PASADENA

Pasadena Water and Power

FINALIZATION OF AN OPTIMIZED STRATEGIC PLAN ESTABLISHING A ROADMAP TO MEET THE GOALS SET FORTH BY CITY COUNCIL-ADOPTED RESOLUTION 9977

City Council

May 5, 2025

Item 13

Background

Pasadena Water and Power

- On March 25, 2024, City Council approved entering a contract with Energy and Environmental Economics, Inc. ("E3") for consulting services related to the development of an Optimized Strategic Plan ("OSP") for achieving the carbon-free goals of Resolution 9977
  - At the Council's direction and under contract to the City Manager, E3 developed a robust technical analysis that provides foundational data and evaluation that lays out the key steps and future decision points that will best position PWP to achieve the goal to source all electricity from carbon free sources by the end of 2030 while maintaining reliability and limiting cost impacts to customers
  - A key theme in the development of the OSP was coordination and collaboration between PWP, stakeholder groups, and the Pasadena community
    - To date, E3 discussed the development and analysis of the multiple OSP portfolios, including:
      - (10) Technical Advisory Panel meetings
      - (4) Updates to the Municipal Services Committee ("MSC")
      - (3) Updates to the Environmental Advisory Panel ("EAC")
      - (1) Community meeting

MSC Recommendation

- On April 8, 2025, the MSC provided staff guidance on the OSP energy resource portfolios, which present a range of options to achieve the goals of Resolution 9977
  - > MSC recommended that staff pursue a final OSP report that includes the 4 portfolios that:
    - Preserve the Glenarm Power Plant as a backup/limited resource
    - Accelerate the development of local solar resources
      - » Potential target of 100 MW

Staff Recommendation

- Adopt the MSC recommendation;
- Direct PWP to complete an Optimized Strategic Plan ("OSP") final report, establishing a roadmap to meet the goals set forth by City Council-adopted Resolution 9977;
- Direct staff to include the following five foundational components in the final OSP report, each of which has been demonstrated to be an important part of a portfolio that balances Resolution 9977 goals of carbon-free energy, reliability, affordability, and equity:
  - > Procurement of external renewables and storage resources, with a focus on resource diversity;
  - > Accelerated development of local solar and storage resources within the PWP service territory;
  - > Development of demand-side programs and rate structures to encourage load flexibility, managed electric vehicle charging, and other cost-effective demand response;
  - > Preservation of the Glenarm Power Plant as a backup/limited resource for reliability; and
  - > Pursuit of a balanced position in the CAISO wholesale energy market, allowing for sales and purchases to manage imbalances in supply and demand;
- Direct staff to continually evaluate and implement approaches to achieve the City's goals set forth in Resolution 9977 by the end 2030 and to utilize the 2028 Waypoint ("Waypoint") to develop a revised Integrated Resource Plan that is consistent with state requirements and Resolution 9977

Development of an Optimized Strategic Plan for Pasadena Water and Power

Update to City Council

May 5, 2025

Nick Schlag, Partner
Mike Sontag, Director
Nathan Lee, Sr. Managing Consultant
Michaela Levine, Sr. Managing Consultant

Energy+Environmental Economics

Agenda – May 5, 2025, Update to City Council

Purpose of Today's Update: Share results from OSP Case Study analysis and request approval of the Plan outline to implement goals of Resolution 9977.

- Background and motivation for the OSP
- Key findings and case studies from the Optimized Strategic Plan technical analyses
- Outline for the Optimized Strategic Plan

Defining "Optimized Strategic Plan"

The Optimized Strategic Plan is…

…a roadmap that lays out the key steps and future decision points that will best position Pasadena to achieve its goal to source all electricity from carbon-free sources by the end of 2030 while maintaining reliability and limiting cost impacts to customers

The Optimized Strategic Plan will…

…consider how new generation resources, investments in transmission and distribution infrastructure, and customer programs can facilitate transition to Pasadena's carbon-free goal

Progress to Date Towards Resolution 9977 Goals

2031 clean energy metrics based on resources currently owned or contracted to PWP (includes projects currently under development)

Metric 1: **86%** of PWP's annual retail sales is generated annually by the carbon-free resources in PWP's portfolio (SB100)

Metric 2: **78%** of annual energy produced by resources owned by or contracted to PWP is from carbon-free sources

Metric 3: **83%** of PWP's hourly energy needs are matched by carbon-free generation resources in each hour across the year

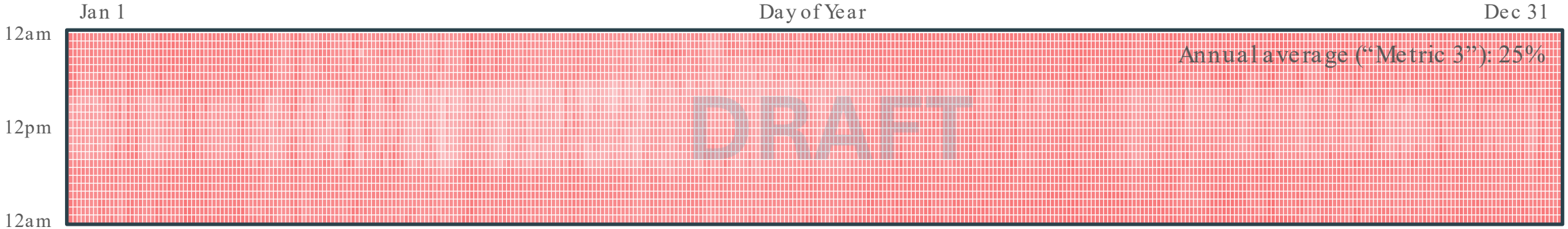
Future projects currently under development

- + Bonanza solar (105 MW) and storage (55 MW)
- + Grace solar (50 MW)
- + Geysers geothermal (25 MW)
- + Coso geothermal (10 MW)
- + CalWind (20 MW)
- + Glenarm battery storage (25 MW)

As published on the PWP Clean Energy Tracker (does not include resources designated as "in progress")

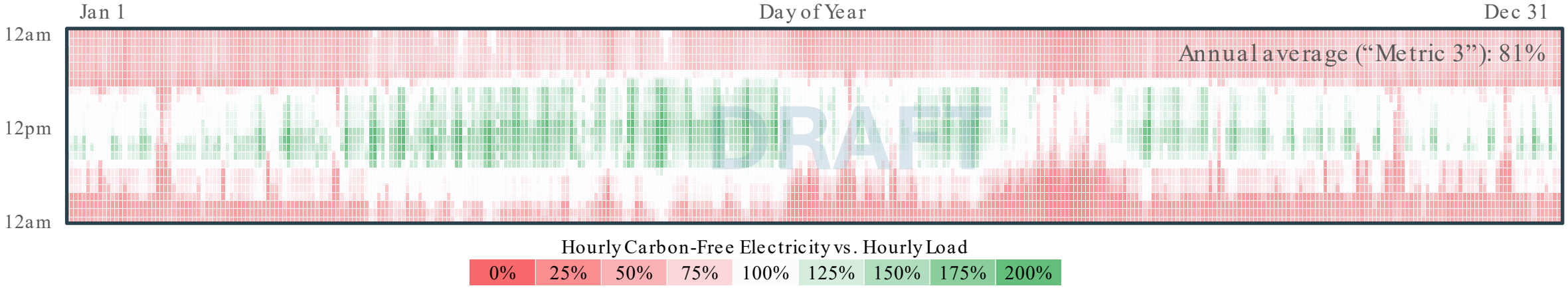
Balance of Carbon-Free Energy Resources based on Currently Executed Contracts

2025 Carbon-Free Electricity Supply



2031 Carbon-Free Electricity Supply (Executed Contracts Only)

Additions: Coso Geothermal (10 MW), Geysers Geothermal (25 MW), Bonanza Solar/BESS (105 MW/55MW), Glenarm BESS (25 MW), Calwind (20 MW), Grace Solar (50 MW) (Does not include in-progress resources)



Optimized Strategic Plan Scope of Work Overview

Technical Analysis

Phase 1
Preparatory Studies

Identify and characterize all potential resource options

- Local Solar and Storage
- New & Emerging Tech
- Demand Response + Flex Loads
- Transmission Options

Phase 2
Portfolio Development

Use detailed power system modeling to construct multiple portfolios that meet clean energy goals and maintain reliability

- Glenarm Conversion/ Replacement
- Long-Term Capacity Expansion

Phase 3
Impact Assessment

Calculate cost metrics; identify feasibility concerns, dependencies, and risks of each portfolio

- Cost Impacts
- Production Cost Modeling
- Distribution System Analysis

Synthesis

Result
Optimized Strategic Plan

Informed by technical analysis, develop an action plan.

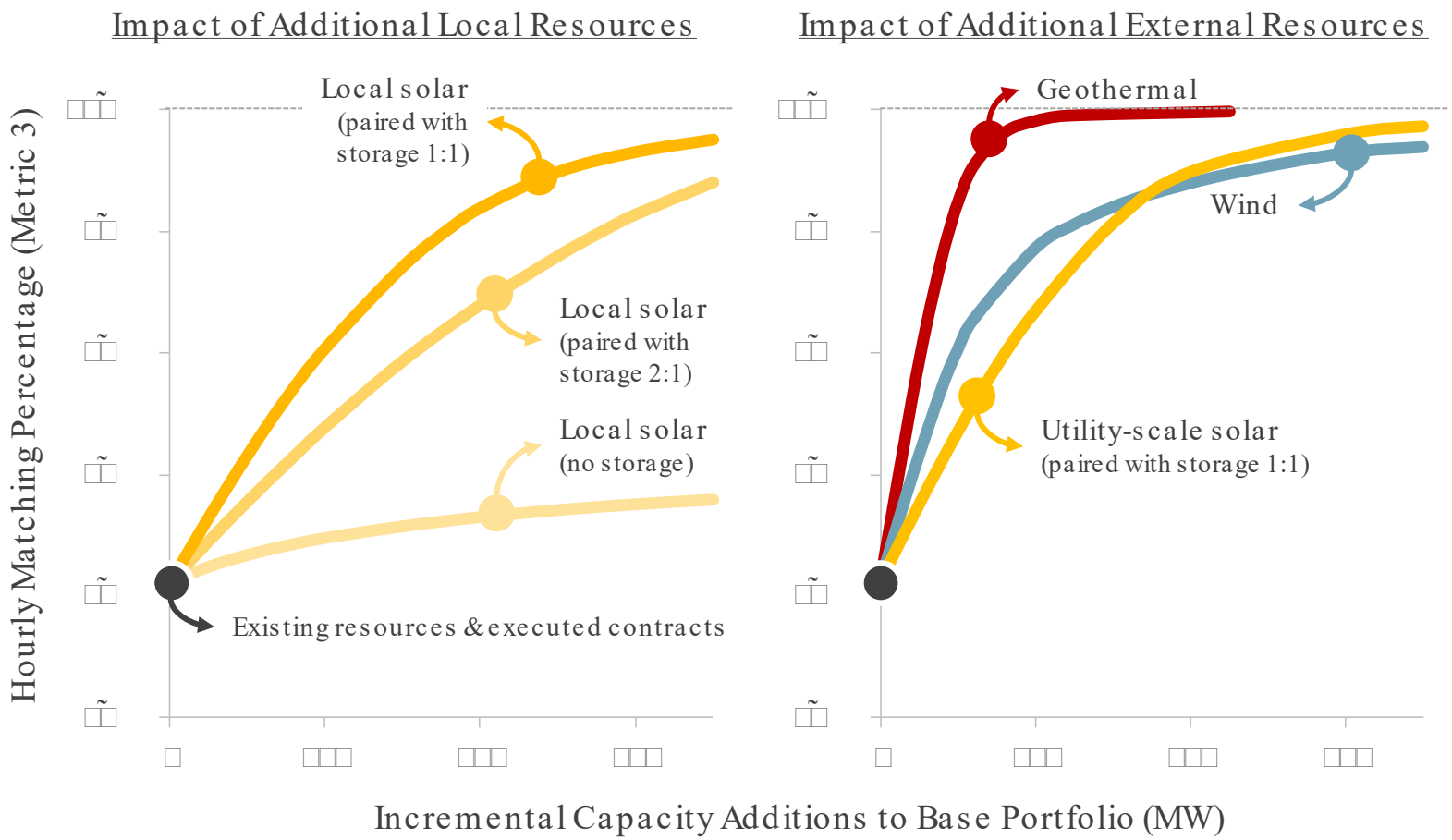
- Action Plan/ Final Report

Resource Options Available to Meet Resolution 9977 Goals

Multiple options for carbon-free generation and storage resources may play a role in the city's long-term plans and each have their own considerations or limitations.

Resource Type	Local	External	Additional Considerations
Solar	✓	✓	Roughly 500 MW of technical potential within the city; potential for utility-scale solar outside the city practically unconstrained; production limited to daytime and coincides with common periods of oversupply
Wind		✓	Limited remaining potential for development of new wind resources within California; high quality wind in other Western states provides an opportunity for resource diversity but requires transmission for delivery
Geothermal		✓	"Clean firm" source of stable carbon-free electricity; potential for new resource development is limited, highly site-specific and typically requires long lead times; few new geothermal projects developed in past decade
Battery Storage (4-hr)	✓	✓	Complementary to variable renewable resources that allows storage of surplus clean energy to discharge during periods of deficit; proven technology widely scaled in California in past decade
Demand Response	✓		A wide range of options to encourage customers to shift loads towards periods of clean energy surplus; effective deployment of demand response and managed electric vehicle charging requires completion of Advanced Metering Infrastructure (AMI) installation; rate design (e.g. time-of-use pricing) and incentive programs are both options to deploy this resource
Managed EV Charging	✓		
Mid Duration Storage (10-hr)	✓	✓	A significant number of innovative long-duration storage technologies are currently in R&D stages of development; most LDES technologies have not yet reached full market readiness, but many signs suggest that this level of technological maturity will not occur until mid 2030s; long-duration storage resources are typically less dense than battery storage and have larger land requirements
Long Duration Storage (100-hr)	✓	✓	
H_2 Hydrogen-Fired Gas Turbine	✓	✓	Operations using 100% H2 have not yet been proven in real world setting, but OEMs are targeting this capability by 2030; would require network to produce, store, & transport H2
H_2 Hydrogen Fuel Cell	✓	✓	

Closing the Gap: How Scaling Individual Resources Impacts Clean Energy Metrics



Three key observations:

1. Closing the gap between PWP's current portfolio and a 100% hourly matching goal requires additions of renewables and storage at a scale of hundreds of megawatts
2. Additions of local resources and external resources each advance PWP towards the Resolution 9977, and there is no minimum threshold of need for any specific type of resource
3. All resources exhibit diminishing marginal returns in their impact on Metric 3, displaying asymptotic behavior as the portfolio approaches 100% - foreshadowing the importance of resource diversity

Three Core Case Studies to Achieve Resolution 9977 Goals

Case Studies	New Resource Options to Meet 2030 Goals
Mature Technologies Only	Solar PV (Distributed & Utility); Land-Based Wind; Geother-mal; Load Flexibility; Battery Storage
Mature Technologies + Green Hydrogen	Solar PV (Distributed & Utility); Land-Based Wind; Geother-mal; Load Flexibility; Battery Storage; Green Hydrogen (H_2) Conversion at Glenarm
Mature Technologies + Long-Duration Storage	Solar PV (Distributed & Utility); Land-Based Wind; Geother-mal; Load Flexibility; Battery Storage; Long-Duration Energy Storage

Common methods & assumptions across all three case studies:

- Natural gas combustion at Glenarm ceases by end of 2030 (either converted to H_2 or replaced)
- No reliance on wholesale market purchases ("24x7 carbon free electricity")
- Quantities of each resource optimized in each case study to meet reliability needs and carbon-free objectives

Additional variations explored to provide PWP and City Council with robust analyses to inform the Optimized Strategic Plan:

+ "Accelerated Local Resources": What are the comparative impacts of portfolios that accelerate the deployment of local solar & storage while maintaining Glenarm Power Plant as a backup for reliability?
+ Timing: How does each strategy change if transition to carbon-free occurs less rapidly?
  - Opportunity to synchronize transition with transmission expansion
  - More plausible timelines for technology readiness for emerging technologies
+ Markets: How does short-term market transaction flexibility impact these case studies, if PWP's owned and contracted generation is carbon-free?

Using Long Term Capacity Expansion to Develop Portfolios

Mathematical optimization problem:

Minimize NPV Investment Costs + Operating Costs

Subject to constraints:

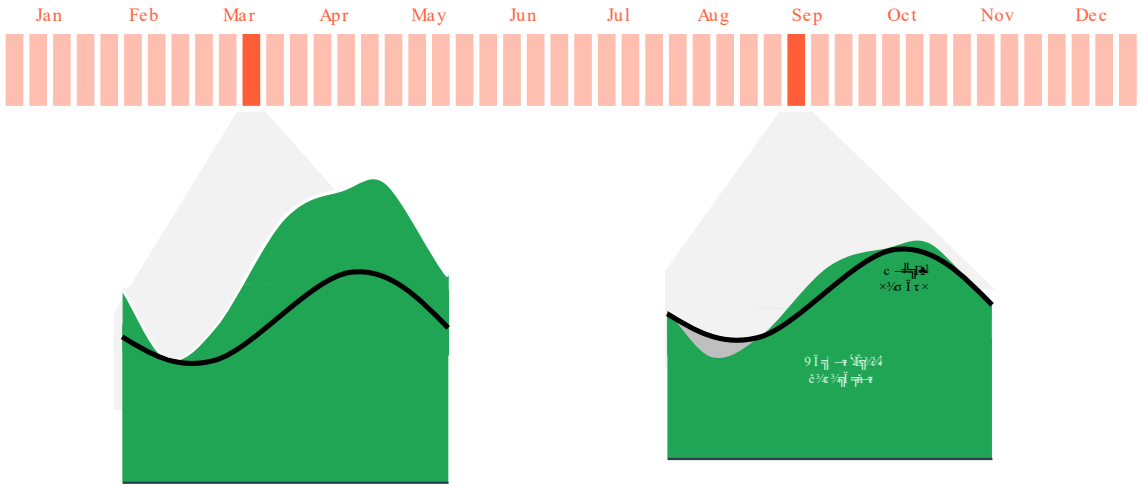
+ Minimum requirements for local resources
+ Resource adequacy requirements
+ Carbon-free energy targets
+ Plant-specific operational limitations
  - Thermal: maximum power, ramp rate
  - Storage: maximum power, state of charge
  - Renewables: hourly availability
+ Hourly power balance

Investment decisions:

New investments selected in each year across 25-year horizon

Operational decisions:

Hourly operations simulated across 48 representative days for each year



Pasadena System Representation in Capacity Expansion Model

Utility Load	
2030 Peak Demand[5]	361 MW
Owned & Contracted Resources	
Glenarm Power Plant	198 MW
Windsor Reservoir Solar	0.7 MW
Glenarm BESS[2]	25 MW
Existing Customer-Owned Resources	
Customer-Owned Solar	28 MW
Customer Owned Storage	1 MW
Candidate Resource Options	
Local Solar PV	
Battery Storage (4hr)	
Mid Duration Storage (10hr)[3]	
Long Duration Storage (100hr)[3]	
Demand Response	
Load Flexibility	
Green Hydrogen[3]	

Local PWP System

TM Goodrich Receiving Station

280 MW limit (expanding to 336 MW by 2035)

External CAISO System

Owned & Contracted Resources	
Palo Verde Nuclear	10 MW
Intermountain Power Plant[1]	108 MW
Magnolia Power Plant	14 MW
Chiquita Canyon Landfill Gas[1]	7 MW
Puente Hills Landfill Gas[1]	13 MW
Hoover Hydro	15 MW
Azusa Hydro	15 MW
Calwind[2]	20 MW
Coso Geothermal[2]	10 MW
Geysers Geothermal[2]	25 MW
Antelope Big Sky Ranch Solar	7 MW
Big Sky Summer Solar	7 MW
Columbia 2 Solar	3 MW
Kingbird Solar	20 MW
Bonanza Solar[2]	105 MW
Grace Solar[2]	50 MW
Bonanza BESS[2]	55 MW
Candidate Resource Options	
Utility-Scale Solar PV	
Wind (California)	
Wind (Out of State)	
Geothermal	
Battery Storage (4hr)	
Mid Duration Storage (10hr)[3]	
Long Duration Storage (100hr)[3]	
Wholesale Energy Market	
CAISO Wholesale Market (SP15)	

Notes:
1. Resources with established plans for retirement or contract expirations prior to end of 2030
2. Resources not yet online today
3. Candidate resources included in a select set of portfolios
4. Based on 2023 IRP forecast.
5. Based on 2023 IRP forecast with blended EV charging developed by E3.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*
Metric 1	86%
Metric 2	78%
Metric 3	83%

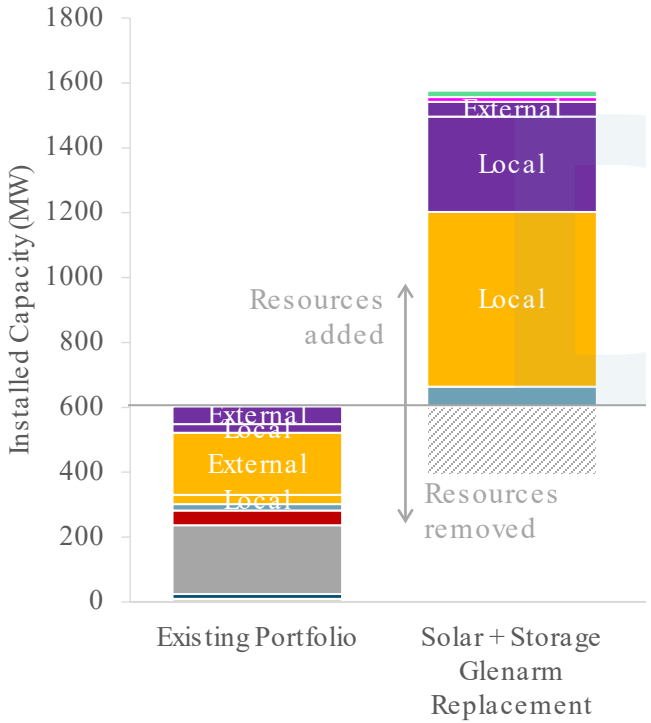
*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Energy+Environmental Economics

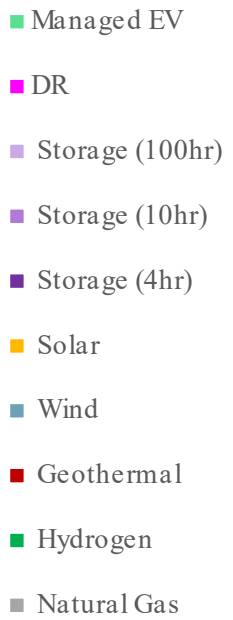
Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)
Metric 1	86%	167%
Metric 2	78%	100%
Metric 3	83%	100%



Without Glenarm, large quantities of new local solar and storage resources are needed to ensure local reliability during transmission contingency conditions

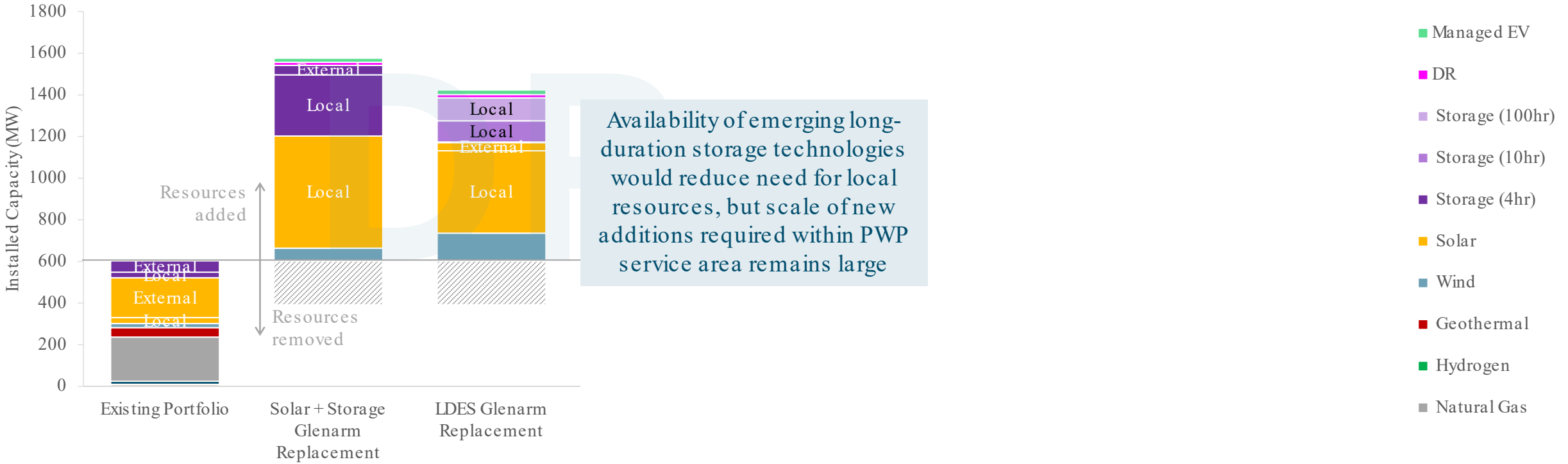


*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)	
Metric 1	86%	167%	183%
Metric 2	78%	100%	100%
Metric 3	83%	100%	100%



Availability of emerging long-duration storage technologies would reduce need for local resources, but scale of new additions required within PWP service area remains large

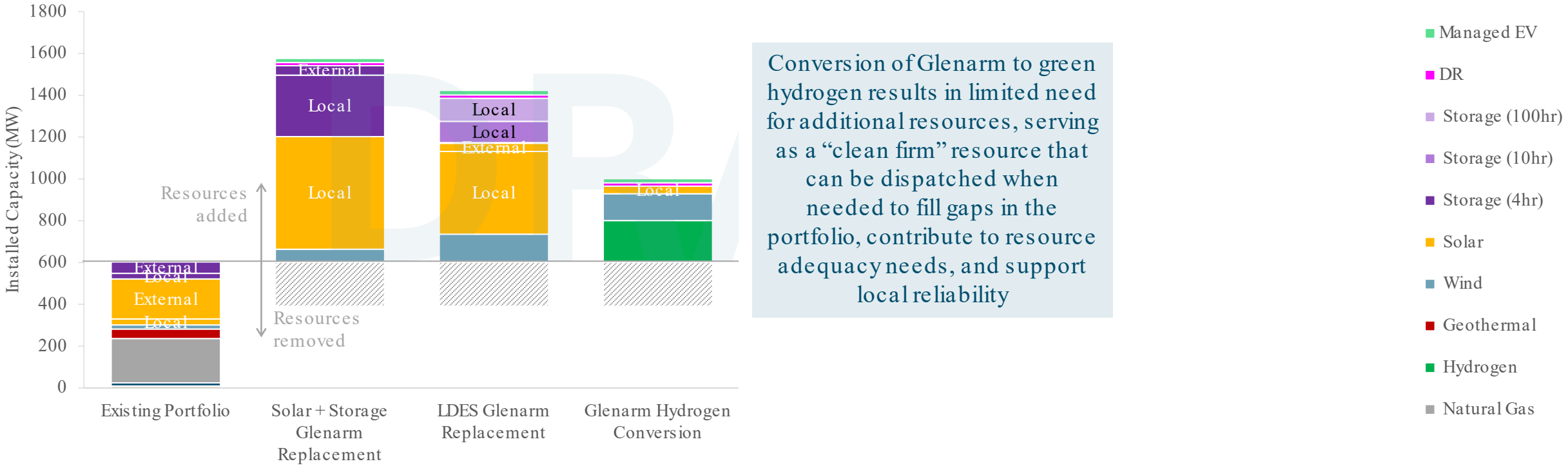
*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Energy+Environmental Economics

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)		
Metric 1	86%	167%	183%	127%
Metric 2	78%	100%	100%	100%
Metric 3	83%	100%	100%	100%



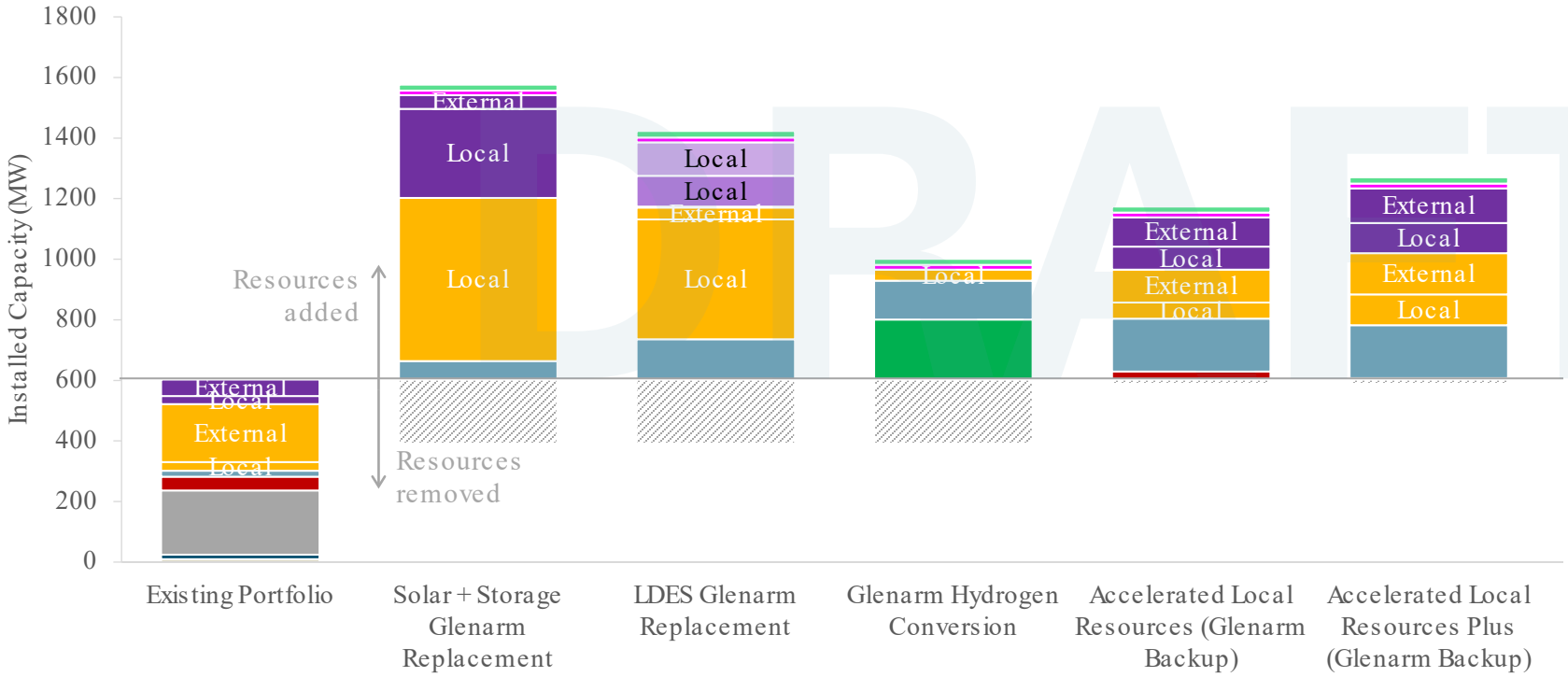
Conversion of Glenarm to green hydrogen results in limited need for additional resources, serving as a "clean firm" resource that can be dispatched when needed to fill gaps in the portfolio, contribute to resource adequacy needs, and support local reliability

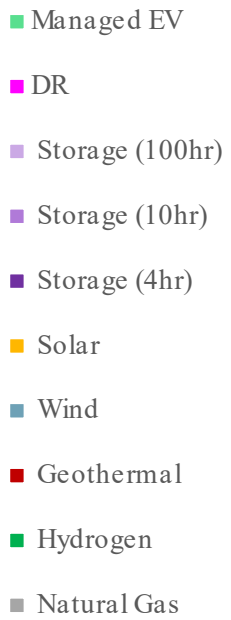
*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)			Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Backup, No Market Purchases)	
Metric 1	86%	167%	183%	127%	170%	171%
Metric 2	78%	100%	100%	100%	100%	100%
Metric 3	83%	100%	100%	100%	100%	100%





With Glenarm as a backup resource for reliability, multiple diverse portfolios combining local and external carbon-free resources can supply 100% of energy needs on an hourly basis under normal operating conditions

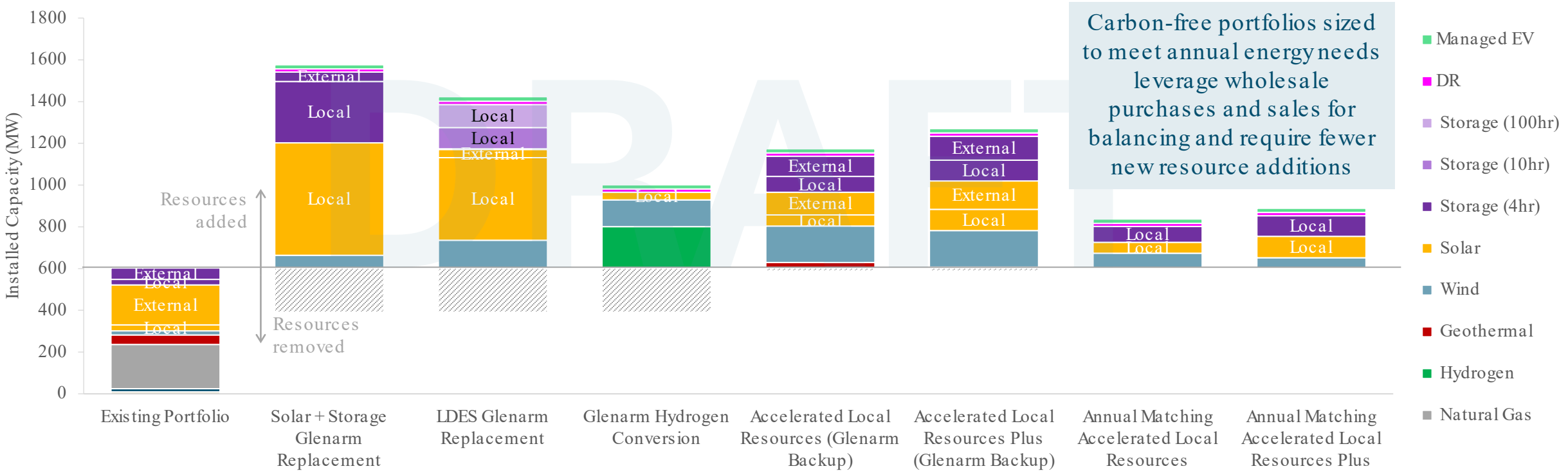
(Two variations in portfolios correspond to different levels of local resource development – both include sufficient local carbon-free resources to meet loads above Goodrich import limits)

*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Installed Capacity Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)			Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Backup, No Market Purchases)		Portfolios Designed to Meet 100% of Annual Needs (Limited Glenarm Ops & Market Purchases)	
Metric 1	86%	167%	183%	127%	170%	171%	108%	108%
Metric 2	78%	100%	100%	100%	100%	100%	96%	96%
Metric 3	83%	100%	100%	100%	100%	100%	94%	95%

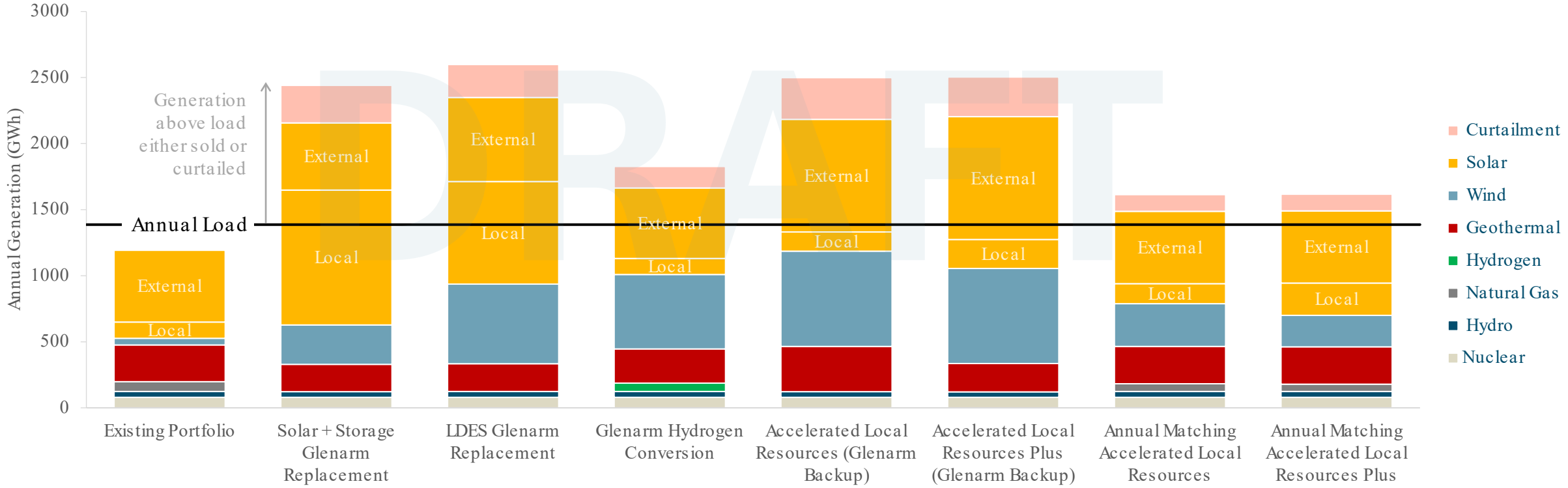


*Metrics reported on the PWP clean energy tracker for Owned/Contracted resources

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Annual Generation Mix Across Case Studies

	Current 2031 Resource Portfolio*	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)			Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Backup, No Market Purchases)		Portfolios Designed to Meet 100% of Annual Needs (Limited Glenarm Ops & Market Purchases)	
Metric 1	86%	167%	183%	127%	170%	171%	108%	108%
Metric 2	78%	100%	100%	100%	100%	100%	96%	96%
Metric 3	83%	100%	100%	100%	100%	100%	94%	95%

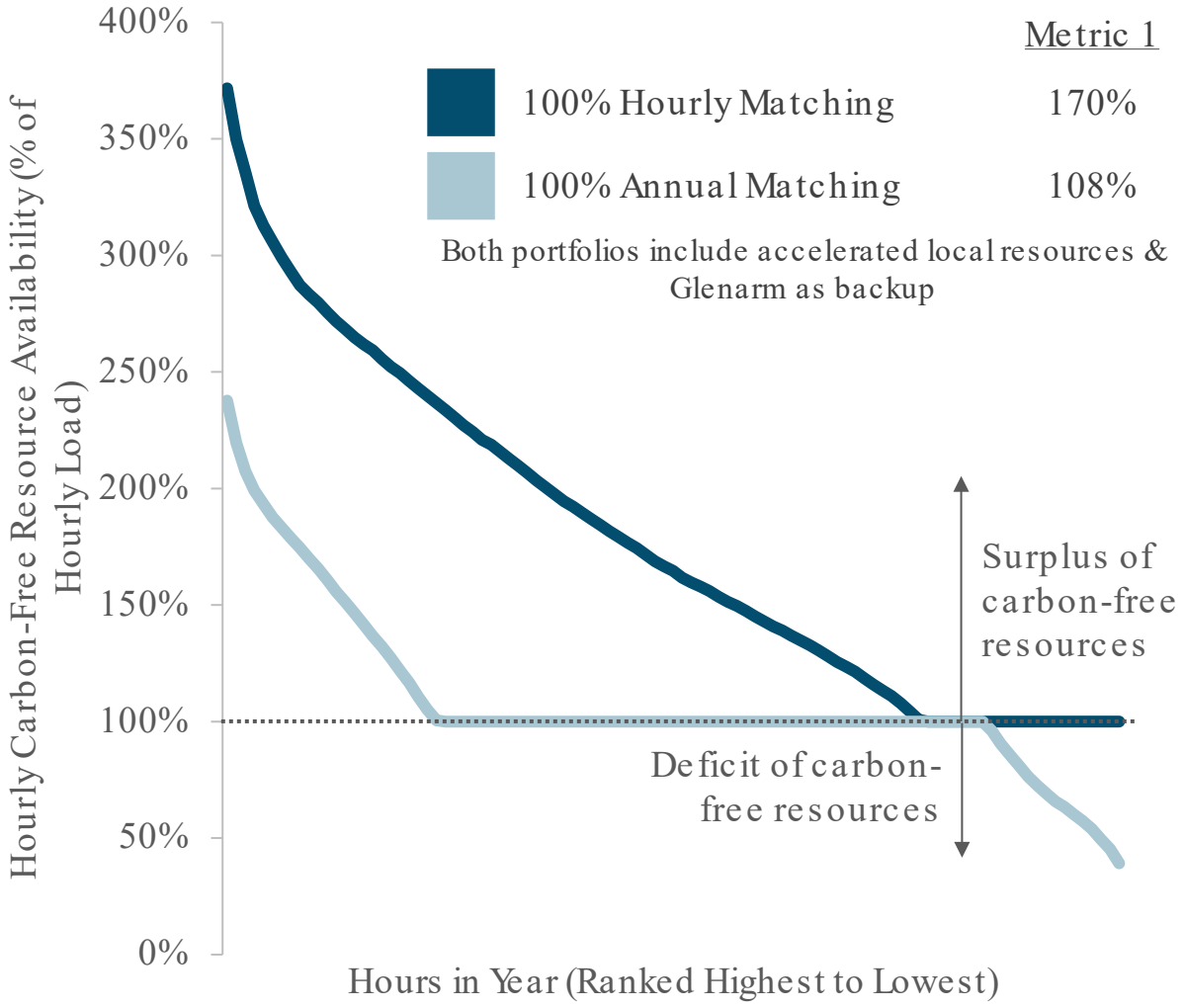


*Metrics currently reported on the PWP clean energy tracker for Owned/Contracted resources

Energy+Environmental Economics

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

2031 Duration Curves of Carbon-Free Energy Resources



100% Hourly Matching:

Supplying load with 100% carbon-free energy during the most constrained conditions across the year requires a portfolio that produces a large surplus of carbon-free energy outside of those constrained periods

+ Surplus carbon-free generation must be curtailed or sold to the market, making PWP heavily dependent on off-system sales
+ Many hours in which PWP would have a surplus of generation could occur when prices in the market are low or negative (e.g. daytime hours in spring)

100% Annual Matching:

A portfolio that is sized to supply 100% of annual energy needs with carbon-free energy results in a "balanced" position in wholesale markets:

+ Carbon-free resources meet or exceed hourly demand across most of the year; in aggregate, surpluses match or exceed deficits
+ Lower reliance on revenues from off-system sales; increased opportunities to maximize value of flexible storage resources

Measuring Incremental Total System Costs

- To compare costs to meet Resolution 9977 goals across case studies on a consistent basis, total system cost includes:
  - All-in costs of all new resources (represented as a PPA-style annualized cost)
    - Costs for naturally occurring adoption of residential and commercial customer solar are not included
  - Changes to fuel and operations & maintenance costs for existing resources resulting from plant retirements and/or dispatch
  - Changes in the CAISO Transmission Access Charge (TAC) due to differences in internal generation
  - Changes in wholesale market cost and/or revenues due to differences in purchases and sales in CAISO wholesale market
- Incremental total system costs compared to a least-cost reference case 2031, designed to meet 100% of annual energy needs with carbon-free resources

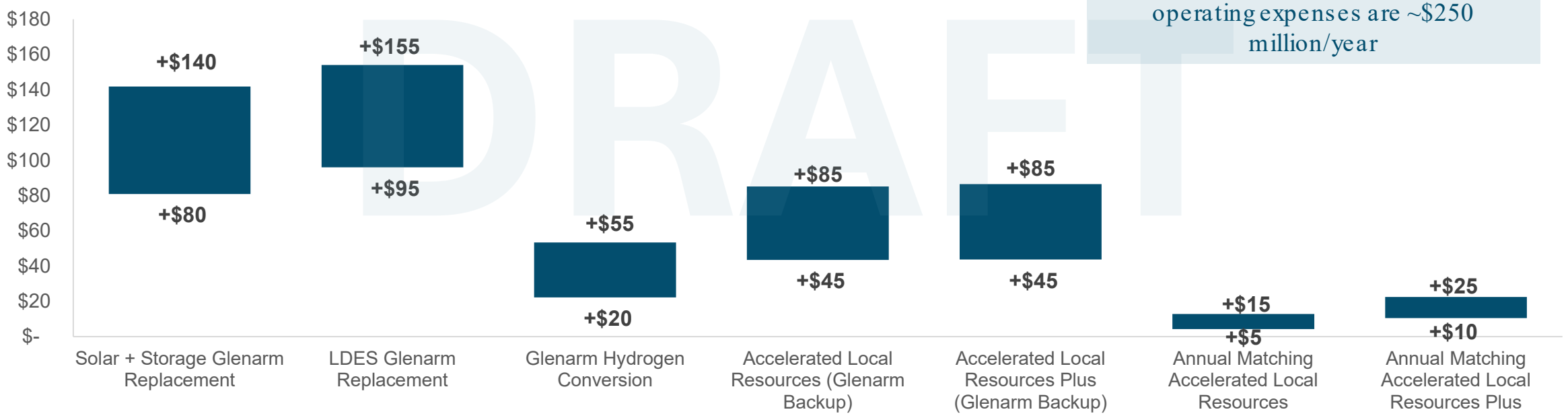
Location	New Resource Type	2031 PPA-Style Cost ($/MWh)
Local	Residential Solar	$160 $140-180
	Non-Residential Solar	$110 $100-122
External	Utility-Scale Solar	$40 $30-50
	In-State Wind	$60 $50-80
	Out-of-State Wind (includes transmission)	$65 $60-75
	Geothermal	$120 $100-140

PPA-style costs are expressed in nominal terms and are calculated to recover capital investment, return on investment, and operating costs over a 20-year period. Ranges shown reflect financing & technology uncertainty.

2031 Cost Comparison Across Case Studies

	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)			Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Backup, No Market Purchases)		Portfolios Designed to Meet 100% of Annual Needs (Limited Glenarm Ops & Market Purchases)	
Metric 1	167%	183%	127%	170%	171%	108%	108%
Metric 2	100%	100%	100%	100%	100%	96%	96%
Metric 3	100%	100%	100%	100%	100%	94%	95%

2031 Relative Incremental Total System Cost
($ million per year)



Note: PWP's current power fund operating expenses are ~$250 million/year

Note: Incremental cost measured relative to a "least-cost" portfolio designed to meet 100% of Pasadena's annual energy needs with carbon-free resources

Summary Results for 2031 Case Studies

	Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Replaced/Converted, No Market Purchases)			Portfolios Designed to Meet 100% of Hourly Needs (Glenarm Backup, No Market Purchases)		Portfolios Designed to Meet 100% of Annual Needs (Limited Glenarm Ops & Market Purchases)	
	Solar-Storage Replacement	LDES Replacement	Hydrogen Conversion	Accel Local Resources	Accel Local Resources Plus	Accel Local Resources	Accel Local Resources Plus
New Resource Needs by 2031							
New Renewables (MW)	600	568	165	363	417	123	151
New Storage (MW)	339	215	-	173	214	76	100
New DR & Load Flex (MW)	35	37	35	35	36	35	35
Clean Energy Metrics by 2031							
Metric 1 (%)	167%	183%	127%	170%	171%	108%	108%
Metric 2 (%)	100%	100%	100%	100%	100%	96%	96%
Metric 3 (%)	100%	100%	100%	100%	100%	94%	95%
Relative Costs in 2031							
Incremental Cost ($M/yr)	+$80-140	+$95-155	+$20-55	+$45-85	+$45-85	+$5-15	+$10-25
Other Considerations	Higher risk						Lower risk
Local Resource Siting							
Technology Readiness							
Upstream H_2 Infrastructure							
Wholesale Market Exposure							
Resource Adequacy Risk							
Local Resilience							
Long-Term Optionality							

Energy+Environmental Economics

Note: Metric calculations are based on a single deterministic year of normal weather conditions and do not capture events where transmission or distribution contingencies would require Glenarm to operate to ensure local reliability. Actual outcomes may vary due to impacts of natural year-to-year weather variability, transmission and distribution contingencies, and dispatch instructions provided by CAISO.

Staff Recommendation

- Adopt the MSC recommendation;
- Direct PWP to complete an Optimized Strategic Plan ("OSP") final report, establishing a roadmap to meet the goals set forth by City Council-adopted Resolution 9977;
- Direct staff to include the following five foundational components in the final OSP report, each of which has been demonstrated to be an important part of a portfolio that balances Resolution 9977 goals of carbon-free energy, reliability, affordability, and equity:
  - > Procurement of external renewables and storage resources, with a focus on resource diversity;
  - > Accelerated development of local solar and storage resources within the PWP service territory;
  - > Development of demand-side programs and rate structures to encourage load flexibility, managed electric vehicle charging, and other cost-effective demand response;
  - > Preservation of the Glenarm Power Plant as a backup/limited resource for reliability; and
  - > Pursuit of a balanced position in the CAISO wholesale energy market, allowing for sales and purchases to manage imbalances in supply and demand;
- Direct staff to continually evaluate and implement approaches to achieve the City's goals set forth in Resolution 9977 by the end 2030 and to utilize the 2028 Waypoint ("Waypoint") to develop a revised Integrated Resource Plan that is consistent with state requirements and Resolution 9977