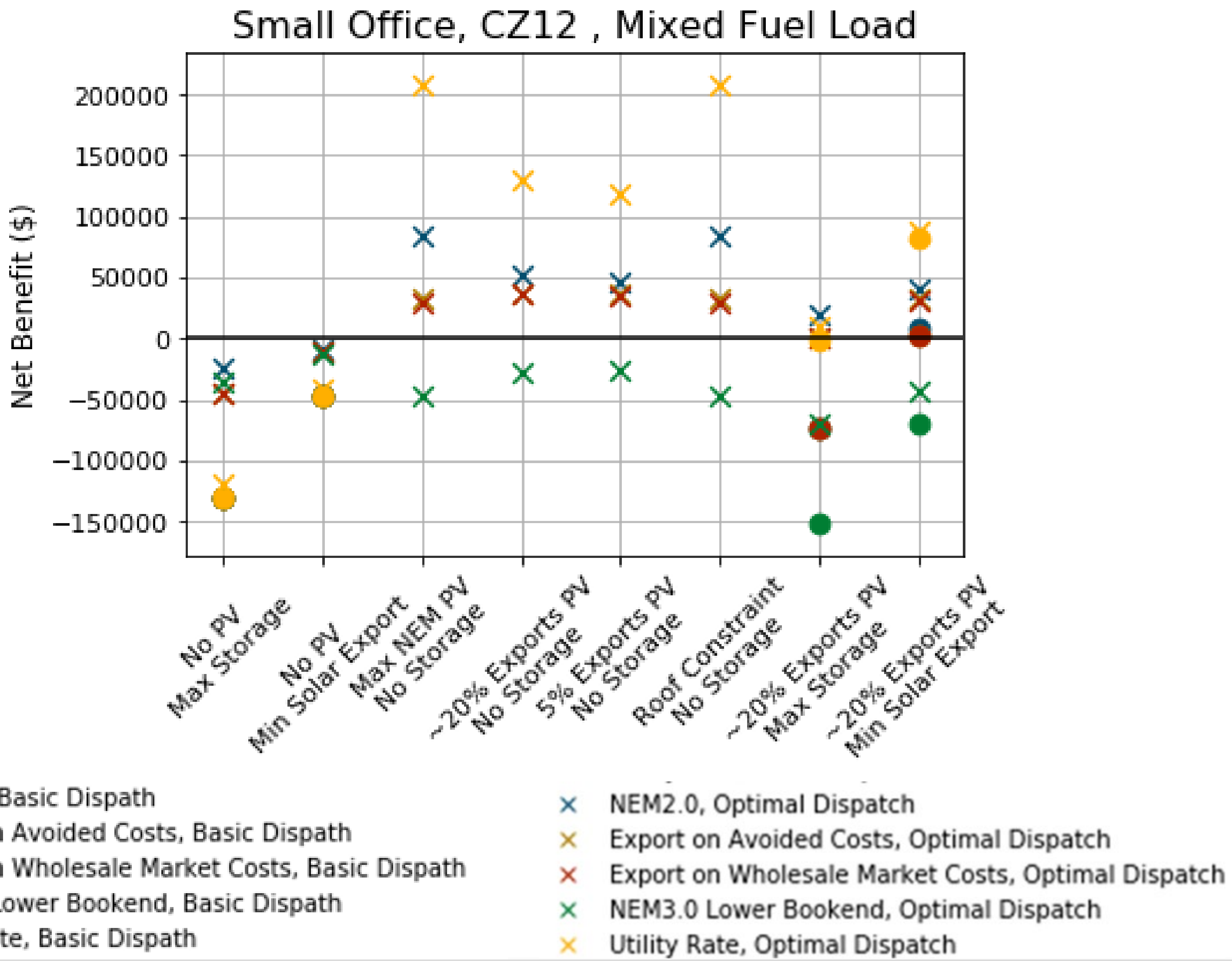
Large Office



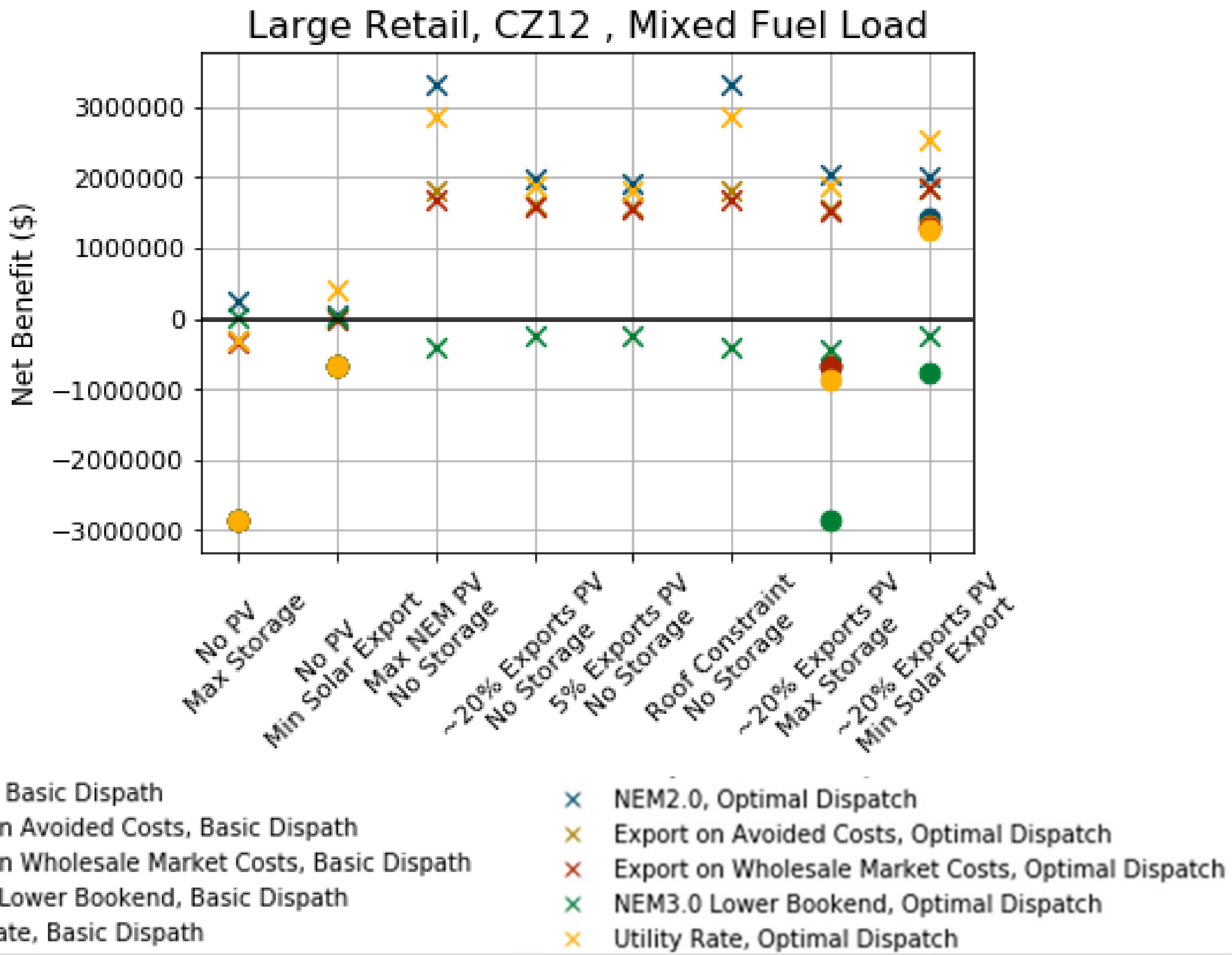
Medium Office

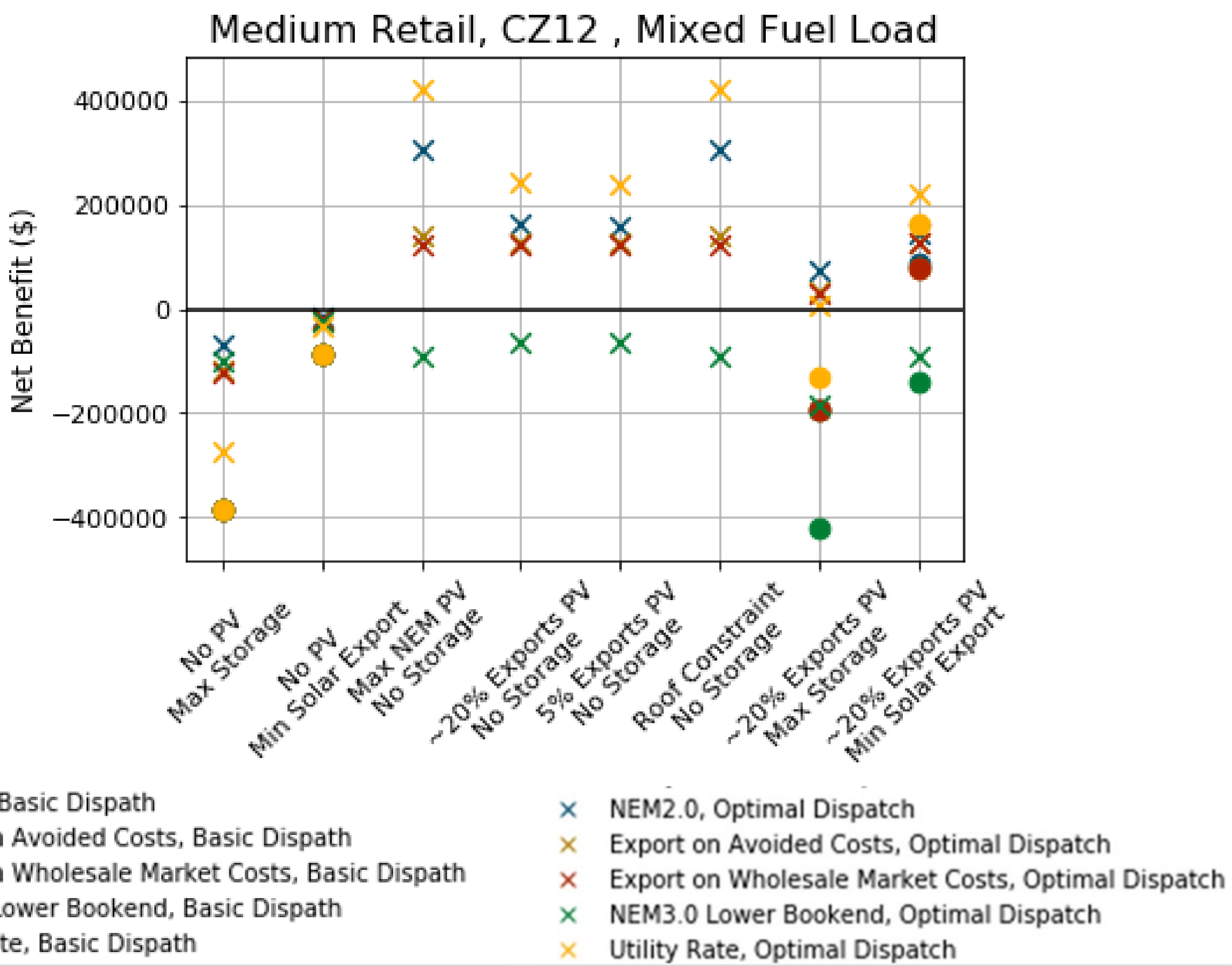


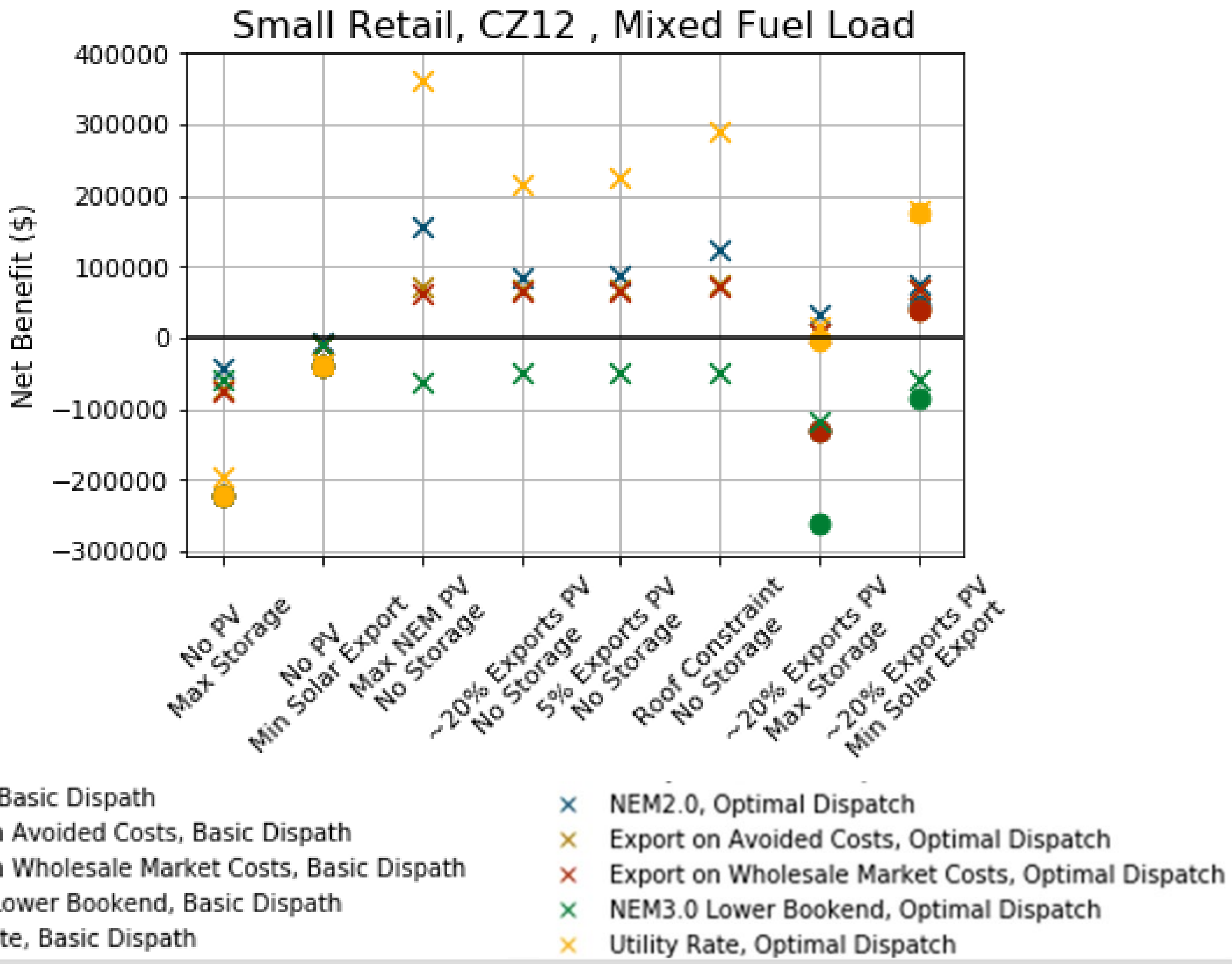
Small Office



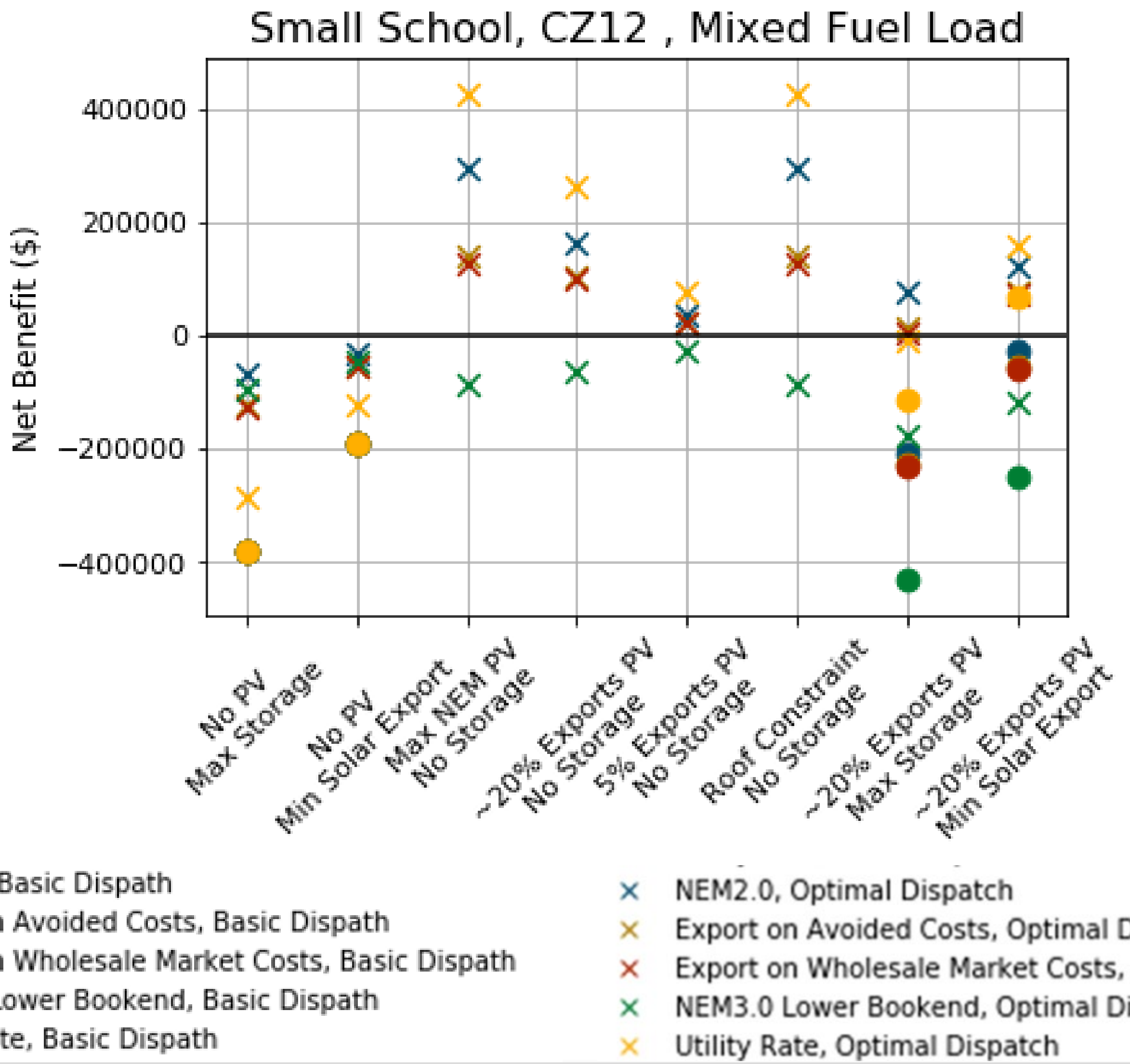
Large Retail



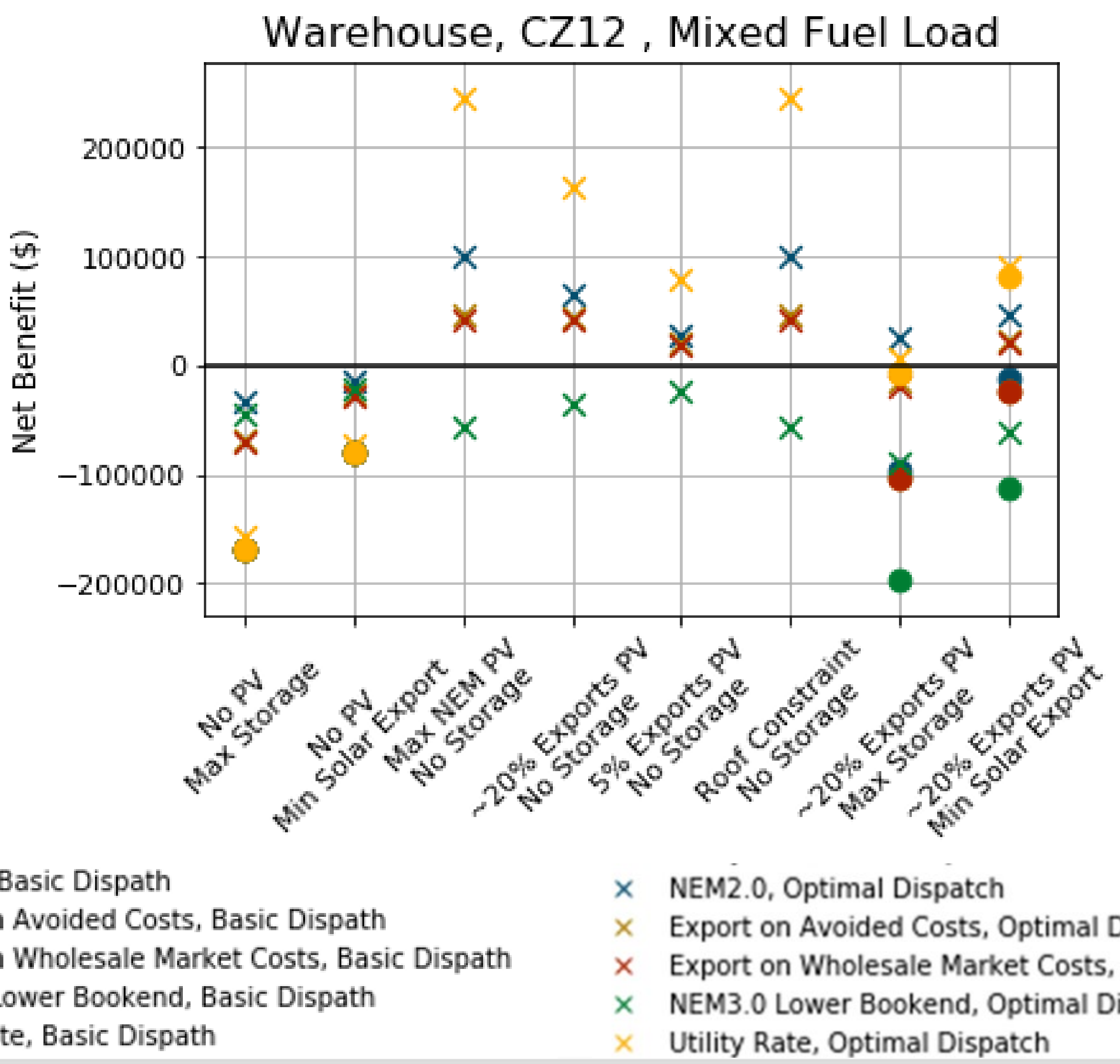

Medium Retail, CZ12 , Mixed Fuel Load
Net Benefit ($)
400000
200000
0
−200000
−400000
No PV
Max Storage
No PV
Min Solar Export
Max NEM PV
No Storage
~20% Exports PV
No Storage
5% Exports PV
No Storage
Roof Constraint
No Storage
~20% Exports PV
Max Storage
~20% Exports PV
Min Solar Export
NEM2.0, Basic Dispath
Export on Avoided Costs, Basic Dispath
Export on Wholesale Market Costs, Basic Dispath
NEM3.0 Lower Bookend, Basic Dispath
Utility Rate, Basic Dispath
NEM2.0, Optimal Dispatch
Export on Avoided Costs, Optimal Dispatch
Export on Wholesale Market Costs, Optimal Dispatch
NEM3.0 Lower Bookend, Optimal Dispatch
Utility Rate, Optimal Dispatch


Small Retail, CZ12 , Mixed Fuel Load
Net Benefit ($)
400000
300000
200000
100000
0
−100000
−200000
−300000
No PV Max Storage
No PV Min Solar Export
Max NEM PV No Storage
~20% Exports PV No Storage
5% Exports PV No Storage
Roof Constraint No Storage
~20% Exports PV Max Storage
~20% Exports PV Min Solar Export
NEM2.0, Basic Dispath
Export on Avoided Costs, Basic Dispath
Export on Wholesale Market Costs, Basic Dispath
NEM3.0 Lower Bookend, Basic Dispath
Utility Rate, Basic Dispath
NEM2.0, Optimal Dispatch
Export on Avoided Costs, Optimal Dispatch
Export on Wholesale Market Costs, Optimal Dispatch
NEM3.0 Lower Bookend, Optimal Dispatch
Utility Rate, Optimal Dispatch

Small School



Warehouse


Warehouse, CZ12 , Mixed Fuel Load
Net Benefit ($)
200000
100000
0
−100000
−200000
No PV
Max Storage
No PV
Min Solar Export
Max NEM PV
No Storage
~20% Exports PV
No Storage
5% Exports PV
No Storage
Roof Constraint
No Storage
~20% Exports PV
Max Storage
~20% Exports PV
Min Solar Export
NEM2.0, Basic Dispath
Export on Avoided Costs, Basic Dispath
Export on Wholesale Market Costs, Basic Dispath
NEM3.0 Lower Bookend, Basic Dispath
Utility Rate, Basic Dispath
NEM2.0, Optimal Dispatch
Export on Avoided Costs, Optimal Dispatch
Export on Wholesale Market Costs, Optimal Dispatch
NEM3.0 Lower Bookend, Optimal Dispatch
Utility Rate, Optimal Dispatch

HRMF and Nonresidential PV/Storage Proposed Draft Language

Staff Pre-Rulemaking Workshop

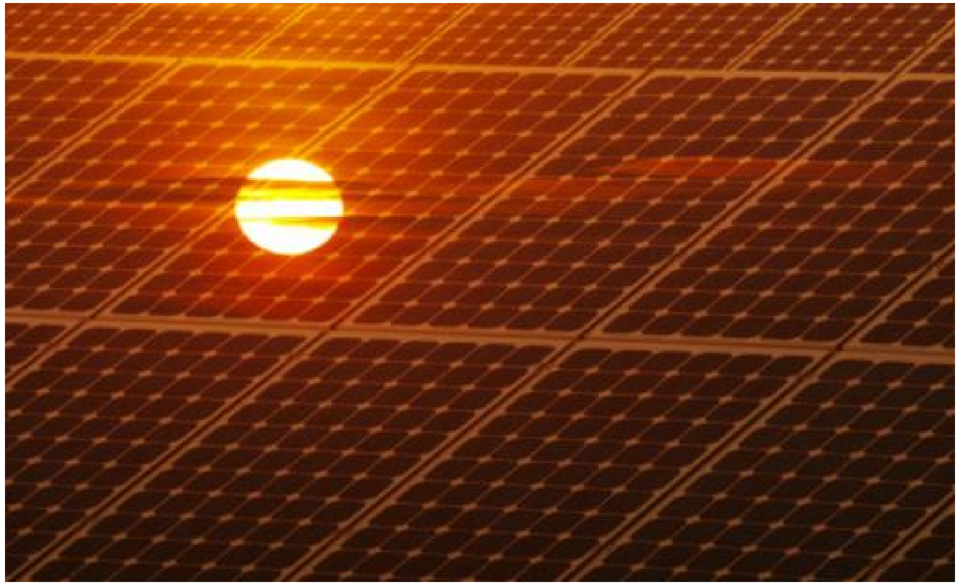
Presenter: Mazi Shirakh, PE: Senior Mechanical Engineer

Date: December 8, 2020

PV/Battery Storage Proposals for HRMF & Nonresidential Buildings

2022 T24 Standards PV Requirements

PV Requirements for:



1. MRMF and HRMF
2. Office
3. Retail and Grocery
4. Educational facilities
5. Warehouses
6. Reduced requirements for Auditorium, Convention Center, Hotel/Motel, Library, Medical/Clinic, Restaurant, Theater
7. Mixed occupancy building where one or more of these types-of-uses makeup at least 80 percent of the floor areas of the building

2022 T24 Standards PV Sizing

i. The PV system size determined by Equation 140.10-A, or (designed limit exports to less than 20% of annual generation)

ii. The total of all available Effective Annual Solar Access Areas (EASAA) multiplied by 14 W/ft². EASAA are roof and carport areas that are at least 80 contiguous square feet that have Effective Annual Solar Access. EASAA include rooftop areas on the building, covered parking areas and carports, and on other newly constructed structures on the site that are capable of structurally supporting a PV system per Title 24, Part2, Section 1511.2. EASAA exclude occupied roofs as specified by Title 24, Part 2, section 503.1.4.

2022 T24 Standards PV Sizing

EQUATION 140.10-A PHOTOVOLTAIC DIRECT CURRENT SIZE

$$kW_{PVdc} = (CFA \times A)/1000$$

WHERE:

kW_{PVdc} = Size of the PV system in kW

CFA = Conditioned floor area in square feet

A = PV capacity factor specified in Table 140.10-A for the building type

2022 T24 Standards PV Sizing

Table 140.10-A – PV Capacity Factors (Partial)

	Factor A – Minimum PV Capacity (W/ft² of conditioned floor area)		
Climate Zone	1, 3, 5, 16	2, 4, 6-14	15
Grocery	TBD	TBD	TBD
Highrise Multifamily	1.82	2.21	2.77
Office, Financial Institutions, Unleased Tenant Space			
< 25,000 ft²	4.04	4.44	5.02
25,000 ft² - 150,000 ft²	2.59	3.13	3.80
> 150,000 ft²	2.16	2.64	3.00

2022 T24 Standards PV Exceptions

1. Exception for small PV systems compared to building loads
2. Exception for areas with high snow loads
3. Exception for multi-tenant buildings not eligible for VNEM and community solar

2022 T24 Standards Battery Storage Sizing

Battery Storage is sized to limit exports to less than 10% of annual generation

EQUATION 140.10-B - BATTERY STORAGE RATED ENERGY CAPACITY

$kWh_{batt} = kW_{PVdc} \text{ x } B / D^{0.5}$

WHERE:

kWh_{batt} = Rated Useable Energy Capacity of the battery storage system in kWh

kW_{PVdc} = PV system capacity required by section 140.10A in kWdc

B = Battery energy capacity factor specified in Table 140.10-B for the building type

D = Rated single charge-discharge cycle AC to AC (round-trip) efficiency

2022 T24 Standards Battery Storage Sizing

Table 140.10-B – Battery Storage Capacity Factors (Partial)

	Factor B – Energy Capacity	Factor C – Power Capacity
Storage to PV Ratio	Wh/W	W/W
Grocery	TBD	TBD
Highrise Multifamily	1.03	0.26
Office, Financial Institutions, Unleased Tenant Space		
< 25,000 ft²	1.48	0.37
25,000 ft² - 150,000 ft²	1.68	0.42
> 150,000 ft²	1.73	0.43
Retail		
< 25,000 ft²	0.93	0.23
25,000 ft² - 150,000 ft²	1.03	0.26
> 150,000 ft²	1.07	0.27

PV and Battery Sizing Example

50,000 Medium Office in CZ12 – The Energy Commission Building, Assuming No Roof Area Limitations

EQUATION 140.10-A PHOTOVOLTAIC DIRECT CURRENT SIZE

$kW_{PVdc} = (CFA \times A)/1000$:
(50,000 x 3.13)/1000 = 152 kWdc PV System

EQUATION 140.10-B - BATTERY STORAGE RATED ENERGY CAPACITY

$kWh_{batt} = kW_{PVdc} \times B / D^{0.5}$:

152 x 1.68 / 0.95 = 268 kWh Battery Storage System

EQUATION 140.10-C - BATTERY STORAGE RATED POWER CAPACITY

$kWh_{batt} = kW_{PVdc} \times C$:

152 x 0.42 = 64 kW Battery Storage System

Actual system will likely be smaller due to roof area limitations

Questions ?

We will Resume Again at 12:30

Cleanup Language

Staff Pre-Rulemaking Workshop

Presenter: Bill Pennington

Mazi Shirakh, PE: Senior Mechanical Engineer

Date: December 8, 2020

Cleanup Language

Community Solar (CS) Revisions

Resource Requirements

1. Location – Distribution circuit serving the municipality or county
2. Size – 20 MW or less
3. New – Developed for the CS program; cover gaps with retired bundled RECs
4. New application if new resources are added (Executive Director review)

Program Requirements

1. Energy bill credit – clarify $ benefits must exceed participation costs
2. Original Home Purchaser – option to install rooftop solar instead
3. Home Opt-out – anytime if T24 compliant rooftop system is installed at that time
4. Public agency Applications – public comment before submission to CEC

2022 Building Standards Cleanup

1. New exception for PVs systems that are less than 1.9 kWDC per building
   - ✓ Addresses the ADU issue
2. Exception 1 – Clarify PV systems are not required to be larger than what can be installed in the Available Effective Annual Solar Access Area (EASAA); clarifies what happens when EASAA is greater than 80 square feet, but smaller than the area required for full NEM compliance
3. No Longer needed Exceptions to Section 150.1(c)14 since items 1 and 2 above will handle these cases
   i. Exceptions 2 (CZ15)
   ii. Exception 3 (2-story buildings)
   iii. Exception 4 (3-story buildings)
4. New Exception for occupied roofs (flat patio areas) – As described by Title 24, Part 2, section 503.1.4.
5. New Exception for areas for high snow loads

2022 Building Standards Cleanup

Definition of Effective Annual Solar Access Areas:

Effective Annual Solar Access Areas (EASAA) are roof and carport areas that are at least 80 contiguous square feet that have Effective Annual Solar Access. EASAA include rooftop areas on the building, covered parking areas and carports, and on other newly constructed structures on the site that are capable of structurally supporting a PV system per Title 24, Part2, Section 1511.2. EASAA exclude occupied roofs as specified by Title 24, Part 2, section 503.1.4

Cleanup Continued

JA 11- Qualification Requirements for Photovoltaic Systems

1. Clarify confusing system orientation language related to prescriptive (90 to 300 DFTN) and performance approach requirements
2. Clarify CFI1 (150-270 DFTN) and CFI2 (105-300 DFTN) requirements
3. **Solar assessment tool** - Amend language based on lessons learned from prior approval of solar assessment tools: create clear list of functions needed for approval
4. Clearly define in Part 6 “Annual Solar Access”, “Effective Annual Solar Access”, and “Effective Annual Solar Access Areas”; EASAA facing north must use the performance path
5. Others?

Cleanup Continued

JA 12 - Qualification Requirements for Battery Storage Systems

1. Allow credit for “unpaired” battery storage systems
2. Clarify that roundtrip efficiency requirements are for prescriptive approach compliance only; performance modeled with actual RT efficiency
3. Add that minimizing GHGs may be a future control strategy for battery storage systems
4. Add control strategy requirements for unpaired battery storage systems; include only TOU and Advanced Demand Flexibility control strategies (not Basic)

Questions?

Open for Comments

Comments on Todays Workshop

Due Date: December 24, 2020 By 5:00 PM

Comments to be submitted to:
https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-03