QUANTA
TECHNOLOGY

REPORT

City of Winter Park
100% Renewable Initiative
Final Report

PREPARED FOR

City of Winter Park

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VERSION HISTORY:

Version	Date	Description
1.0	03/06/2023	Draft Submission for CWP Review
2.0	03/10/2023	Draft Final Submission for CWP Review
3.0	05/04/2023	Final Submission

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1 EXECUTIVE SUMMARY

The City of Winter Park (CWP) is located in Central Florida adjacent to Orlando in Orange County. Winter Park's vision is a city of arts and culture, cherishing its traditional scale and charm while building a healthy and sustainable future for all generations. CWP owns its electric distribution assets, and its utility supplies electricity to approximately 14,276 customers. CWP does not generate power but has contracts with the Florida Municipal Power Association (FMPA) and Orlando Utilities Commission (OUC) to purchase approximately 100 MW of power yearly and approximately 10 MW from Covanta, which derives power from burning waste.

CWP is committed to a sustainable future and has created a sustainability action plan (SAP) that calls for reducing greenhouse gas emissions (GHG) and targets all electricity consumption from renewable-fueled resources. Specifically, three primary targets were defined for evaluation as possible CWP goals for evolving toward a sustainable electric energy supply. The three potential targets under consideration for the future CWP energy supply include:

- **Target 1:** 100% renewable energy supply by 2050
- **Target 2:** 100% net-zero carbon energy supply by 2050
- **Target 3:** 80% renewable energy supply by 2035 and then 100% by 2050

It is important to note that while a net-zero carbon scenario was analyzed as Target 2, CWP is primarily focused on roadmaps based upon true 100% renewable or carbon-free targets. Therefore, primary conclusions and roadmap considerations are centered around 100% renewable paths (Targets 1 and 3).

Each target was further analyzed by way of scenario considerations. A scenario in this context is a set of future conditions that collectively describe the external environment/conditions under which supply options are to be assessed. In the case of a resource plan, a scenario description includes a multi-year forecast of external drivers or assumptions important to the analysis, including load forecasts, EV growth, costs for renewables and battery storage, distributed solar and storage, the cost for natural gas fuel, energy efficiency (EE) and demand response (DR) forecasts, and financial assumptions.

To better account for future conditions, Quanta Technology used a planning methodology that considers ranges of plausible future conditions founded on variations of multiple scenarios rather than analysis on a single scenario associated with a target. Therefore, the three base targets were expanded into a total of 15 different scenarios:

- Six focused on achieving Target 1 (100% renewable by 2050)
- Five focused on achieving Target 2 (100% net-zero carbon by 2050)
- Four focused on achieving Target 3 (80% renewable supply by 2035 and then 100% by 2050)

This analysis indicates that CWP's adoption of a path toward 100% renewables can be accomplished for a reasonable cost of power for the next 20 years. However, beyond the next 20 years (i.e., during the last 6 years analyzed in this report from 2043–2050), the technology selection and the costs remain understandably more uncertain and, based on the technology options and costs assumed in this study, could bring a substantial increase in CWP's power costs. This rapid rise in costs near the end of the study period was driven by assumptions on technology costs which resulted in a sharp increase in cost during the final years of the study.

Quanta Technology believes that additional cost-effective technologies will be available well before 2043. The power industry is expending considerable time and money on identifying options that could deliver lower-priced energy sources, including offshore wind, long-term energy storage technologies, and new technologies for geothermal energy, among others. While the costs projected in the last 6 years of the study are high, based on the current assumptions, the costs before 2043 are comparable to projected CWP costs and could be lower. CWP should not avoid adopting its renewable targets because of costs that are not expected to occur for over 20 years. CWP should regularly reevaluate its targets and plans for its electric energy supply. Should continuing on a path to 100% renewable prove too costly in future years, CWP can adjust accordingly.

A recommended roadmap was developed and principally centered around the following:

- **Short-term (May–July 2023):** Focusing on alignment, definition, and goal setting/validation, which includes defining and committing to a clean energy supply target and establishing multiple interim targets for renewable contributions along the path to 2050.
- **Mid-term (August 2023–February 2025):** Focusing on designing customer EE and DR programs, time of use (TOU) rates, and prioritizing utility-scale renewable purchases over solar for city assets.
- **Long-term (March 2025–April 2027):** Focusing on implementing EE and DR programs, TOU rates, and changing the net energy metering (NEM) rate credited to the customer to a cost-based TOU rate.

A complete list of the recommended activities and projects in the roadmap is included in Section 7.2. Appendix A provides definitions of terms used in this report, and Appendix B provides a list of acronyms used in this report.

2 PROJECT SCOPE

2.1 Overview

The City of Winter Park (CWP) is 10 square miles with over 30,000 residents. CWP's Electric Utility Department supplies electricity to approximately 14,276 customers (12,048 residential properties and 2,228 commercial customers). CWP does not generate power but has contracts with the Florida Municipal Power Association (FMPA) and Orlando Utilities Commission (OUC) to purchase approximately 100 MW of power yearly. In addition, CWP purchases approximately 10 MW of power from Covanta, which derives power from burning waste. In 2023, CWP will also purchase 20 MW of solar energy through its partnership with the FMPA.

CWP is committed to a sustainable future and has passed resolutions to promote its commitment. On January 14, 2008, the CWP City Commission (City Commission) passed a resolution stating that CWP would pursue measures to become a certified Green Local Government through the Florida Green Building Coalition (FGBC). In 2011, CWP was officially certified as a Green Local Government at the Gold level. As part of those efforts, CWP has created a sustainability action plan (SAP) that calls for reducing greenhouse gas emissions (GHG) and targets all electricity consumption from renewable-fueled resources by 2035.

CWP defines sustainability as "responsible and proactive decision-making that minimizes negative impact and maintains a balance between social, environmental, and economic growth to ensure a desirable environment for all species now and into the future." CWP believes its efforts to invest in sustainability will bring numerous benefits increasing quality of life, reducing dependence on fossil fuels, protecting and enhancing the environment, and realizing economic value and savings.

CWP contracted Quanta Technology to conduct a study that outlines a roadmap and a feasible action plan for CWP to reach its sustainability objectives. CWP stressed the importance of creating a realistic, practical plan with feasible implementation options. The study was centered around the assessment of three potential targets under consideration for the future CWP energy supply:

- **Target 1:** 100% renewable energy supply by 2050
- **Target 2:** 100% net-zero carbon energy supply by 2050
- **Target 3:** 80% renewable energy supply by 2035 and then 100% by 2050

Net-zero carbon refers to a state in which the greenhouse gases going into the atmosphere are balanced by removing carbon from the atmosphere. Generally, utilities plan to achieve net zero by reducing their carbon emissions and acquiring carbon offsets, carbon credits, or renewable energy credits (RECs) to offset any remaining carbon emissions.

It is important to note that while a net-zero carbon scenario was analyzed, CWP is primarily focused on roadmaps based upon true 100% renewable or carbon-free targets. This is primarily due to net-zero carbon plans using carbon offsets or renewable energy credits to reach the intended goal instead of reaching a sustainability goal oriented around true zero-carbon options (see Appendix B: List of Abbreviations and Acronyms for term definitions).

2.2 Scope of Work

The scope of work for the contracted study primarily involved the following activities:

1. **Data gathering:** Quanta Technology presented CWP with a list of over 25 data items to be analyzed and serve as the basis for many of the inputs used in the subsequent modeling effort. CWP diligently provided the data items, including electric utility organization and staff descriptions, maps and descriptions of transmission interconnections, data on generators or energy storage owned by CWP and power purchase agreements, system consumption data including load profiles, historical energy consumption data peak demand, energy forecasts, photovoltaic (PV) data, electric vehicle (EV) data, home electrification forecasts, and historical and current city carbon levels. This data was sometimes supplemented with relevant industry sources where CWP data was unavailable.

2. **Initiation workshop and strategic discussions:** CWP and Quanta Technology held a one-day workshop comprised of several core sessions with targeted discussion, including background discussion, an overview of Quanta Technology's probabilistic integrated resource planning (IRP) process, an alignment around metrics and modeled scenarios, a review and preliminary analysis of supplied data, and several discussions on assumptions and next steps.

3. **Modeling plausible scenarios to reach zero emissions:** Utilizing the provided data items along with the information learned from the initiation workshop, Quanta Technology commenced an effort to customize its IRP process using the supplied data and learned information and used its proprietary capacity expansion program, known as probabilistic integrated resource planning (pIRP).

   The three agreed scenarios (100% renewable 2050, 100% net-zero carbon 2050, and 80% renewable 2035) were analyzed. They were augmented by capturing a total of 15 different scenarios representing variations in key scenario elements such as adoption rates, load forecasts, pricing variations, and cost of capital/debt. These results better assist CWP in selecting the best path, targets, and portfolio mix to reduce the carbon emissions from their electricity consumption. Ultimately CWP will need to balance the achievement of targets against affordability, available generation options in Florida, and CWP's comfort level in adopting new generation technologies (e.g., biofuels and green hydrogen).

4. **Results compilation:** Quanta Technology worked collaboratively with the CWP to review draft results and align on assumptions and material to be presented. Additional questions for key stakeholders were also considered and addressed as part of the presentation of the final results. Results are captured in this report and summarized in an executive stakeholder presentation.

5. **Stakeholder presentations:** The executive stakeholder presentation was delivered to a joint session of the Utilities Advisory Board and the Keep Winter Park Beautiful and Sustainable Advisory Board, as well as a separate presentation for the City Commission.

3 PROBABILISTIC IRP MODELING OVERVIEW

3.1 Philosophy and Approach

The robust response from regulators, utilities, and corporations to climate change in recent years has culminated in many declaring their commitments to carbon reduction goals reaching 100% between 2035–2050.

Traditional integrated resource planning (IRP) processes and tools have served the industry well over the past 30 years. However, they are increasingly challenged due to the following:

- Increased uncertainties in load development, electrification, technology, and grid development.
- Reliability concerns are not modeled due to the high penetration of inverter-based resources (IBRs including batteries, solar, and wind).
- The dependence of resource development on the availability of T&D hosting capacities is not co-optimized.
- Resilience requirements associated with intermittent weather-dependent resources and grid vulnerabilities are not modeled.
- Energy storage capacity (i.e., duration) is pre-selected and not optimized.
- Energy storage value is often restricted to energy balancing, while the full benefits stack is not exploited.

Quanta Technology, LLC, and Sandia National Laboratories embarked on a multi-year effort to create a probabilistic IRP (pIRP) software tool to address these challenges and ensure robust pathways to reaching 100% carbon reduction goals while preserving system reliability and resilience.

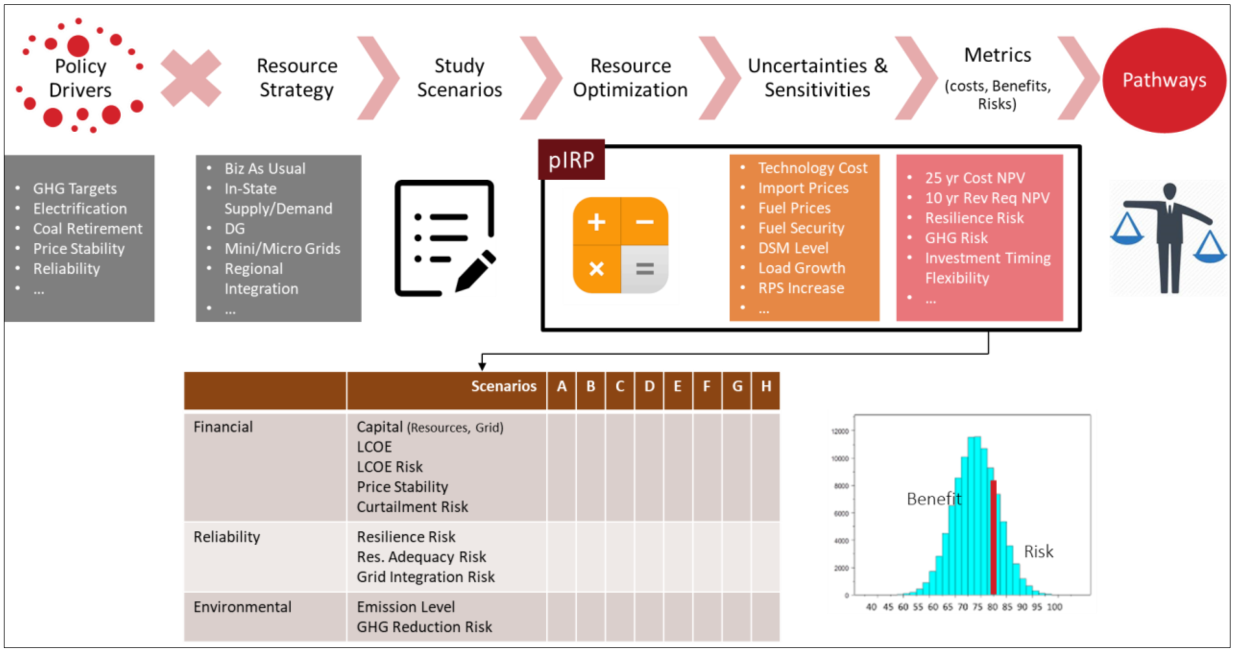
pIRP is a significant enhancement to traditional IRP tools to assist utilities in evaluating and selecting decision pathways that are flexible and adaptable in the face of increasing uncertainty and changes in technology, policy, consumption patterns, and business models. The traditional scenario planning and sensitivity analysis approaches are augmented with the probabilistic analysis and real option valuation methods to balance the costs and risks properly.

The drive to high renewable futures based on intermittent technologies such as solar PV and wind will necessarily drive the need for flexible companion assets such as battery energy storage and DR and long-duration storage options and renewable fuel-based solutions. pIRP optimizes the capacity buildout to reduce the overall cost to ratepayers while achieving renewable goals and maintaining system reliability.

Figure 1 shows the complete process of capacity planning, starting with defining policy drivers and resource strategies to derive a set of study scenarios. Policy drivers can include carbon reduction goals, electrification adoption rates, and affordability targets, among other factors. Resource strategy includes the practical aspects of resource development options, such as focusing on self-sufficiency or reliance on imports and a preference toward centralized versus microgrids and distributed resources. The set of scenarios bound the range of various factors that are important to decision-makers.

In addition to defining discrete scenarios, pIRP allows the development of probabilistic uncertainty models of key drivers and factors for more complete characterizations of risks and uncertainties, including resource capacities, cost impacts, and carbon reduction levels.

The output of the pIRP is a set of metrics and resource plans. These can be calculated for each discrete scenario or summarized across the range of probabilistic samples.



	Scenarios	A	B	C	D	E	F	G	H
Financial	Capital (Resources, Grid) LCOE LCOE Risk Price Stability Curtailment Risk								
Reliability	Resilience Risk Res. Adequacy Risk Grid Integration Risk								
Environmental	Emission Level GHG Reduction Risk								

Figure 1. pIRP Process Overview

3.2 pIRP Model Overview

The following are the key modeling features of pIRP:

- The power system is modeled spatially and temporally. pIRP uses a zonal representation for system resources and models distribution hosting capacities, transmission deliverability capability within each zone, and energy transfer capability between zones. The ability to expand these grid capabilities and the associated costs are also modeled. pIRP utilizes time buckets to represent periods of time within a day. The duration of time buckets is flexible, but the finer the resolution, the longer the simulations will require.

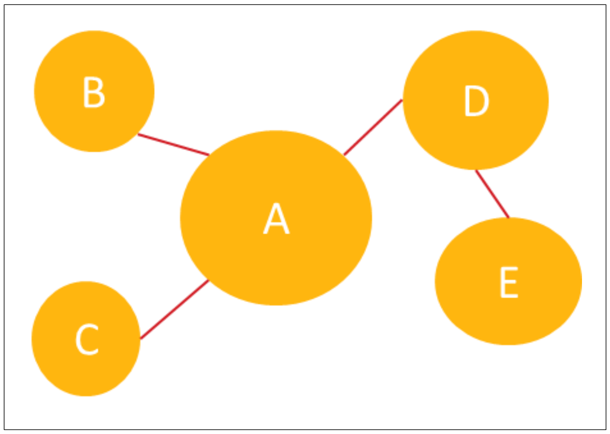
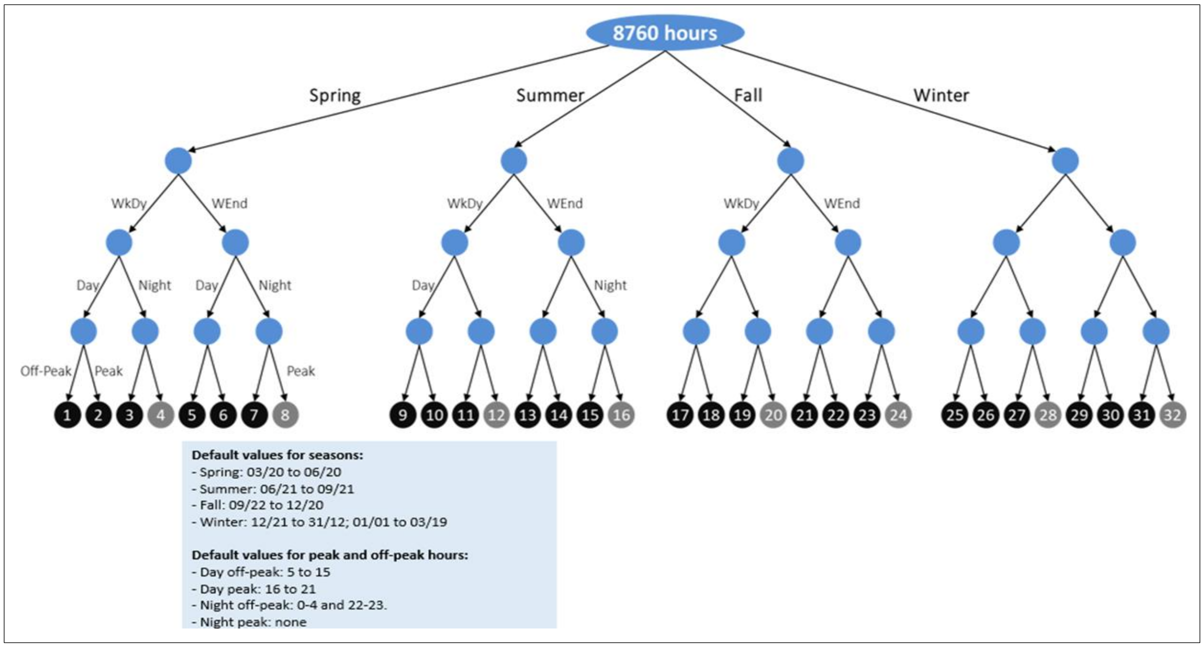


Figure 2. Zonal Representation of the Power System



Default values for seasons:
- Spring: 03/20 to 06/20
- Summer: 06/21 to 09/21
- Fall: 09/22 to 12/20
- Winter: 12/21 to 31/12; 01/01 to 03/19

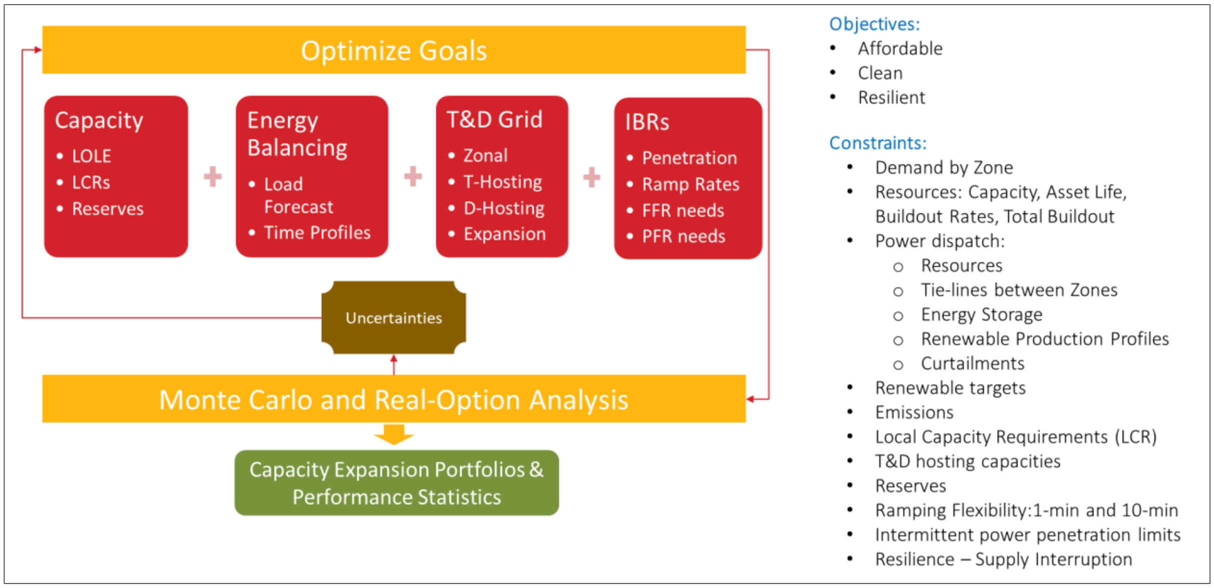
Default values for peak and off-peak hours:
- Day off-peak: 5 to 15
- Day peak: 16 to 21
- Night off-peak: 0-4 and 22-23.
- Night peak: none

Figure 3. Time Buckets Representation of Time

- The load forecast of each zone can be specified by providing peak and hourly profiles of multiple load components such as residential, commercial, streetlight, EV charging, and storage charge-discharge profiles. The tool provides flexibility in defining load components.
- Users can define many resource types, such as solar PV, nuclear, and renewable energy credits (RECs). Each resource type has many attributes that differentiate it from other resources, such as its capacity credit or effective load carrying capability (ELCC), asset life, ability to store energy, and duration of storage.
- Fuels can be specified regarding their cost projections, carbon content, and whether they are renewable.
- The user specifies existing resources and acceptable types of future resources in each zone. Each resource will have many attributes such as its connectivity to transmission or distribution system, heat

rate, outage rates, per unit capital and operational costs, fuel selection, capacity buildout capability annually, and in total, 8760 production profiles, if applicable, maximum operational hours in a year, minimum generation levels, ramp rates, etc.

- T&D hosting capacities and tie-line power transfer capabilities. The maximum expansion capability and per-unit costs can be specified.
- Uncertainty can be modeled using statistical functions and associated parameters. Data inputs (such as peak load, load growth rates, fuel cost, ELCC, etc.) can be treated as uncertain.
- Resilience against renewable drought can be specified, such as lack of solar or wind resource production over several consecutive days. This resilience aspect including energy supply during and after storm events was out of scope for this study. Average weather was assumed in the development of resource portfolios.
- pIRP imposes several constraints, including energy balance for each zone at the time bucket, capacity requirements in each zone, including reserve margins, ramping requirements to ensure frequency stability, variable resource penetration limits, and resilience targets.
- pIRP formulates the capacity expansion as a linear program (LP) and runs a Monte Carlo using Latin hypercube sampling to generate probable outcomes.
- The user specifies for each zone the renewable targets over time.
- The user selects the duration of the optimizations (1–30 years).
- pIRP co-optimizes resource capacity buildout (including retirements), resource dispatch and curtailments, and T&D grid expansion to achieve minimal cost to ratepayers while achieving renewable targets and reliability constraints. Figure 4 summarizes the various components of pIRP.



Objectives:

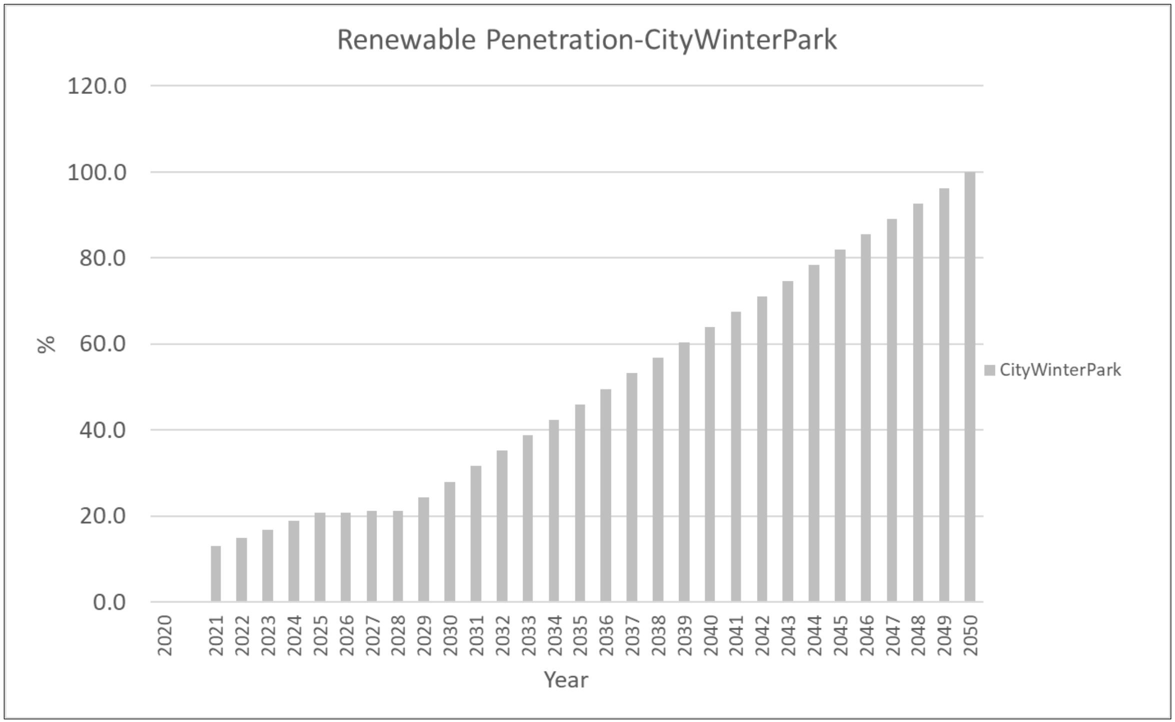
- Affordable
- Clean
- Resilient

Constraints:

- Demand by Zone
- Resources: Capacity, Asset Life, Buildout Rates, Total Buildout
- Power dispatch:
  - Resources
  - Tie-lines between Zones
  - Energy Storage
  - Renewable Production Profiles
  - Curtailments
- Renewable targets
- Emissions
- Local Capacity Requirements (LCR)
- T&D hosting capacities
- Reserves
- Ramping Flexibility:1-min and 10-min
- Intermittent power penetration limits
- Resilience – Supply Interruption

Figure 4. pIRP Modeling Capability

- The output of pIRP can be summarized physically and financially for each zone and each year (sample output is shown in Figure 5, Figure 6[1], and Figure 7).



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[1] Technologies referenced in Figure 6 and elsewhere in the report are defined in Table 12 in Appendix B: List of Abbreviations and Acronyms

Figure 5. pIRP Sample Output 1

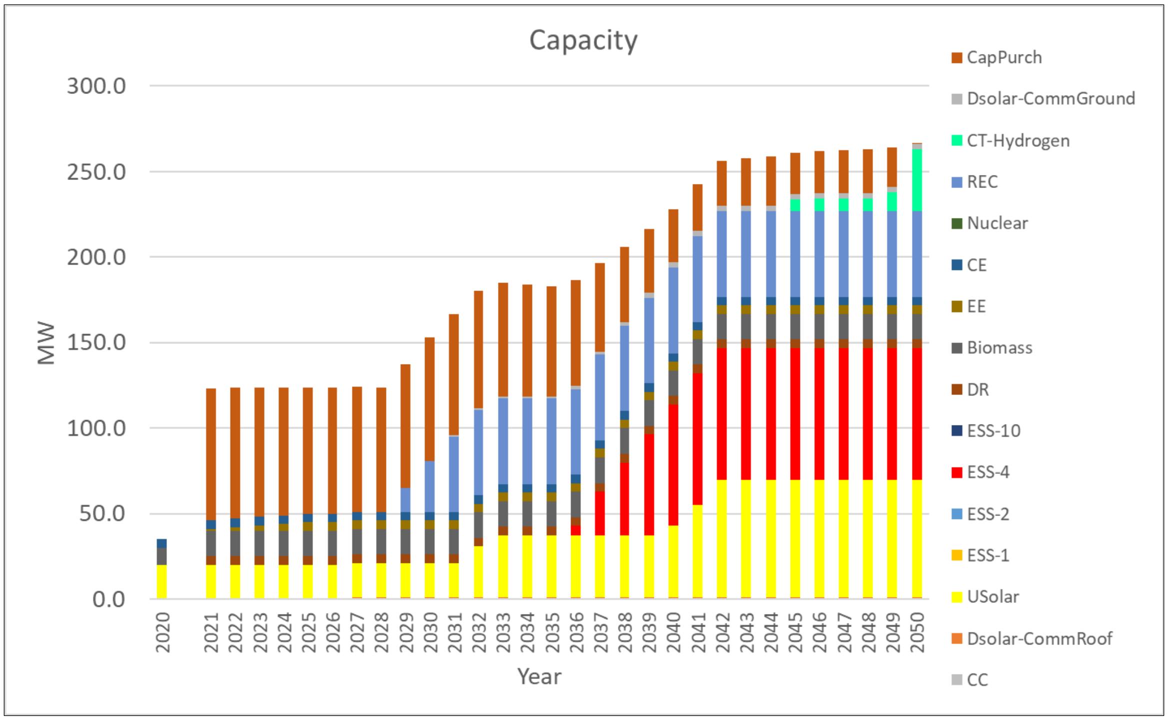

Figure 6. pIRP Sample Output 2

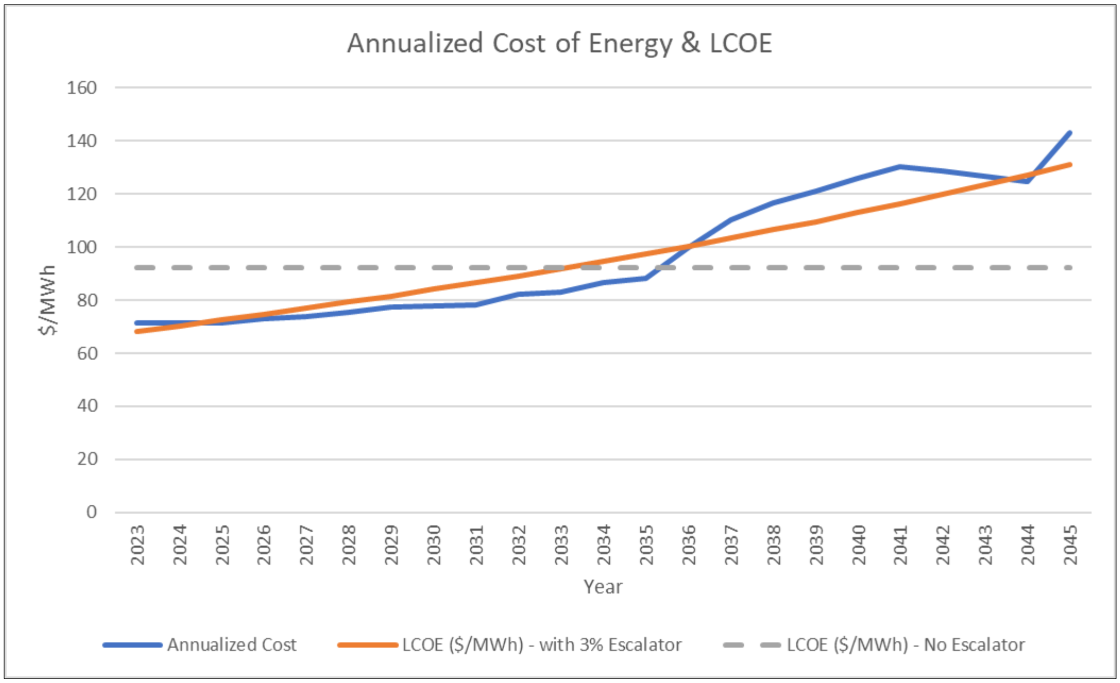

Figure 7. pIRP Sample Output 3

4 CWP LOAD FORECASTS AND OTHER DATA INPUTS

4.1 Overview

Any long-range analysis of supply resource options requires much data, including historical data, current and future energy resource characteristics, and forecasts regarding future conditions and costs. The data requirements required for this study can be generally categorized into the following topics:

1. Load forecast
2. Distributed solar and storage
3. EV growth
4. Renewables and battery storage costs
5. EE and DR forecast
6. Natural gas fuel price forecast
7. Renewable energy credit (REC) Pricing
8. Financial assumptions

Quanta Technology worked with CWP to develop a set of historical data and then determine forecasting methods and assumptions that would provide the needed input data to the terminal year of the study (2050). These forecasted data and assumptions provide the foundation of the technical analysis used to select the preferred resource portfolios that could meet CWP renewable targets at the lowest costs. Since developing a single accurate forecast for the next 27 years is nearly impossible, planners typically develop multiple forecasts of conditions intended to provide a likely range of future outcomes for most of the needed assumptions.

The following subsections summarize the data sources and methods used to create forecasts for each planning element.

4.2 Gross Customer Usage

To estimate the type and cost of energy resources needed by CWP to achieve its 2050 renewable targets, the analysis must first start with a forecast of the energy and peak demand of CWP customers. CWP was able to provide Quanta Technology with ten years of historical data. The most recent ten years of CWP annual energy are shown in Figure 8.

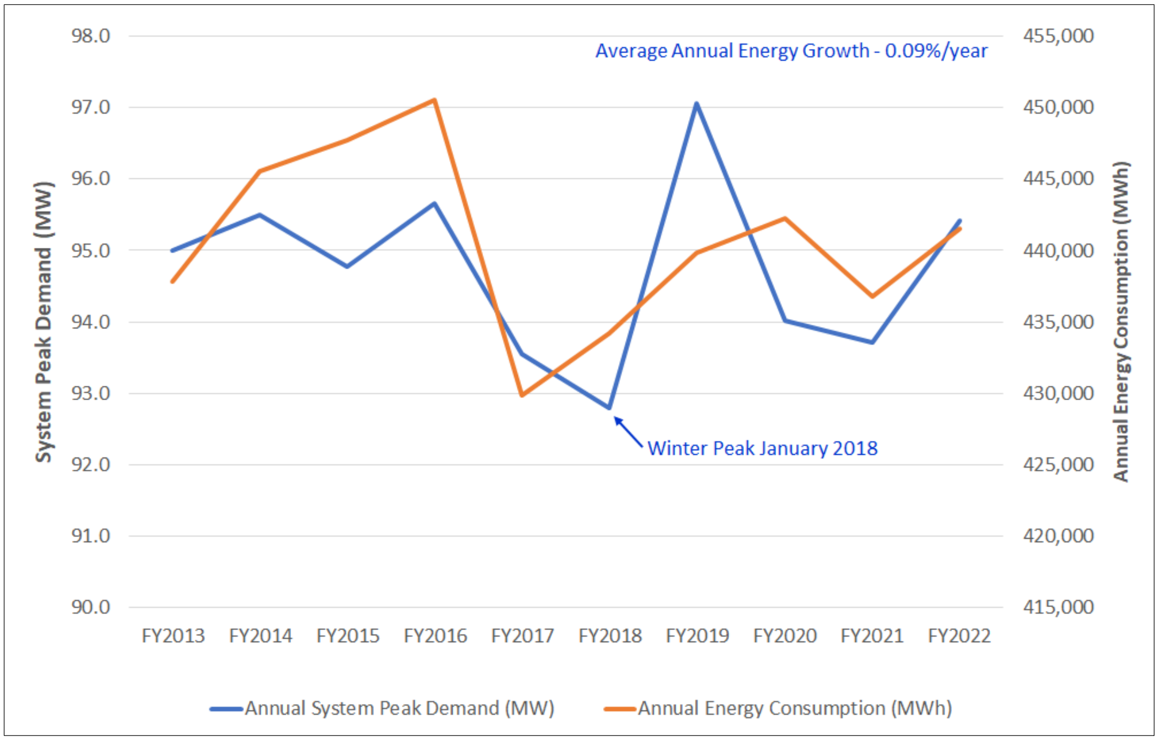

Figure 8. Historical Annual CWP Energy Consumption and System Peak Demand

The average annual energy use growth rate for these last ten years has been 0.09%. This was virtually zero growth in sales when much of this time included a generally robust economy and real estate market. Each of the last six years (2017–2022) has recorded lower annual sales than the previous three years (2014–2016). While a six-year downward trend is significant, the time period included multiple years of impacts from the COVID-19 pandemic and may not predict future energy consumption.

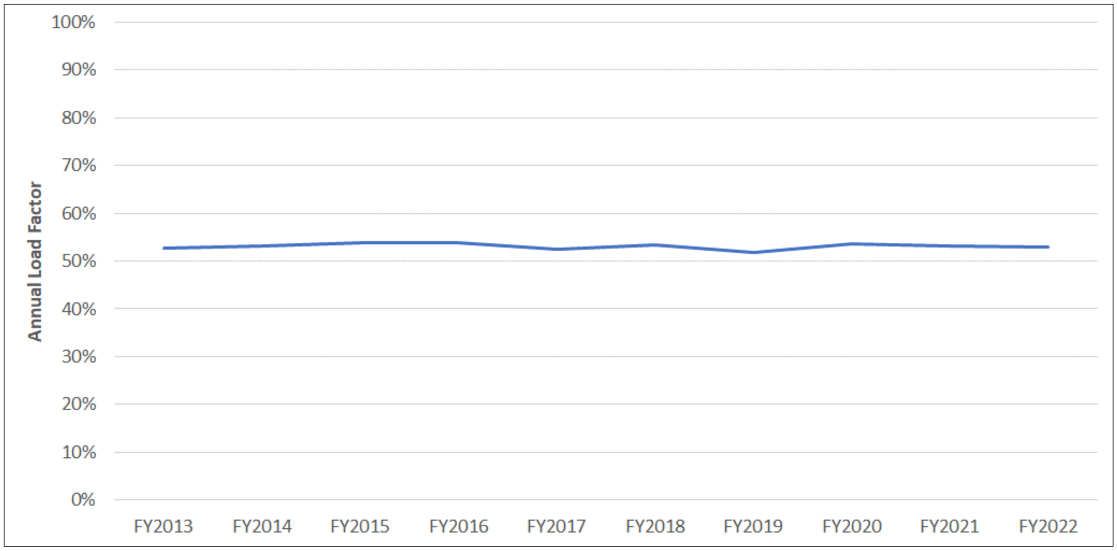

Figure 9 provides the historical annual load factor for CWP for the last ten years, which has been remarkably consistent, indicating that there has been very little change in the demand served by CWP.

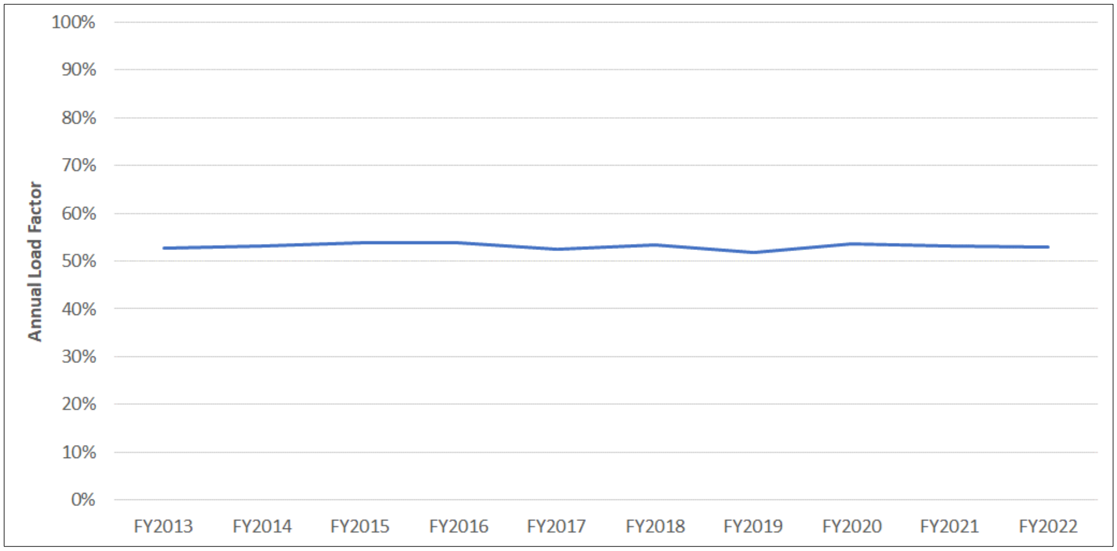

Figure 9. CWP Annual System Load Factor

CWP did not have a recent, long-range energy and demand forecast that could be used for this analysis. Developing a long-range forecast of CWP energy and demand using typical methods[2] was beyond the scope of this analysis. Even with excellent data and a rigorous methodology, forecasting is an inexact science. Since this analysis aimed to assess the feasibility of CWP achieving its 100% renewable targets, creating a precise CWP forecast was less important to the results than analyzing results across a range of forecasts that would serve to bracket the CWP energy forecast. Since central Florida is served by multiple utilities, Quanta Technology and CWP staff decided that the load growth projections of other nearby Florida utilities could serve as potential, reasonable proxies for the CWP's expected growth.

The Florida Public Service Commission (PSC) requires that each of the large utilities in Florida file a ten-year site plan (TYSP), which includes information on the utilities in the state. Among the data in these filings is an annual forecast of its energy requirement for the next ten years. Quanta Technology reviewed the individual 2022 TYSP filings of the utilities and the summary of all the files prepared by PSC: Review of the 2022 TYSP of Florida's Electric Utilities[3] From the reporting utilities, Quanta Technology selected four utilities that were believed to provide useful input to the estimation of the future CWP growth rate: Orlando Utilities Commission (OUC), Florida Municipal Power Agency (FMPA), Florida Power and Light (FPL) and Tampa Electric Company (TECO). The ten-year energy forecasts for each of these utilities were normalized to their respective 2022 sales and then charted in Figure 10.

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[2] Typical energy forecasts for long range utility resource planning are based on weather normalized data and end-use or class-differentiated, econometric, multivariable regression.

[3] FL PSC Review of the 2022 Ten-Year Site Plans of Florida's Electric Utilities, October 2022.

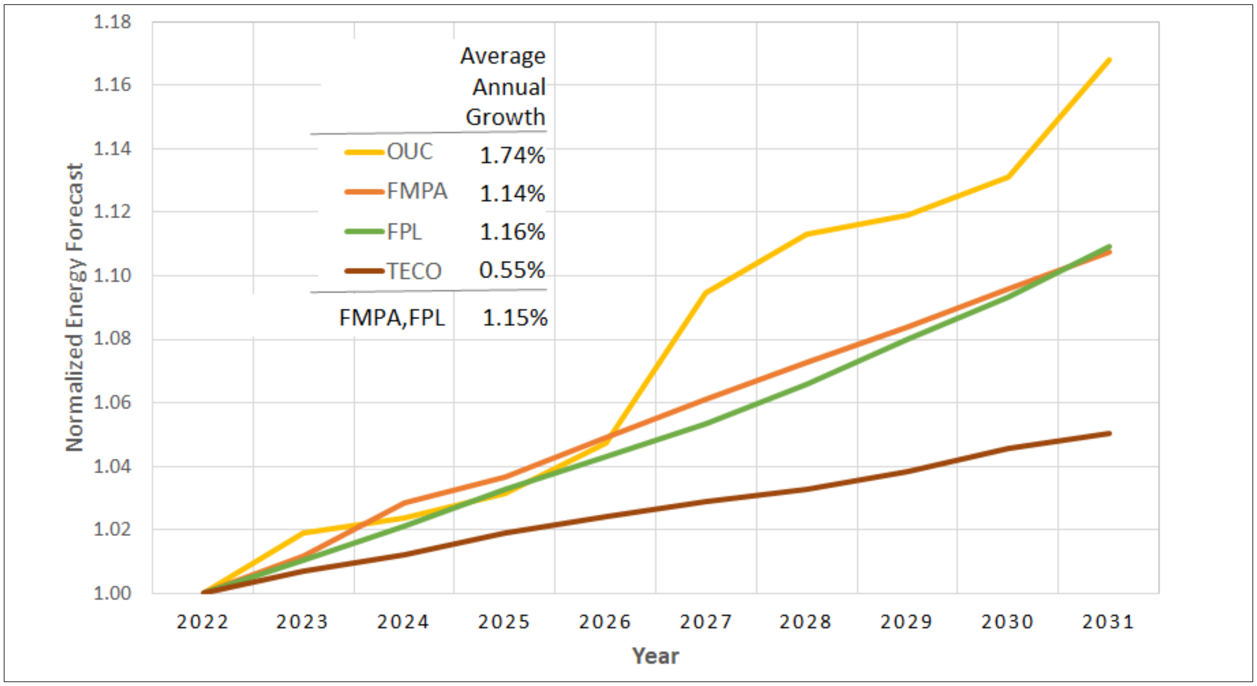

Figure 10. Forecast of Florida Utility Growth Rates

As can be seen in Figure 10, the average annual growth rates vary from a high of 1.74% for OUC to a low of 0.55% for TECO. OUC, FMPA, and FPL have a similar growth trajectory in the first four years (2022–2026) until OUC diverges with a significantly higher growth rate in the last five years (2027–2031) than the other two utilities.

CWP is already densely developed with limited opportunity for future growth from new customers or developing vacant land. Its historic growth over the last nine years has been virtually flat, averaging only 0.09% yearly. CWP's future growth will be driven by the expanded energy use from its existing customers through increasing the energy density of existing customers, such as by expanding floor space and end uses on existing residential and commercial lots.

After reviewing the growth projections in the 2022 TYSP of the nearby utilities, Quanta Technology selected an expected CWP energy growth rate consistent with CWP's average annual growth rate over the last ten years, or 0.09%. This average reflects a continuation of virtually flat load growth for the embedded end users and customers. This expected load growth does not explicitly consider the potential impacts of end-use electrification (e.g., changing gas space and water heating to electric appliances). However, as discussed later in this report, Quanta Technology has addressed the forecasted impacts from increased distributed generation (principally distributed solar), distributed batteries, and EV charging separately as energy and load modifiers to the embedded system energy and peak demand.

Quanta Technology selected the annual average of the projected FMPA and FPL energy growth, or 1.15%, as the value of the high- or upper-end load forecast for this CWP study. While still low, this 1.15% represents a significant annual growth for embedded load, particularly when the growth rate does not include the expected impacts from EV charging. Quanta Technology believes the 1.15% annual growth should be on the upper end of growth rates that CWP could expect. This upper-end growth was selected for CWP since a higher growth rate was thought to make achieving the target renewable generation more difficult. Figure 11 below shows the expected and high energy forecast for CWP.

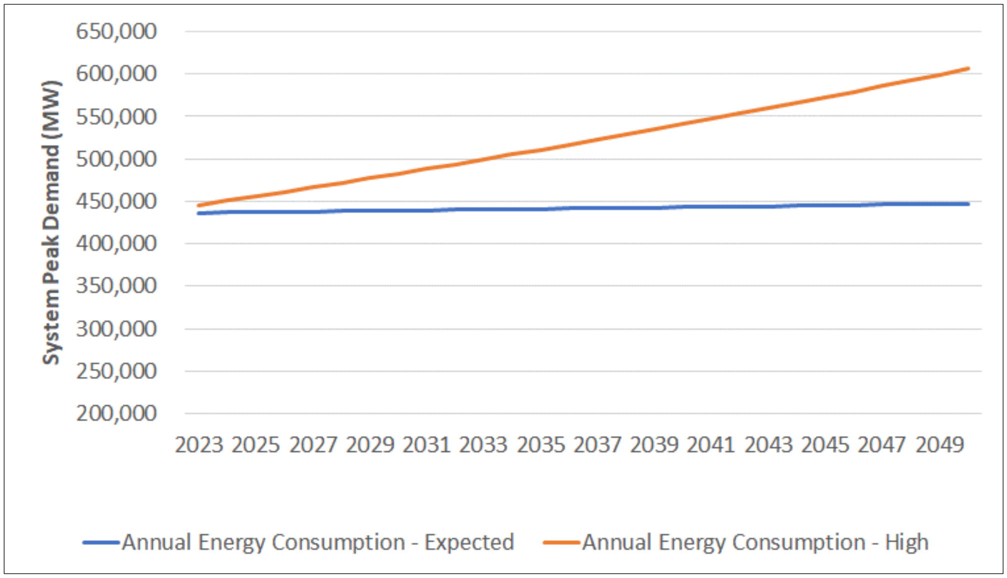

Figure 11. CWP Forecasted Annual Energy Consumption

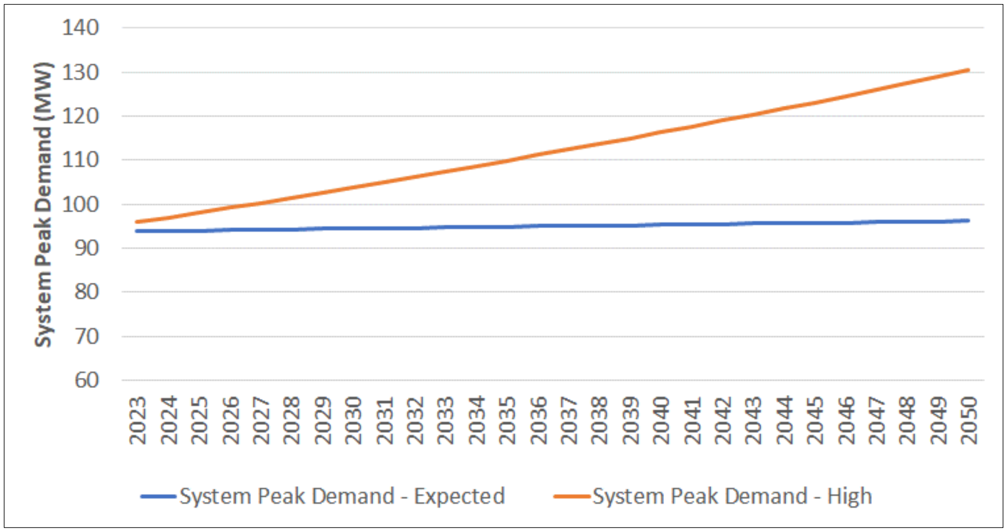

Figure 12. CWP Forecasted System Peak Demand

The energy and demand forecasts in the prior charts are forecast prior to any adjustment for the impacts of EE, DR, and electric vehicles (EVs).

4.3 Distributed Solar and Storage

Distributed solar and storage are highly dependent on various industry forces, including technology advancements in EVs, storage, and PVs, as well as consumer adoption. The technology model for distributed solar and storage is considered mature technology that assumes:

- EV chargers will incrementally improve
- PV modules will incrementally improve
- Battery storage is commercially available for households and modeled after the size of a Tesla Powerwall

CWP and its residents have some influence on distributed solar and storage adoption rates, and these rates have further been segmented into different categories:

- Residential single-family homes
- Multifamily homes
- Commercial buildings
- CWP assets
  - Commercial buildings
  - Industrial areas

Appendix D: NREL PVWatts Solar Production Estimateshows the NREL PV Power Estimate for a 1000 square-feet roof, which was used on a unit basis to provide estimates for solar production. Multiple residential single-family homes (SFH) adoption assumptions for solar, storage, and EV were created for this study. Solar rooftop installations in Florida expanded due to state tax credits. Without tax credits, adoption slowed drastically. We do not assume tax credits will be the sole driver of adoption, but they will certainly be one of the key drivers. Early EV adopters have also been shown to be closely aligned with those SFH which have installed solar PV. Our model assumes growth across a mix of three types of SFHs with rooftop solar PV, batteries, and EV chargers:

1. An SFH with 500 sq ft of solar PV panels, a Tesla Powerwall battery, and an EV charger that draws on average 24 kWh per day
2. An SFH with 743 sq ft of solar PV panels and a Tesla Powerwall battery that has a net-zero energy draw per day. A net-zero energy installation has sufficient solar PV energy production capacity to offset 100% of the location’s annual energy consumption. No EV is included in this SFH variation.
3. An SFH with 928 sq ft of solar PV panels, a Tesla Powerwall battery, and an EV charger that has a net-zero energy draw per day

Forecasts for the residential solar PV and batteries are provided in Appendices E and F. The residential batteries in these installations are assumed to be controlled by the home owner.

Multifamily homes and commercial buildings are considered net-consumers of energy. Forecasting solar PV and EV charger installations on landlord-owned multifamily homes is complex principally because they are site-specific and landlord-specific. It is likely that solar PV and EV chargers on landlord-owned, multifamily homes will significantly lag the installations for SFHs and have only a small impact on CWP loads within the next 5–10 years. For these reasons, Quanta Technology did not include a separate forecast for the multifamily homes.

For CWP-owned assets, the adoption rate of solar on these commercial buildings was based on the year of expected roof replacements. For buildings that did not have an estimated year of roof replacement, the expected solar kWs were evenly distributed until 2050. Industrial areas such as the CWP lift stations were included in this analysis.

In addition, Quanta Technology developed an estimate of the EV charging that will be performed by business commuters that work within the CWP and charge their vehicles at work during the day.

For each of the elements discussed in this section, an expected forecast was created, as well as a high and low forecast. These three forecasts of the contributions from the distributed solar, storage, and EV charges were then added to the different scenarios as noted in Table 6 and Table 7.

4.4 Electric Vehicles

Like the development of the CWP energy forecasts for this study, Quanta Technology looked to the forecasts of other Florida Utilities and their 2022 TYSP to develop a forecast of CWP EV charging loads. Table 1 summarizes the expected growth in the number of EVs in each of the utilities noted[4].

Table 1. 2022 TYSP: Estimated Number of EVs

Year	FPL	DEF	TECO	JEA	GRU	TAL	Total
2022	116,202	33,325	12,218	4,220	1,065	1,158	168,722
2023	162,141	42,404	14,890	5,477	1,331	1,469	227,712
2024	220,697	52,918	17,742	6,939	1,664	1,832	301,792
2025	293,809	65,134	20,785	8,589	2,080	2,253	392,650
2026	391,240	79,267	24,119	10,419	2,600	2,736	510,381
2027	512,104	95,455	27,808	12,441	3,250	3,288	654,346
2028	657,776	114,021	31,977	14,689	4,063	3,921	826,447
2029	831,693	135,439	36,561	17,187	5,078	4,640	1,030,598
2030	1,037,328	160,059	41,599	19,951	6,348	5,459	1,270,744
2031	1,273,609	188,139	47,156	22,993	7,935	6,378	1,546,210

Table 2 summarizes the expected annual energy consumption for cumulative EV charging in each utility noted.[5]

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[4] FL PSC Review of the 2022 Ten-Year Site Plans of Florida's Electric Utilities, October 2022, Table 2.

[5] FL PSC Review of the 2022 Ten-Year Site Plans of Florida's Electric Utilities, October 2022, Figure 15.

Table 2. 2022 TYSP: Estimates EV Annual Charging Consumption (GWh)

Year	FPL	DEF	TECO	JEA	GRU	TAL	Total
2022	231.0	24.0	34.6	17.2	3.8	3.5	314.2
2023	401.0	54.1	45.5	24.1	4.8	4.5	534.0
2024	623.0	91.9	57.3	32.1	6.0	5.6	816.0
2025	908.0	138.9	70.3	41.2	7.5	6.9	1,172.7
2026	1,289.0	199.0	---	51.2	9.4	8.4	1,641.6
2027	1,771.0	274.5	100.8	62.3	11.7	10.1	2,230.5
2028	2,361.0	366.8	118.3	74.7	14.6	12.1	2,947.6
2029	3,075.0	470.4	137.9	88.5	18.3	14.4	3,804.4
2030	3,930.0	586.2	159.5	103.7	22.9	17.0	4,819.2
2031	4,913.0	712.2	183.0	120.5	28.6	19.9	5,977.1

Table 3 summarizes the expected annual energy consumption per vehicle for charging EVs in each utility noted. The per-vehicle energy consumption in Table 3 is derived by dividing the annual charging energy for all EVs shown in Table 2 by the annual number of EVs in Table 1.

Table 3. Annual Energy Consumption Per EV (kWh)

Year	FPL	DEF	TECO	JEA	GRU	TAL	Average
2022	1987.9	720.2	2831.9	4075.8	3568.1	3022.5	1862.2
2023	2473.2	1275.8	3055.7	4400.2	3606.3	3063.3	2345.1
2024	2822.9	1736.6	3229.6	4626.0	3605.8	3056.8	2703.8
2025	3090.4	2132.5	3382.2	4796.8	3605.8	3062.6	2986.6
2026	3294.7	2510.5	---	4914.1	3615.4	3070.2	3216.4
2027	3458.3	2875.7	3624.9	5007.6	3600.0	3071.8	3408.7
2028	3589.4	3217.0	3699.5	5085.4	3593.4	3085.9	3566.6
2029	3697.3	3473.2	3771.8	5149.2	3603.8	3103.4	3691.4
2030	3788.6	3662.4	3834.2	5197.7	3607.4	3114.1	3792.4
2031	3857.5	3785.5	3880.7	5240.7	3604.3	3120.1	3865.6

Quanta Technology used the FPL data in the tables above, together with FPL service territory population and FL State vehicle registration data, to estimate the percent registered vehicles in FPL's service territory that it expects to be EVs for the next ten years.

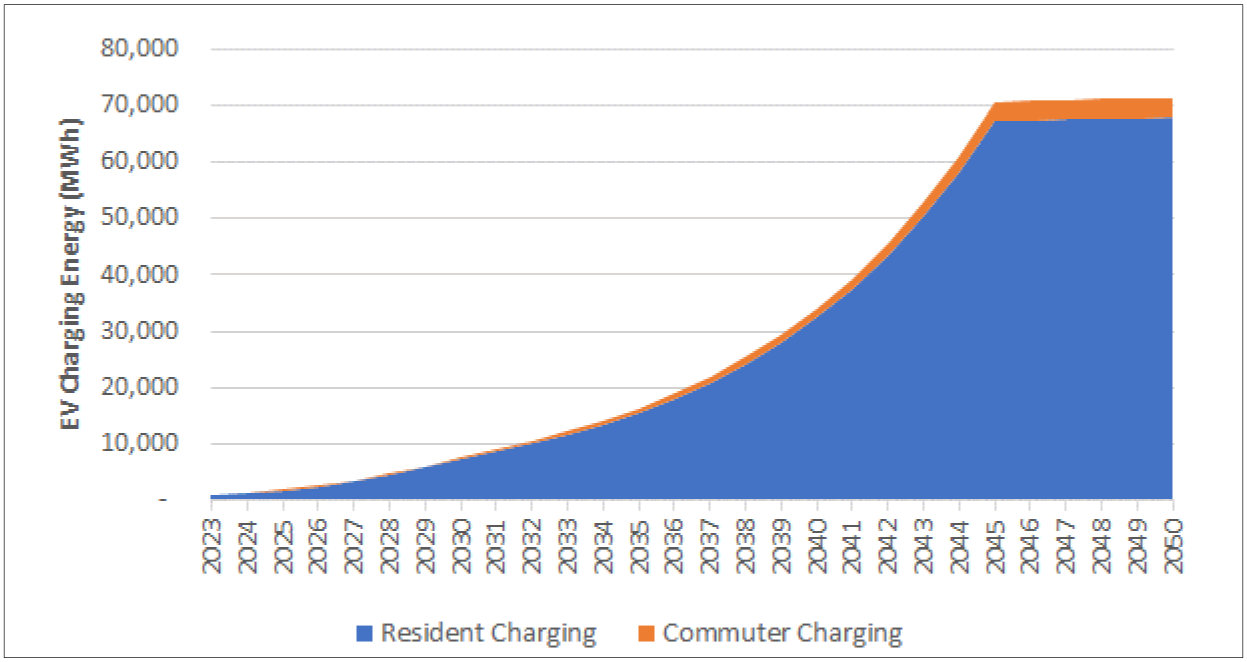

Figure 13. Resident and Commuter Annual EV-LDV Charging Energy: Expected Scenario

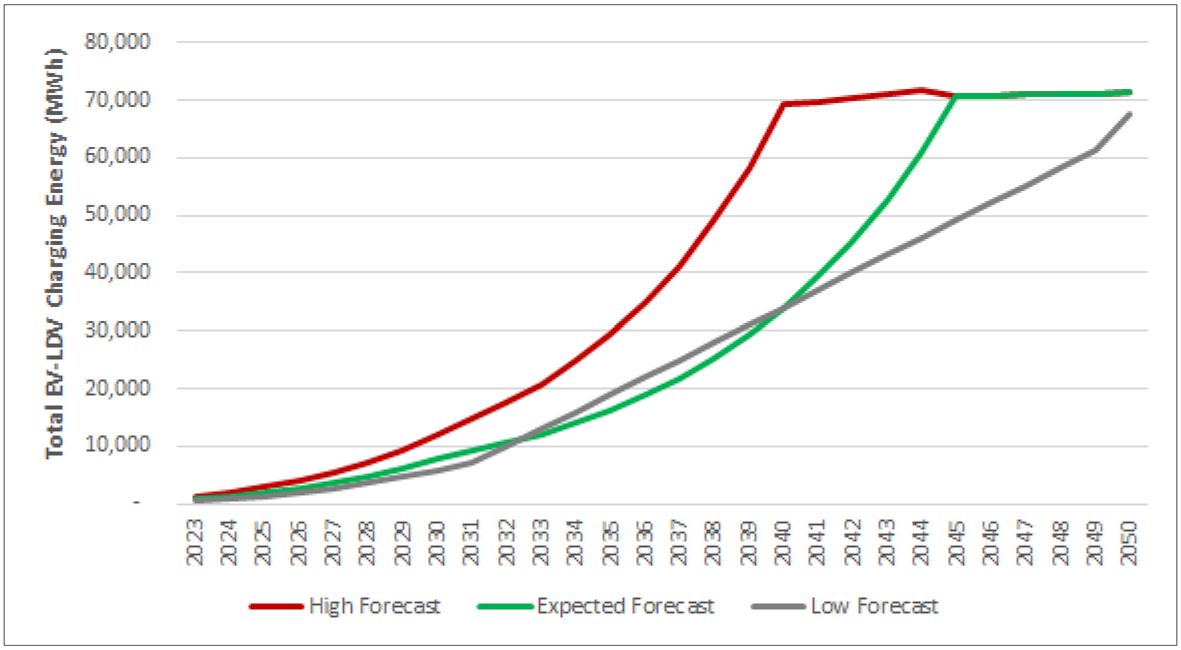

Figure 14. Annual Resident and Commuter EV-LDV Charging Energy

As seen in Figure 14, the high and expected forecasts each reach a maximum EV penetration, estimated to be 95% of registered light-duty vehicles (LDVs). The high forecast reached this maximum in 2040, and the expected forecast reached this maximum in 2045. The low forecast is still growing in the final year of the forecast and will reach a maximum of 90% penetration in the year 2050. Since EVs and their charging load are a new addition to utility planning, much uncertainty is associated with forecasting how rapidly the charging load will grow. Assessing higher growth rates of EVs that, in turn, have higher charging impacts is prudent in a feasibility analysis such as this study. In assessing new loads, it is better to be conservatively high rather than too low when assessing the costs of serving customer loads with a new set of resources. The forecasts of the LDV EVs for CWP residents are provided in Appendix G.

4.5 Generation Technologies and Battery Storage

Quanta Technology used the technical characteristics and cost data from the National Renewable Energy Laboratory (NREL) Annual Technology Baseline and a 2022 NREL Solar and Energy Storage Cost Benchmarks Analysis[6] (collectively referred to as NREL Data) The NREL Data provides an extensive database on renewable, fossil, and energy storage technologies that are regularly used as a basis for future costs in utility resource planning. The NREL data also provides projected costs of technologies, for example, the decreases expected in solar PV and battery costs from greater manufacturing volume and other technology advances. Table 4 provides a summary of the costs for the set of technologies that were considered in the resource plan for CWP.

Table 4. Generation and Storage Technologies Costs

Technology	Installed Cost $/kW (REC in $/MWh)	Cost Year	Annual Cost Escalation	Cost Stabilization Year	Fixed O&M ($/KW-yr)	Variable O&M ($/MWh)
Combustion Turbine (CT)	$1,000	2021	2%	10	15.00	2.00
Internal Combustion Engine (CE)	$650	2021	2%	5	30.00	10.00
Green Hydrogen Fueled CT (CT-Hydrogen)	$1,500	2021	2%	10	20.00	4.00
City Owned Distributed Solar, Rooftop (Dsolar-CommRoof)	$2,208	2021	-2%	10	18.10	0.00
City Owned Distributed Solar, Ground-mount (Dsolar-CommGround)	$2,328	2021	-2%	10	17.20	0.00
Utility Scale Solar PV (USolar)	$1,386	2021	-2%	5	16.10	0.00
Battery Energy Storage System – 1 hr. (ESS-1)	$710	2021	-2%	5	15.00	0.00
Battery Energy Storage System – 2 hr. (ESS-2)	$1,070	2021	-2%	5	14.00	0.00
Battery Energy Storage System – 4 hr. (ESS-4)	$1.790	2021	-2%	5	12.00	0.00
Battery Energy Storage System – 10 hr. (ESS-10)	$3,950	2021	-2%	5	10.00	0.00
Biomass	$500	2021	2%	5	10.00	0.00
Demand Response (DR)	$50	2021	2%	5	10.00	0.00
Energy Efficiency (EE)	$20	2021	2%	5	10.00	0.00
Renewable Energy Credit (REC)	$2.5	2021	2%	10	0.00	0.00

Quanta Technology did not consider some of the technologies listed in the NREL Data since they were inappropriate for CWP and Florida (e.g., hydroelectric, pumped storage, and distributed wind

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[6] Ramasamy, Vignesh, Jarett Zuboy, Eric O'Shaughnessy, David Feldman, Jal Desai, Michael Woodhouse, Paul Basore, and Robert Margolis. 2022. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83586. www.nrel.gov/docs/fy22osti/83586.pdf.

technologies). The CAPEX costs shown in Table 4 include assumed interconnections costs but do not include any grid upgrades. The costs of solar PV and utility-scale battery storage technologies are assumed to decline by 2% annually (based on the Annual Cost Escalation data) until 2026 (based on the Cost Stabilization Year data) and remain flat afterward. In 2021, the cost of a utility-scale solar PV was assumed to be $1,386/kWac (assuming a DC to AC ratio of 1.4).

The cost of natural gas is assumed to be $3.00/MMBTU in 2019, and it is expected to increase at a 2% escalation per annum. The utility and transportation industries are planning to use an increasing quantity of batteries in their efforts to reduce carbon emissions. Mining minerals, manufacturing, and disposing of these increasing quantities of batteries bring environmental issues to a scale new to the world economy. At the request of CWP, Quanta Technology has prepared a summary of the lifecycle considerations of batteries in Appendix C.

4.6 Energy Efficiency and Demand Response

According to the United States Department of Energy, EE and DR can be described as:

> *Energy efficiency is the use of less energy to perform the same task or produce the same result. Energy-efficient homes and buildings use less energy to heat, cool, and run appliances and electronics, and energy-efficient manufacturing facilities use less energy to produce goods.*
>
> *Energy efficiency is one of the easiest and most cost-effective ways to combat climate change, reduce energy costs for consumers, and improve the competitiveness of U.S. businesses. Energy efficiency is also a vital component in achieving net-zero emissions of carbon dioxide through decarbonization.*[7]
>
> *Demand response provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.*[8]

Quanta Technology's experience with other utilities confirms this statement. Most utilities find that numerous EE measures, such as programs that incentivize the shift from incandescent or fluorescent lights to LED lighting, are much less expensive than purchasing or generating electricity saved in these programs. In essence, many energy efficiency measures cost the utility less to manage the EE program and pay incentives than the costs to generate or buy the energy. It is widely accepted that any program to reduce the environmental impacts of electric energy supply on the environment should include a robust energy efficiency program that first attempts to cost-effectively reduce the energy required.

Quanta Technology had limited data on CWP's forecasted plans and projected impacts of energy efficiency programs for the CWP system. However, since these energy efficiency programs can generally offer the lowest cost "energy resource" available to utilities, Quanta Technology estimated the impacts that the future energy efficiency programs implemented by CWP, together with the energy efficiency improvements implemented by CWP customers on their own, will be approximately 2% of the total CWP

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[7] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, https://www.energy.gov/eere/energy-efficiency

[8] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, https://www.energy.gov/oe/demand-response

energy requirement in the early years of the study and grow to approximately 10% in 5 years and remain approximately constant for the remainder of the study[9]. The DR was estimated to be constant at 5 MW for the study period. A total DR of 5 MW was considered easily achievable in a program that includes customer and city-owned facilities. These high-level estimates were deemed reasonable because CWP does not have an existing EE and DR program in place for its retail customers.

4.7 Fuel Price

Each Florida utility filing a TYSP also files a fuel price forecast for the fuel used in their plans. The PSC has compiled and averaged the fuel price forecasts in the plan reviews. Figure 15 summarizes the filing utilities' average historical and forecasted fuel prices. Quanta Technology chose to extrapolate the average fuel forecasts shown in the TYSPs for use in the CWP study.

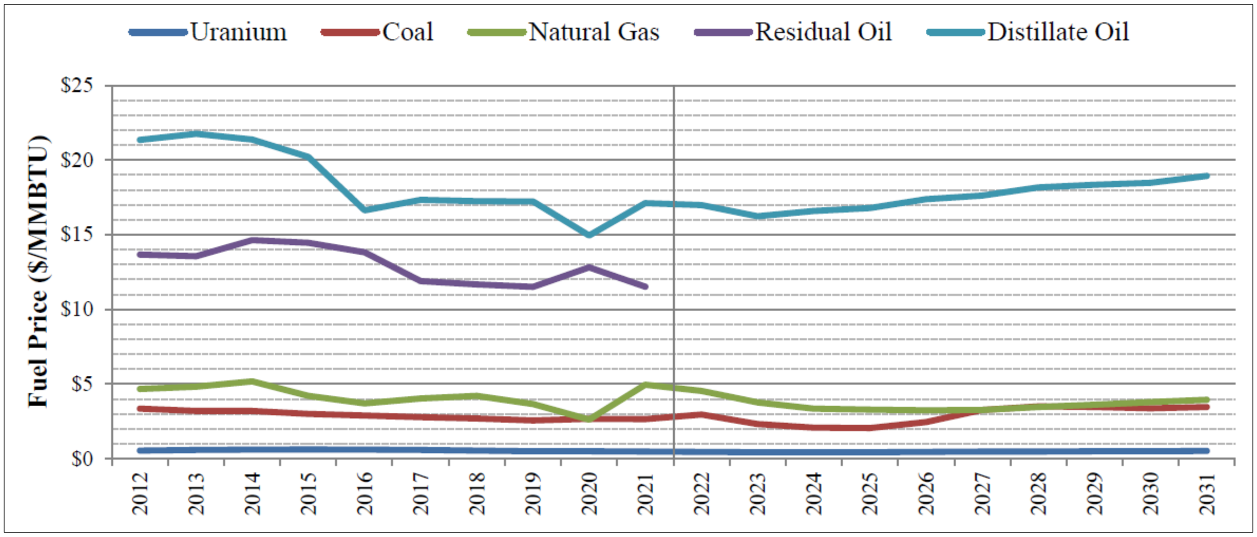

Figure 15. TYSP Utilities: Average Fuel Price of Reporting Electric Utilities

4.8 Renewable Energy Credits

One of CWP's three primary renewable targets was achieving a 100% net-zero carbon energy supply by 2050. Net zero implies that some carbon may be released into the atmosphere during electricity generation. However, any carbon released will be counterbalanced by acquiring carbon offsets, carbon credits, or RECs to offset carbon emissions from the energy supply portfolio. The ownership of RECs and carbon credits has become an accepted method to prove to regulators, constituents, or stockholders that an entity has caused the specified renewable energy production or reduction in carbon emissions. Utilities use RECs and carbon credits to prove compliance with legislated renewable portfolio standards (RPS) or the carbon content of their energy supply targets. Cities and corporations use them to demonstrate to constituents and shareholders that they have reduced their carbon footprint by X% or use Y% renewable generation to supply their operations.

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[9] The EE estimate does not address growth of individual end-use energy efficiency improvements. It should be noted that while EE programs do result in lost utility revenue due to the reduction in MWh sold, these programs are also accompanied by a reduction in energy supply costs. In addition, all DR and EE measures should be selected based on the ability to implement and manage them with a positive benefit to cost ratio.

Neither the state of Florida nor the Federal government has established any state mandate for carbon emission limitations or RPS for Florida's utilities. While several cities and utilities in Florida have adopted renewable or carbon emission goals, the goals are considered voluntary. The markets for RECs were originally driven by utilities and other entities with a legislative requirement to meet renewable or carbon targets. However, private corporations and cities quickly adopted the use of RECs and carbon credits, similar to CWP, to document their progress toward achieving their voluntary renewable or carbon goals.

The markets have created different types of RECs with different pricing to meet the different needs of their buyers. LevelTen Energy, a player in the REC market, offers the following concise explanation:

> "*RECs are priced differently depending on whether they are compliant or voluntary market RECs. Compliance market RECs are used to meet renewable portfolio standards (RPS), must meet certain criteria in the RPS statutes, and are often more expensive. Voluntary REC markets are almost exclusively driven by climate-related sustainability goals, making them more common for corporate clean energy purchasers. Since there are fewer strings attached, voluntary market RECs have lower prices. Some states have a tier system for RECs to indicate their positive environmental impact. For example, Tier 1 RECs come from new wind and solar projects. The RECs with a higher carbon-reduction impact are typically more expensive than RECs with a lower impact, like those produced in an already clean grid.*[10]"

As noted above, due to the lack of need to meet different state-level requirements for RPS compliance in a specific state, voluntary RECs tend to be much less expensive than compliance RECs. In addition, voluntary market RECS are more locationally fungible in that voluntary RECs created in one state can fulfill voluntary renewable targets in any state.

With the current lack of a Florida RPS, Quanta Technology would recommend that any future REC purchases made by CWP to meet environmental targets should be made from the lowest-priced RECs available, which would be expected to be the voluntary market. Quanta Technology has reviewed various voluntary market historical and current pricing to define a REC pricing projection for this study. The forecast of the voluntary REC pricing for this study was based on forecasts of solar and wind RECs at a national level for the years 2023–2042. Linear regression was then used to extrapolate this data for an additional eight years to 2050. Figure 16 illustrates the input forecast and the extrapolated REC prices. The average price was used as the expected REC price for this study[11].

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[10] Introduction to Renewable Energy Certificates (RECs), RTI Essentials and Best Practices, May 14, 2020, LevelTen Energy, Ben Serrurier.

[11] REC pricing data compiled from multiple sources.

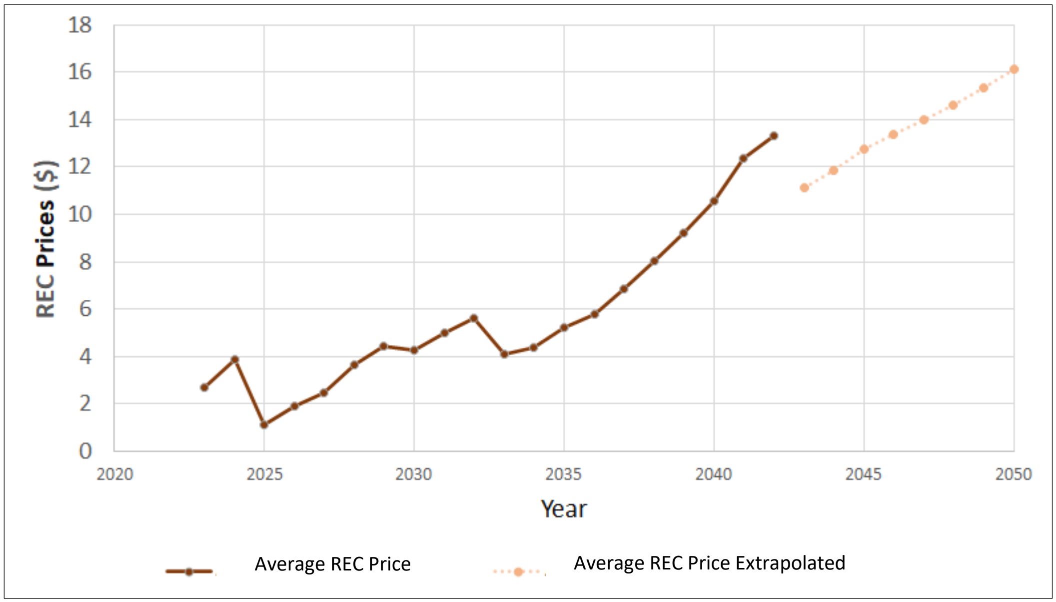

Figure 16. REC Price Forecast

4.9 Financial Assumptions

The primary financial metric to assess optional portfolios of future supply resource options for CWP was the net present value of revenue requirements (PVRR). PVRR is a metric commonly used for public and investor-owned utility decision-making, and for other industries, for analysis that includes multiple years and/or long-lived assets. PVRR is a discounted cash flow analysis that assesses the forecasted cash outlay for capital expenditures, operations, and expenses for each year of the study. For this study, the period of the analysis was 2025–2050. The forecasted annual cash requirements are then discounted based on the cost of capital of CWP. Each year's resulting discounted cash requirements are then summed to arrive at a single value representing the PVRR. This methodology allows different optional supply portfolios to be compared with a single financial metric.

Several financial assumptions are required to perform long-term resource plans and to calculate the PVRR. To assess the possible project financing options available to CWP, Quanta Technology estimated the potential cost of new supply resources being developed and owned by third-party developers and the costs should CWP choose to own new supply resources. The developer's cost of capital determines the cost of new resources for which CWP would contract through a PPA. The CWP cost of capital, which represents an estimate of the CWP interest for their future general obligation bonds, is used for estimating the annual costs of CWP ownership of new supply resources and the present value discount factor used for all scenarios.

Table 5. Primary Financial Assumptions

Item	Value
CWP Cost of Capital	3.5%
Developer Cost: Cost of Debt	6.0%
Developer Cost: Cost of Equity	10.0%
Developer Cost: Percentage Debt	50.0%
Developer Cost: Percentage Equity	50.0%
Developer Cost: Cost of Capital	8.0%
Annual Inflation	2.0%

5 SCENARIO DESCRIPTIONS

5.1 Targets and Scenarios

As noted in early sections, this study was centered around the assessment of three potential targets under consideration for the future CWP energy supply:

- **Target 1:** 100% renewable energy supply by 2050
- **Target 2:** 100% net-zero carbon energy supply by 2050
- **Target 3:** 80% renewable energy supply by 2035 and then 100% by 2050

Based on the explicit language in the targets, the study required it to create a forecast and assumption for the year 2050. Since forecasting future conditions (e.g., energy consumption, costs, technology progression, legislative requirements) is such an imprecise science, planners in many industries, including utility resource planners, have adopted scenarios to address the uncertainty of forecasts.

While the scenario is a common term, a definition used in planning is useful for clarity. As used in this report and commonly understood in planning:

A scenario is a set of future conditions that collectively describe the external environment and conditions within which one is attempting to plan or make a decision. In the case of a resource plan, a scenario description includes a multi-year forecast of external drivers or assumptions important to the analysis. Examples of elements typically included in resource planning scenario descriptions are customer load forecasts, the projected cost of supply options, the forecasted growth of distributed generation installations, etc. A single planning target, or input, such as achieving a 100% renewable supply by 2050, does not constitute a scenario, only a single planning input. A scenario requires many planning inputs.

Since it is so difficult to accurately predict future conditions, rather than just planning for a single set of future conditions, a single scenario, planners often create and use multiple scenarios that collectively describe a range of plausible future conditions. Evaluating how resource options perform across a range of potential future conditions enables assessing the resources' flexibility and ability to adapt to changing conditions.

Quanta Technology used this planning methodology with multiple scenarios to assess different options and combinations of resources to achieve each of the three renewable targets that CWP is considering. These three optional targets were expanded into a total of 15 different scenarios:

- Six focused on achieving Target 1 (100% renewable by 2050)
- Five focused on achieving Target 2 (100% net-zero carbon by 2050)
- Four focused on achieving Target 3 (80% renewable supply by 2035 and then 100% by 2050)

Each of these scenarios looked at different expected forecasts for the following eight categories of planning elements which were referenced at the beginning of this section:

1. Load forecast
2. Distributed solar and storage
3. EV growth
4. Renewables and battery storage costs
5. EE and DR forecast
6. Natural gas fuel price forecast
7. REC pricing
8. Financial assumptions

Table 6 summarizes the eleven scenarios developed to assess resource options for the first two renewable targets, 100% renewable by 2050 and net-zero carbon by 2050. Table 7 summarizes the four additional scenarios developed to assess resource options for the third renewable target, 80% renewables by 2035 and 100% by 2050.

Table 6. Scenarios Details for 100% Renewable by 2050 and Net-Zero Carbon by 2050

Scenario Count	1	2	3	4	5	6	7	8	9	10	11
Scenario Element	Target 1: 100% Renewable by 2050						Target 2: Net-Zero Carbon by 2050				
	1a	1b	1c	1d	1e	1f	2a	2b	2c	2d	2e
2050 Renewable Target	100%	100%	100%	100%	100%	100%	---	---	---	---	---
2050 Net-Zero Carbon Target	---	---	---	---	---	---	100%	100%	100%	100%	100%
Renewable Electric Supply by 2035	---	---	---	---	---	---	---	---	---	---	---
Load Forecast	Expected	High	Expected	Expected	Expected	Expected	Expected	High	Expected	Expected	Expected
Natural Gas Fuel Price Forecast	Base	Base	Base	Base	High	Low	Base	Base	Base	High`	Low
Distributed Solar and Storage	Expected	High	Low	Expected	Expected	Expected	Expected	High	Low	Expected	Expected
EV Growth	Expected	High	Low	Expected	Expected	Expected	Expected	High	Low	Expected	Expected
Technology Costs	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected
EE and DR Forecast	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected	Expected
REC Pricing	---	---	---	---	---	---	Expected	Low	High	Expected	Expected
Developer Cost of Capital	8.00%	8.00%	8.00%	-	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%	8.00%
CWP Cost of Capital	---	---	---	3.50%	---	---	---	---	---	---	---

Load forecasts are as follows:

- **Expected:** 0.09%, based on the average of historical CWP growth
- **High:** 1.15%, based on average FMPA and FPL forecasts

Table 7. Scenarios Details for 80% Renewable by 2035

Scenario Count	12	13	14	15
Scenario Element	Target 3: 80% Renewable by 2035 and 100% by 2050			
	3a	3b	3c	3d
2050 Renewable Target	100%	100%	100%	100%
2050 Net-Zero Carbon Target	---	---	---	---
Renewable Electric Supply by 2035	80%	80%	80%	80%
Load Forecast	Expected	Expected	Expected	Expected
Natural Gas Fuel Price Forecast	Base	Base	High	Low
Distributed Solar and Storage	Expected	Expected	Expected	Expected
Electric Vehicle Growth	Expected	Expected	Expected	Expected
Technology Costs	Expected	Expected	Expected	Expected
EE and DR Forecast	Expected	Expected	Expected	Expected
REC Pricing	---	---	---	---
Developer Cost of Capital	8.00%	-	8.00%	8.00%
CWP Cost of Capital	---	3.50%	---	---

Load forecasts are as follows:

- **Expected:** 0.09%, based on the average of historical CWP growth
- **High:** 1.15%, based on average FMPA and FPL forecasts

6 COST AND FEASIBILITY COMPARISONS

6.1 Target 1: 100% Renewable Energy Supply by 2050

The first of CWP's potential energy supply targets identified 2050 as the date for achieving a 100% renewable energy supply. Developing and constructing a utility-scale solar photovoltaic generation facility takes multiple years. Developers of these plants typically identify co-owners and those seeking a PPA to purchase power from the plant owners as early as the development cycle. Having the future energy output of the facility fully committed to either owners or buyers will lower the risks associated with the project and, in turn, the costs of financing. Based on this typical multi-year cycle for solar facility development, Quanta Technology has assumed it will take a few years for CWP to find favorable PPA contracts or ownership positions for its renewable supply. Figure 17 provides the projected renewable energy percent of the CWP requirement for Target 1 (100% renewable by 2050) and Target 2 (80% renewable by 2035). While Target 2 shows a more rapid rise in the renewable energy contribution, both show a slower growth in the study's early years, reflecting that it will take time for CWP to identify, negotiate and execute favorable renewable energy supply options.

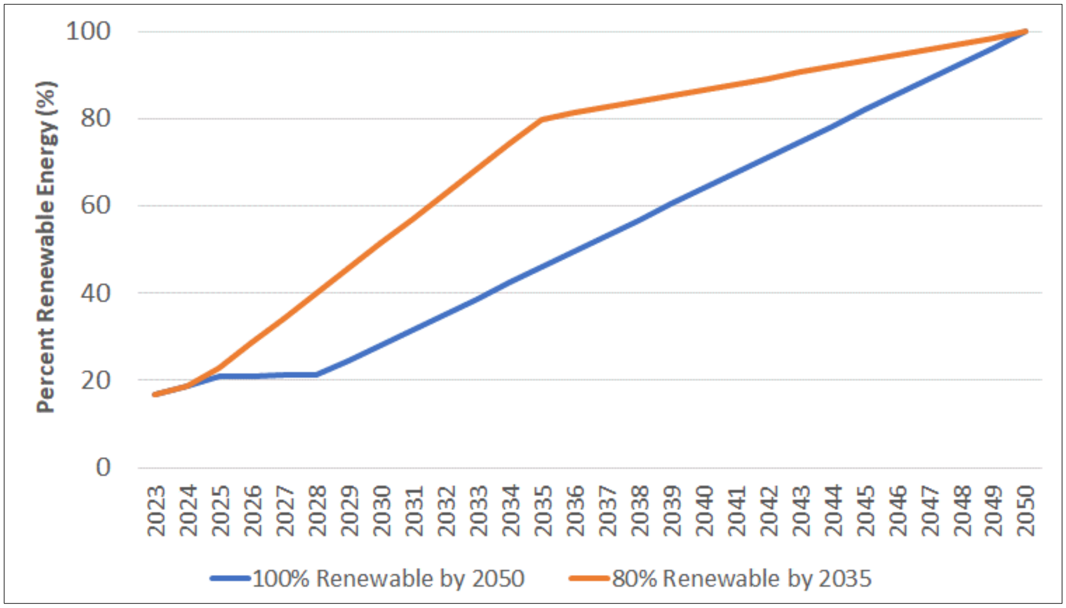

Figure 17. Comparison of Renewable Energy Results for the Two Renewable-Based Targets

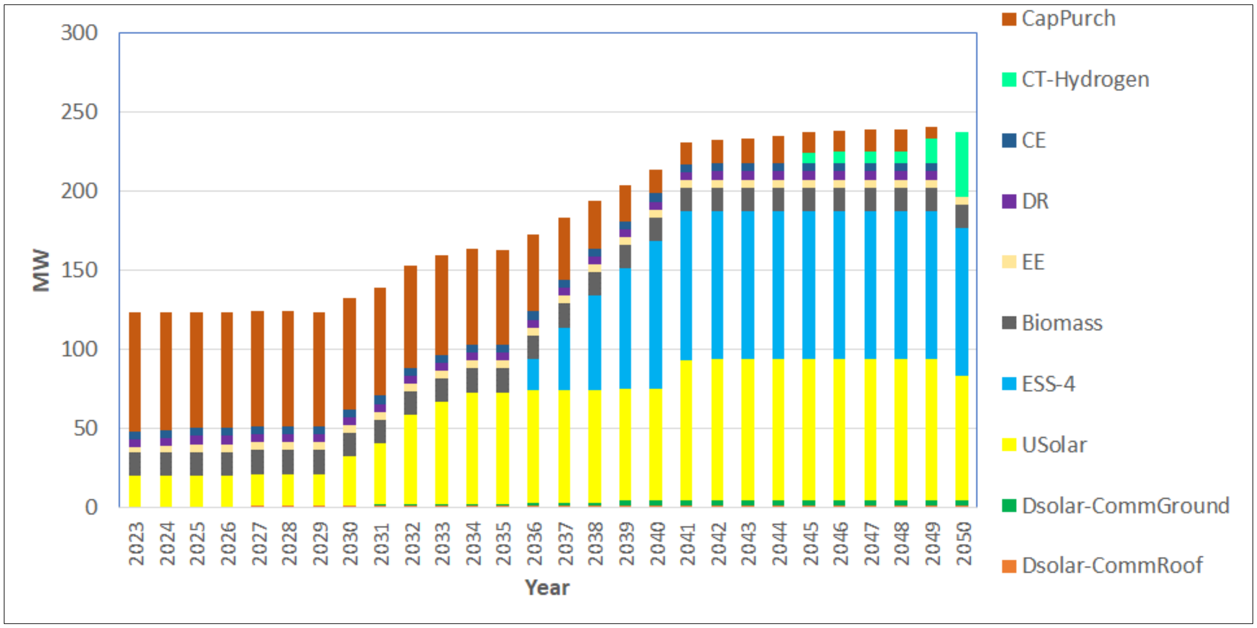

Figure 18 provides a chart showing the detailed technologies selected for the pIRP model as the least cost supply additions for Scenario 1A[12], the first of the six scenarios defined to assess Target 1.

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[12] Technologies referenced in Figure 18 and elsewhere in the report are defined in Table 12 in Appendix B.

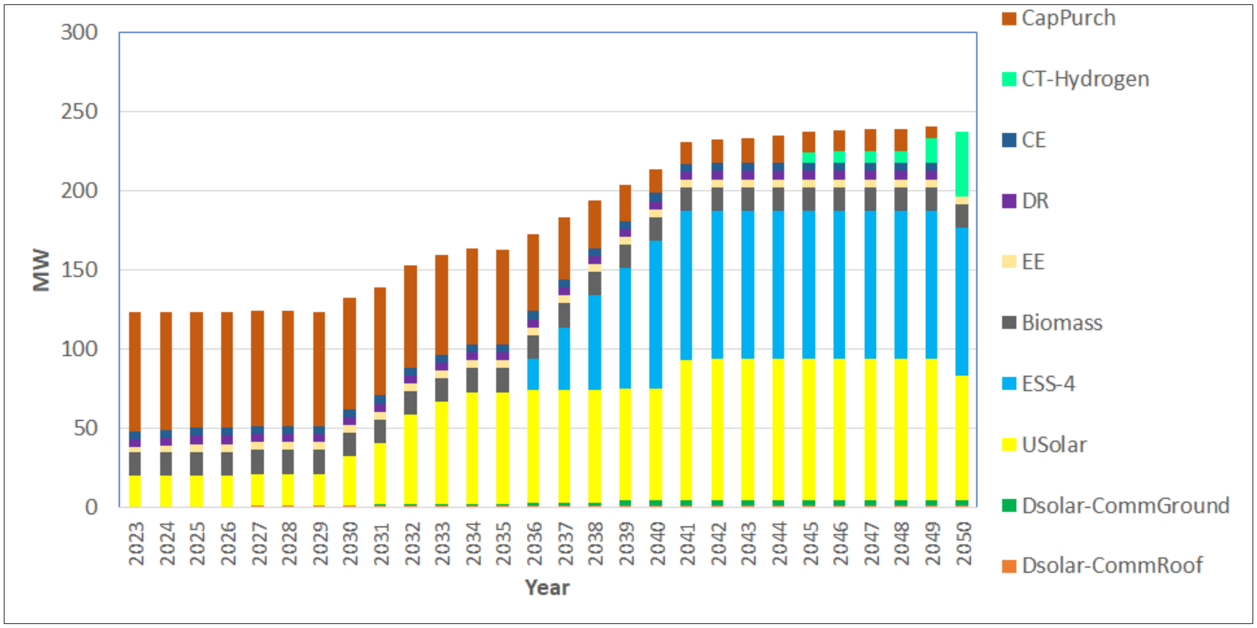


Figure 18. Capacity Additions for Scenario 1A

Solar and wind energy technologies, the two most common renewable energy sources, are considered variable renewable energy (VRE) sources since the energy production of both goes up and down based on the amount of solar or wind energy available. Whereas fossil resources, such as natural gas-fueled CTs or combined cycle plants, are described as dispatchable energy sources that can change the output of the energy produced based on the changing requirements of the system.

A system cannot operate with 100% VRE technologies. It must have other dispatchable technologies that can adjust to supply power as needed in response to the up and down production of VREs and the changes to customer demands. In this analysis performed for CWP, the dispatchable technologies selected by the pIRP model included biomass-fueled plants, batteries, CT-Hydrogen, nuclear, concentrated solar power, and geothermal, which were all even more expensive than CT-Hydrogen plants (see Section 4.5). While biomass is assumed to be a less expensive dispatchable resource than CT-Hydrogen in this study, Quanta Technology has limited the amount of biomass generation available for the pIRP to choose to supply CWP energy requirements. Quanta Technology believes that limiting the biomass generation available to CWP is a prudent assumption for several reasons, but primarily by the expectation that the proximity and quantity of biofuels in Florida will be limited and in high demand as all utilities seek to reduce the carbon emissions of their energy supply. Limiting the amount of biomass energy available to the pIRP model selects the next higher-cost energy resource once the biomass generation reaches its limit. A table listing the annual capacity purchases by technology for Scenario 1A can be found in Appendix F, Table 16.

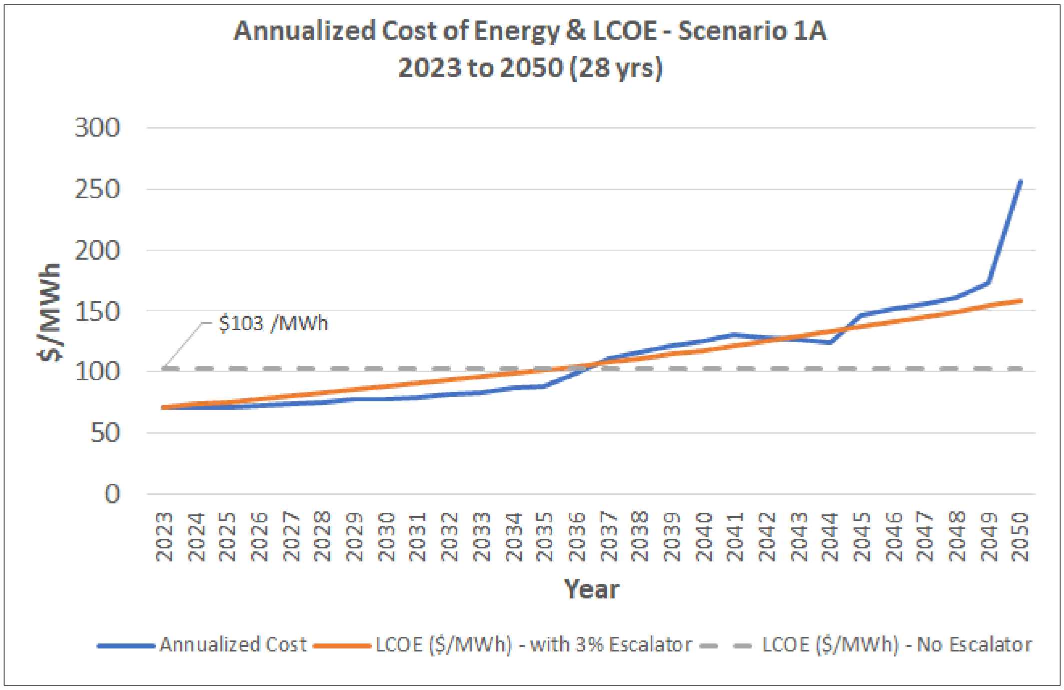


Figure 19 illustrates the annual energy cost for Scenario 1A based on three different measures of energy costs. The first measure in the blue line is the actual projected cost of revenue requirements for the energy supply in nominal dollars (inflation included), divided by the total energy consumptions, shown in $/MWh. Notice the blue line's steep growth in the cost of power beginning in 2045 and the sustained high costs in the final six years of the study (2045–2050). This rise in costs is driven by introducing an extremely high-cost renewable energy technology to meet the needs of CWP. The high-cost technology added, which drives the costs up in the final years, is combustion turbine generators (CT) fueled with green hydrogen (CT-Hydrogen). The pIRP model selected the CT-Hydrogen technology for the final years of the study. This steep cost rise as the supply portfolio approaches 100% clean energy is typical of other 100% renewable and zero-carbon studies. The energy cost of imports and exports between CWP and neighboring utilities is assumed to be $50/MWh in 2021 and is expected to escalate at 2% annually in nominal terms.

Note that the Annualized Cost in the blue line and the other cost presentation are all based on nominal dollars. The two alternative cost streams discussed below, the levelized cost of energy (LCOE) and the LCOE with an escalator, are constructed using a present value discounting of the Annualized Costs to 2021 dollars.

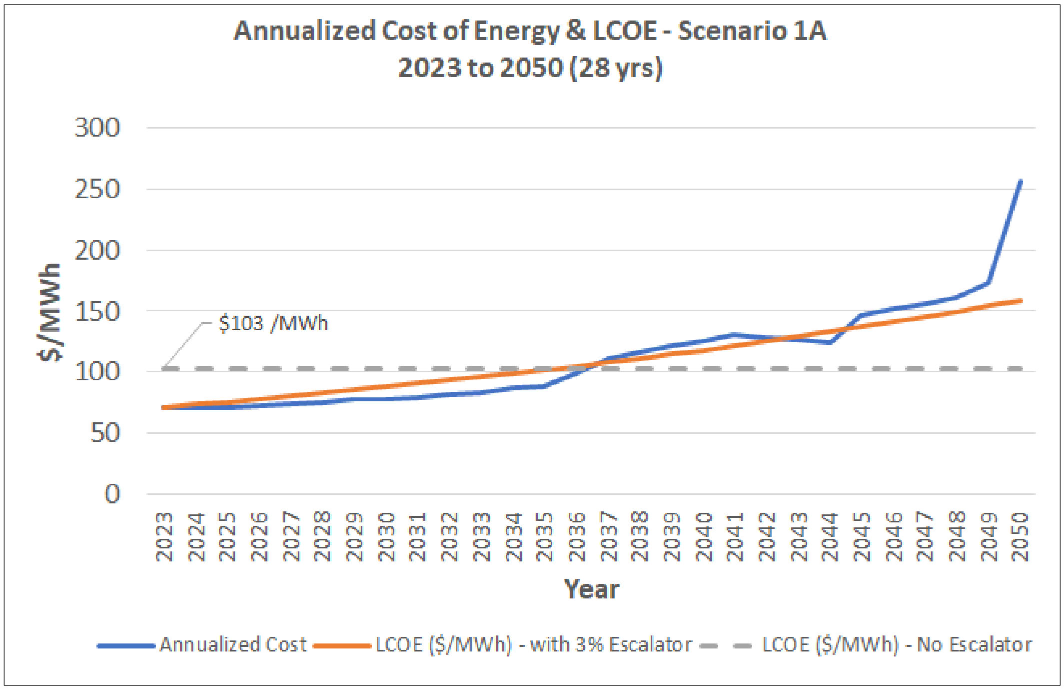


Figure 19. Annualized Cost of Energy and LCOE: Scenario 1A Based on 2023–2050

The dashed horizontal line presents the levelized cost of energy (LCOE) with no annual escalation, $103/MWh, which is the cost of energy equivalent to the blue line's actual energy cost if both were stated on a present value (PV) basis. Note that this report's PV and LCOE values are based on present value discounting to 2021 dollars. The LCOE calculation takes the entire stream of forecasted actual annual costs shown in the blue line and creates an equivalent single constant $/MWh value. The LCOE calculation flattens the year-to-year variations in actual costs and provides a single $/MWh to represent the multi-year stream of differing values shown in the actual costs (blue line). In application, the results of the 1A would provide an LCOE that partially pays for the high costs in the final six years by increasing the costs paid in the prior years.

Finally, the orange line shows the LCOE with an annual escalation of 3%. The 3% escalation is not equivalent to inflation but is the value selected by Quanta Technology to convert the LCOE to an equivalent stream of annual costs that better match the increasing trend in production costs. The orange line is equivalent to the dashed gray and blue lines if all three were compared on a PV basis. An LCOE with an escalation is a common method that provides a lower cost than the LCOE without escalation in the early years and a higher cost later. In these 1A results, note that both LCOE methods provide higher than actual costs in the early years, but both also serve to provide lower than the actual cost in the final years of the study, where a steep climb in forecasted actual costs is seen.

As noted earlier, forecasting future conditions becomes more complex and uncertain the further one extends the analysis into the future. Unfortunately, the final six years of the results of Scenario 1A above have a significant impact on the overall results and the LCOE values shown. Changes to the results of the last six years of the study could, in turn, significantly impact overall LCOE results.

To illustrate the impacts of the later years in the study results, Quanta Technology shortened the period of the results assessed to determine the LCOE values from the original period of 2023–2050, or a total of 28 years, to the period from 2023–2042, or a period of 20 years. The same results from the full 28-year analysis were used to perform this analysis, but only the first 20 years of the results were used to calculate the LCOE with and without escalation. The results of assessing only the first 20 years of the result of Scenario 1 are shown in Figure 20.

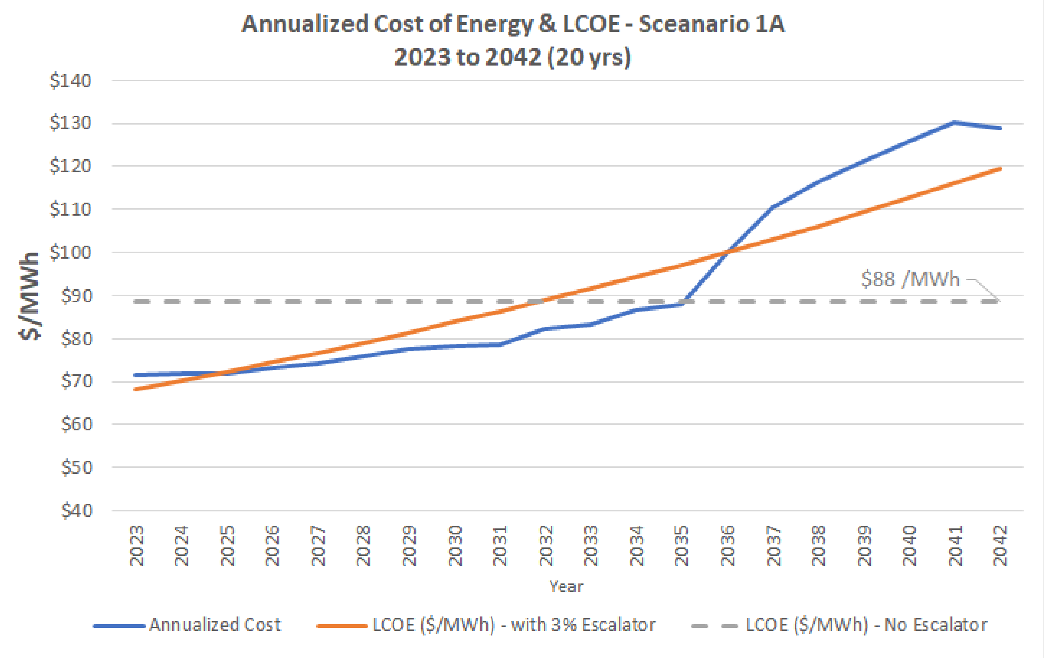
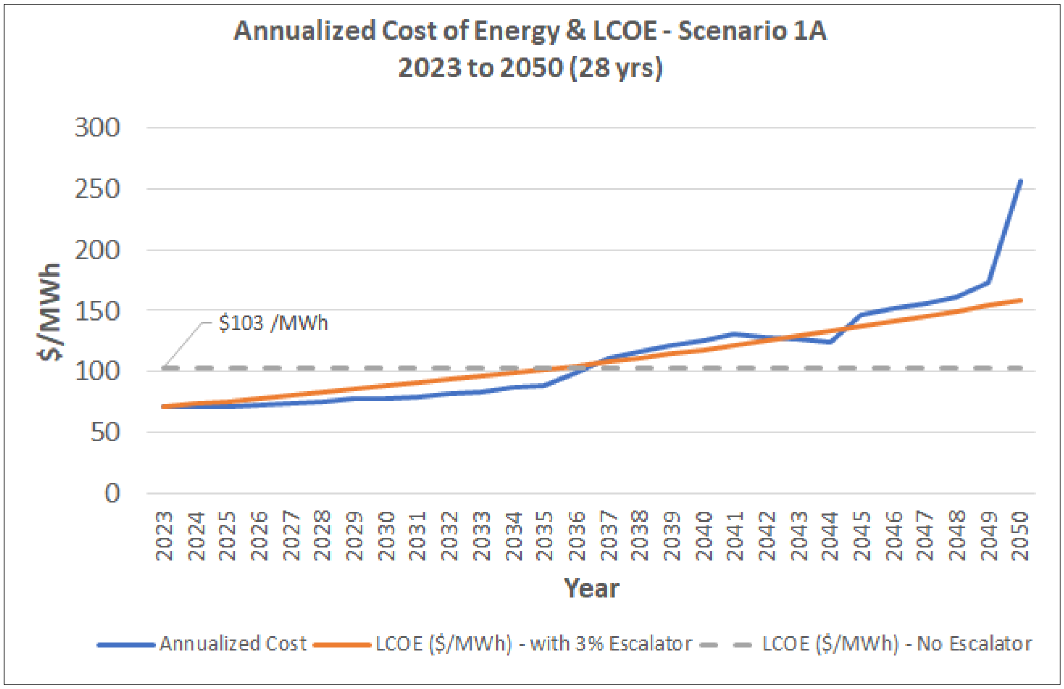


Figure 20. Annualized Cost of Energy and LCOE: Scenario 1A Based on 2023–2042

Scenario 1A reaches a 71% renewable contribution to the CWP energy supply by 2042. The results in 20 years analysis of Figure 20 show an identical blue line as the first 20 years in Figure 19. However, using the shorter time horizon for the present value calculations produces significantly reduced LCOE values. The LCOE with no escalation of $103/MWh for the 28-year analysis in



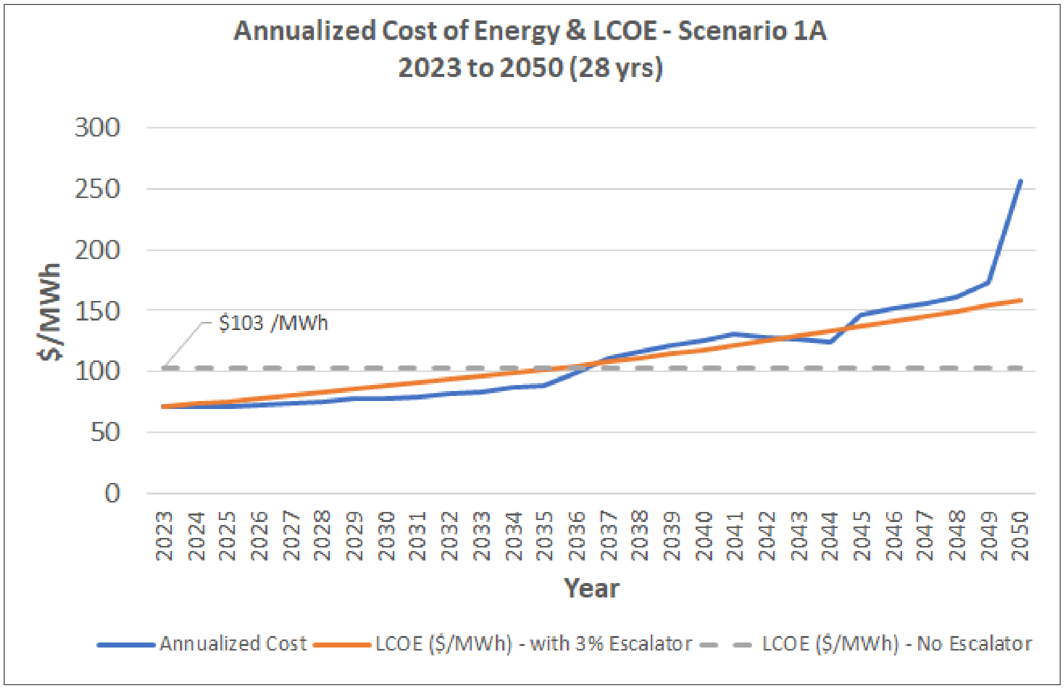


Figure 19 drops to $88/MWh in the 20-year analysis of Figure 20, a 15% reduction in the value. The lower LCOE in the 20-year analysis is driven by eliminating the costs in the final 8 years.

Quanta Technology took CWP estimated 2023 powers costs, projected at $27M or $65/MWh[13], and then escalated them for 20 years at a 3% yearly increase. The results of the projection of CWP costs with a 3% escalation are shown as the solid, maroon-colored line in Figure 21. The forecasted annual costs of the increasing CWP costs in the maroon line were then used to calculate an LCOE for those costs, shown as $83/MWh in the dashed maroon line in Figure 21. The results show the Scenario 1A costs are only $5/MWh, or 15%, more than the projected costs of the current CWP power portfolio based on their respective 20-year LCOE power costs.

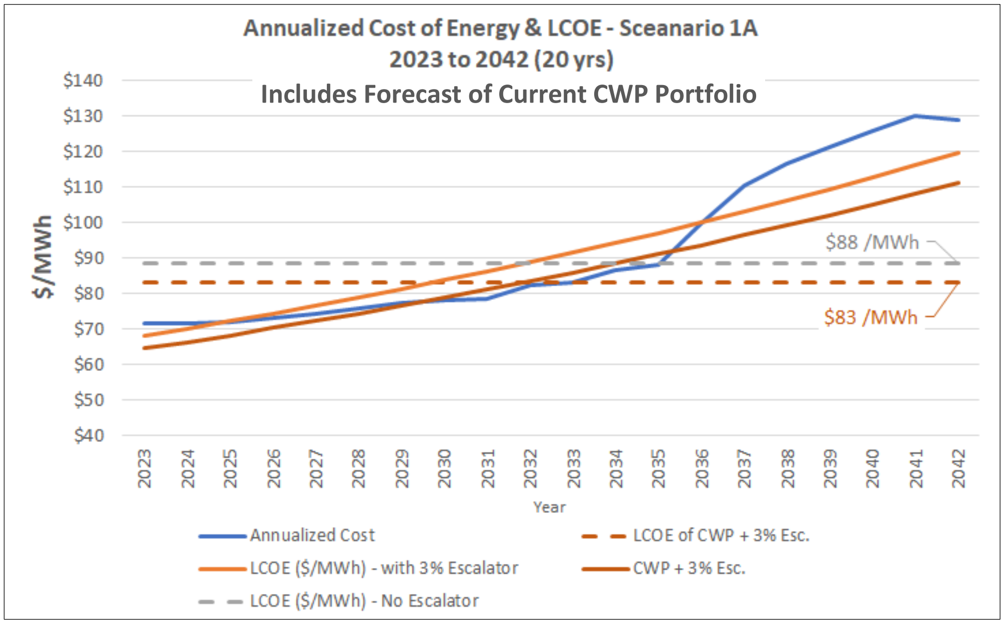


Figure 21. 20-Year Scenario 1A Analysis with Current CWP Portfolio Costs

Another interesting finding is provided in Figure 22, which shows only the annual costs from Scenario 1A (i.e., the forecast annual power cost with no levelization) as the blue line and the CWP current costs projected with a 3% increase per year as the maroon line. As can be seen, the two streams of projected costs are similar until 2035. This indicates Scenario 1A could be adopted by CWP with minimal rate impact until 2035.

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[13] CWP 2023 cost energy based on the October 25, 2022, Electric Cost of Service Analysis provided by CWP.

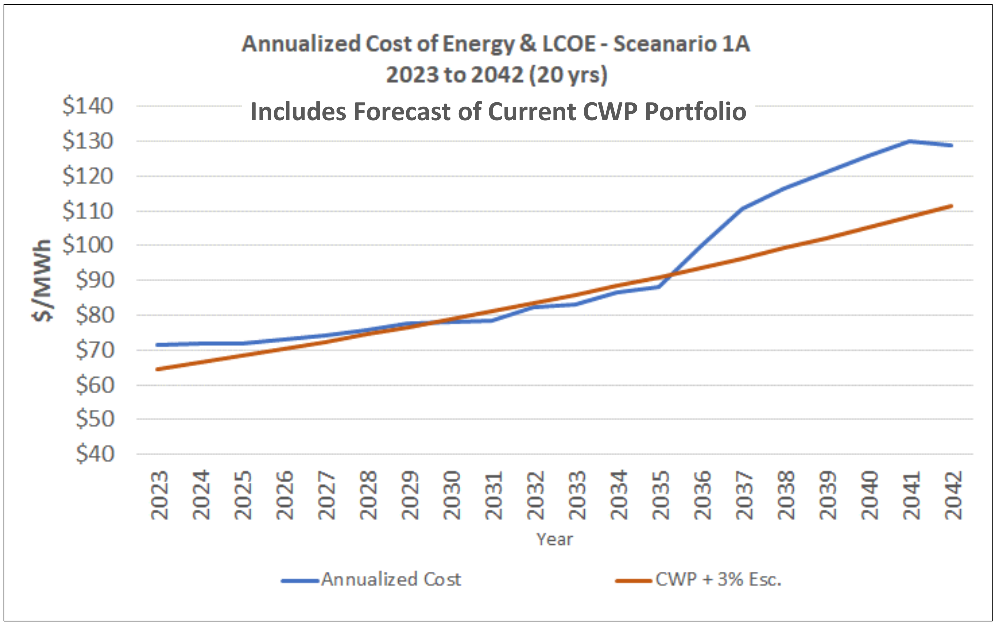


Figure 22. Comparison of Scenario 1A to the Current CWP Costs with a 3% Annual Escalation

6.2 Target 2: 100% Net-Zero Carbon by 2050 Target

The chart shown in Figure 23 summarizes the technologies and capacities selected by the pIRP model for Scenario 2A, which focuses on achieving 100% net-zero carbon by 2050. While much of the technologies and capacities selection is similar to Scenario 1A, the notable difference is the fact that the mix of purchases continues to include significant purchases from the fossil generation in the Florida power market to the end of the study period and then includes RECs to offset the fossil generation purchases. A table listing the annual capacity purchases by technology for Scenario 2A can be found in Appendix F, Table 17.

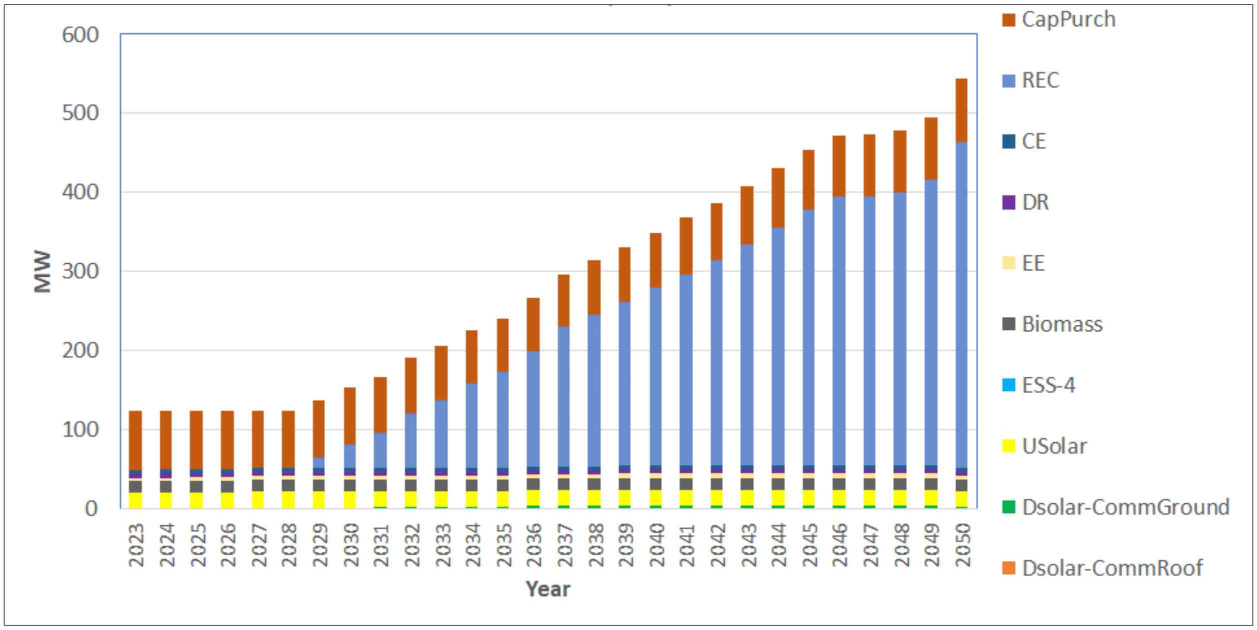


Figure 23. Capacity Additions for Scenario 2A

Figure 24 summarizes Scenario 2A's annual costs, LCOE with no escalation, and LCOE with a 3% annual escalation for the 28 years to 2050. The LCOE of this net-zero carbon scenario with no escalation, $88/MWh, is 15% lower than Scenario 1A, $103/MWh.

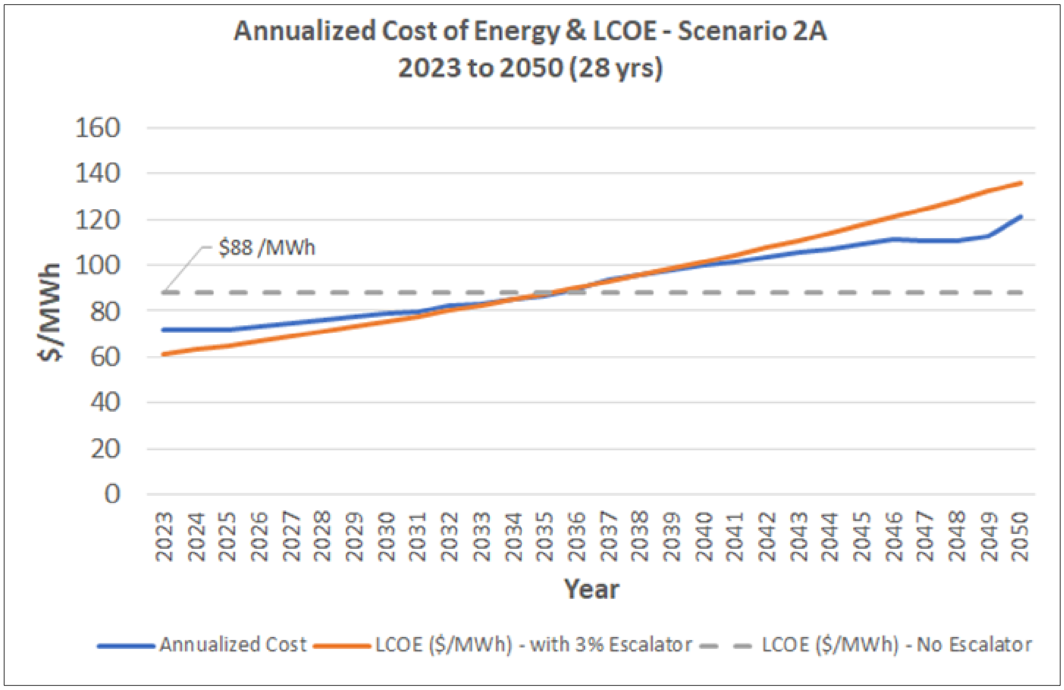


Figure 24. Annualized Cost of Energy and LCOE: Scenario 2A Based on 2023–2050

Figure 25 uses the same annual costs stream to summarize Scenario 3A annual costs, LCOE with no escalation, and LCOE with a 3% annual escalation for the 20 years to 2042.

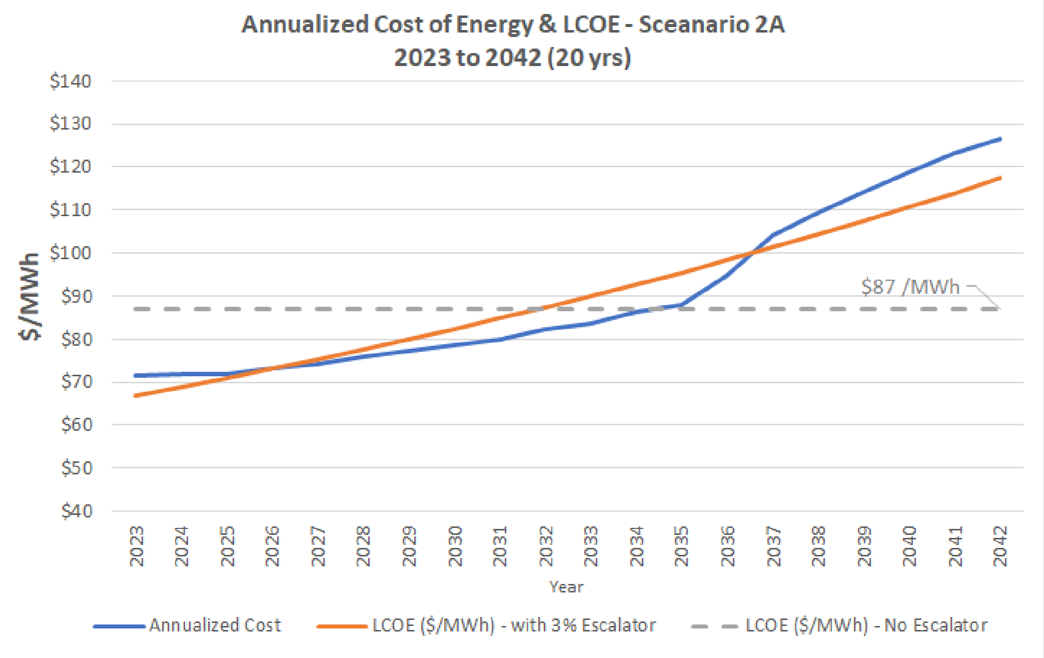


Figure 25. Annualized Cost of Energy and LCOE: Scenario 2A Based on 2023–2042

6.3 Target 3: 80% Renewable by 2035 Target

The chart shown in Figure 26 summarizes the technologies and capacities selected by the pIRP model for Scenario 3a, which focused on achieving 80% renewable by 2035 and 100% by 2050. The technologies selections are identical to Scenario 1a, except they added a more rapid pace in the first years of the analysis to reach the 80% renewable goal by 2035, versus Scenario 1, which does not reach 80% renewables until 2045, 10 years later. The notable difference is that the mix of purchases continues to include significant purchases from the fossil generation in the Florida power market to the end of the study period and then includes RECs to offset the fossil generation purchases. A table listing the annual capacity purchases by technology for Scenario 3A can be found in Appendix F, Table 18.

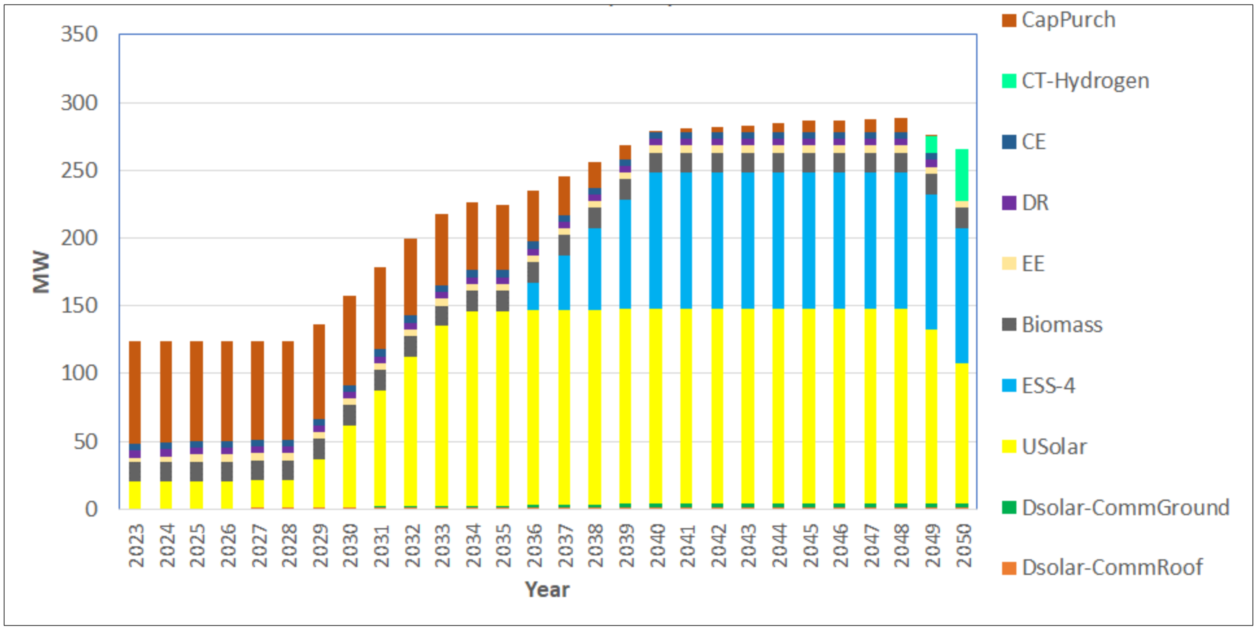


Figure 26. Capacity Additions for Scenario 3A

Figure 27 summarizes Scenario 3A’s annual costs, LCOE with no escalation, and LCOE with a 3% annual escalation for the 28 years to 2050. Note that the LCOE for this scenario, $101/MWh, is very similar to the $103/MWh LCOE value of Scenario 1A. Figure 28 uses the same annual costs stream to summarize Scenario 3A’s annual costs, LCOE with no escalation, and LCOE with a 3% annual escalation for the 20 years to 2042. The 20-year LCOE for Scenario 3A, $90/MWh, is only $2/MWH, or 2% over the equivalent value for Scenario 1a, $88/MWh.

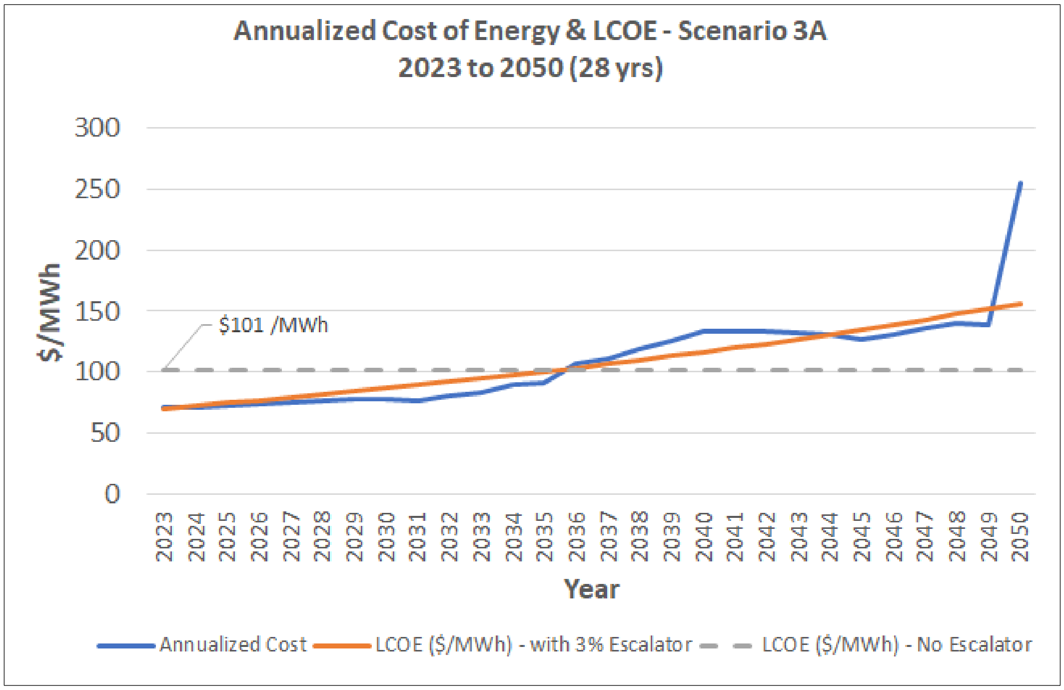


Figure 27. Annualized Cost of Energy and LCOE: Scenario 3A Based on 2023–2050

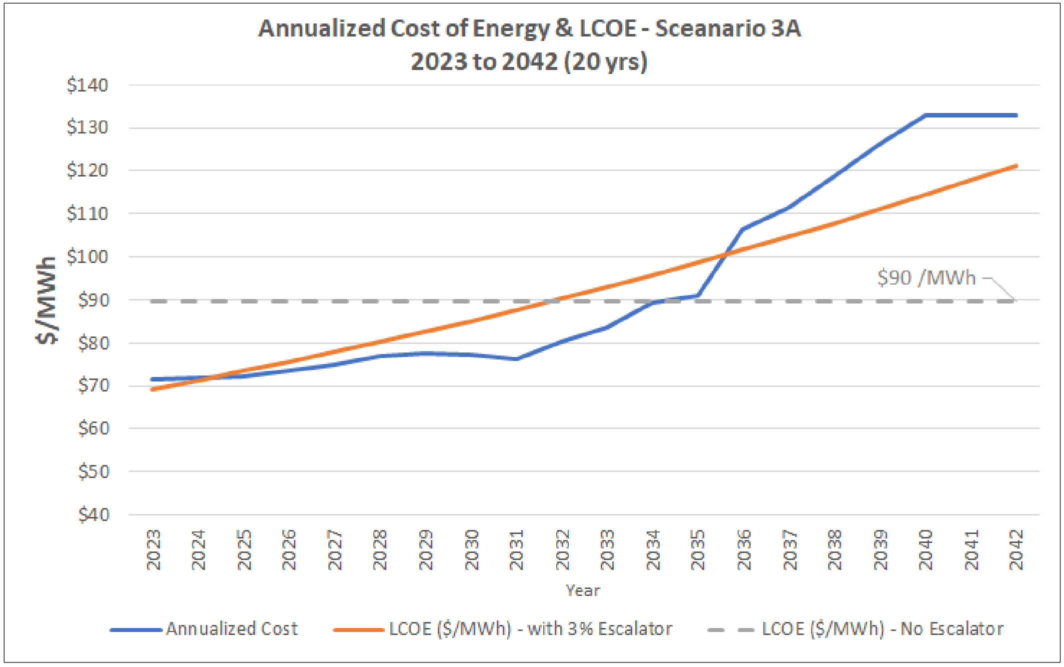
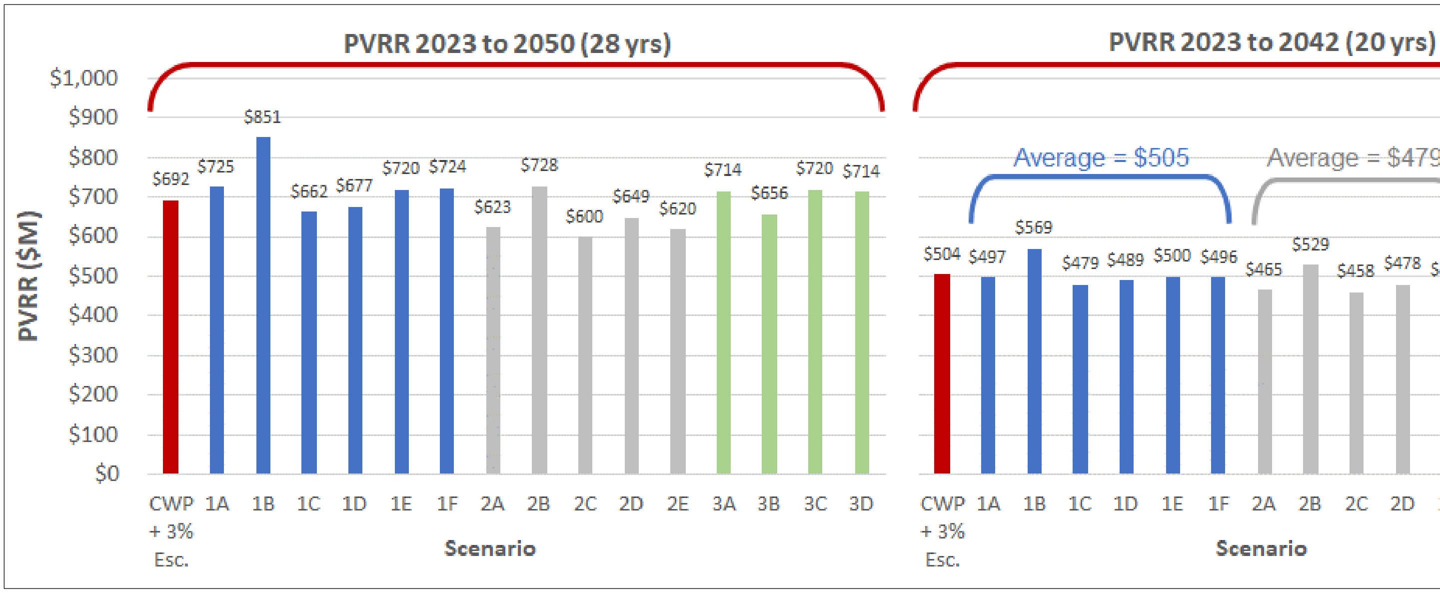


Figure 28. Annualized Cost of Energy and LCOE: Scenario 3A Based on 2023–2042

6.4 Summary of PVRR for All Scenarios

The chart on the following page, Figure 29, summarizes the PVRR results for all the scenarios and the full 28-year PVRR and the PVRR results for only the first 20 years of the analysis. Looking at the 28-year PVRR results, the CWP projected costs are in the same range as the other scenarios.



However, the 20-year PVRR results show a very tight range of costs. In the 20-year PVRR results, the difference between the forecast CWP costs ($504/MWh) and the average of Scenario 1 variations ($505/MWh) and the average of the Scenario 3 variations ($498/MWh) is only 1%. Scenario 2 variations provide the lowest average LCOE ($479/MWh), but the Scenario 1 variation average is still only 5% lower than the current CWP costs and the Scenario 1 variation.

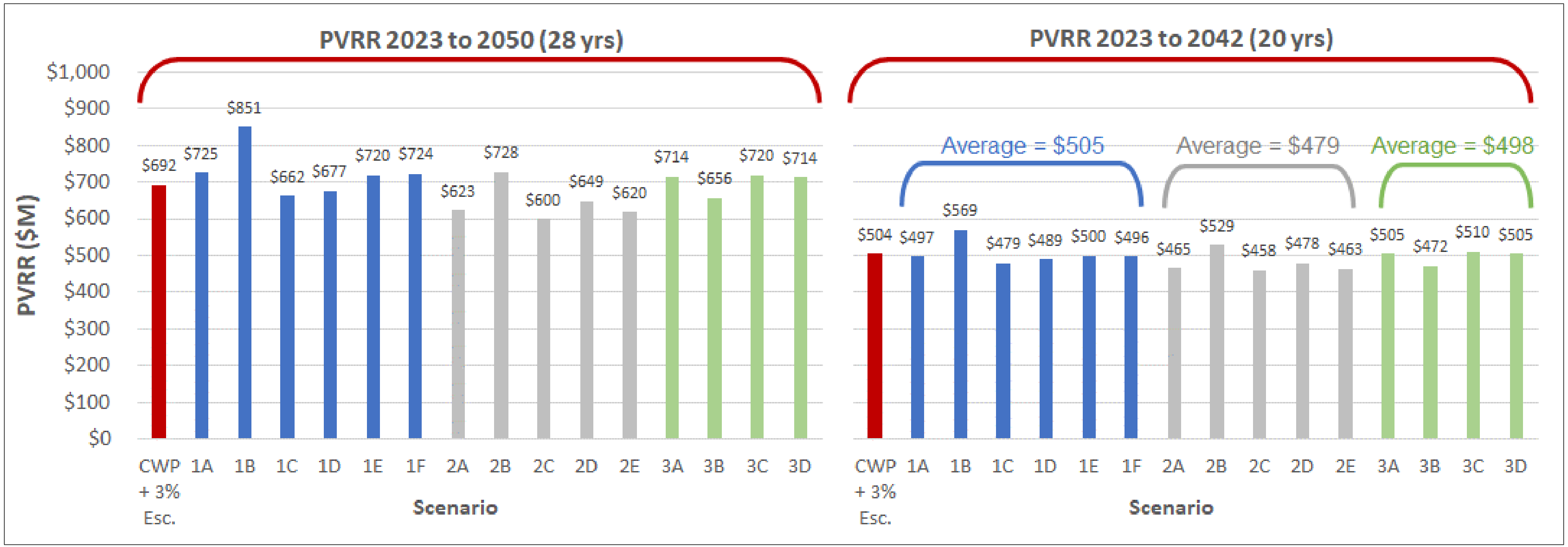


Figure 29. Summary of 28-Year and 20-Year PVRR Results for All Scenarios

7 CONCLUSIONS AND RECOMMENDED ROADMAP

7.1 Conclusions

During the study, CWP informed Quanta Technology that their primary interest had evolved to a focus on zero carbon resources and renewables (Targets 1 and 3) rather than the net-zero option (Target 2) that would allow the continuation of energy supply from carbon-emitting energy resources. With this refined focus by CWP, this section focuses only on the conclusions related to the scenarios for Targets 1 and 3.

While this study defined a proxy cost estimate for CWP’s continuing path of purchasing from energy sources that include a substantial portion of carbon-producing technologies, Quanta Technology believes the proxy of a 3% escalation in costs is optimistically low. The actual costs can be expected to be higher. Establishing optimistically low projections of CWP costs for comparison with the results of this study is consistent with the intent of this study to determine the feasibility of the targets under consideration (i.e., if the results are favorable comparing them to optimistically low CWP costs, then they will be more favorable against higher CWP costs projections).

This analysis indicates that CWP’s adoption of a path toward 100% renewables can be accomplished for a reasonable cost of power for the next 20 years. However, beyond the next 20 years (i.e., during the last 6 years analyzed in this report, 2043–2050), the technology selection and the costs remain understandably more uncertain and, based on the technologies options and costs assumed in this study, could bring a substantial increase in CWP’s power costs. As noted earlier, the rapid rise in costs near the end of the study period was driven by assumptions on technology costs and availability which drove the inclusion of green hydrogen-powered CTs in the resource mix and the associated rise in costs.

Quanta Technology believes that additional cost-effective technologies will be available well before 2043. The power industry is expending considerable time and money on identifying options that could deliver lower-priced energy sources, including offshore wind, long-term energy storage technologies, and new technologies for geothermal energy, among others. While the costs projected in the last 6 years of the study are very high, based on the current assumptions, the costs before 2043 are comparable to projected CWP costs and could be lower. CWP should not avoid adopting its renewable targets because of costs that are not expected to occur for over 20 years. CWP should regularly reevaluate its targets and plans for its electric energy supply. Should continuing on a path to 100% renewable prove too costly in future years, CWP can adjust accordingly.

7.2 Recommended Roadmap

This study provides results indicating that Targets 1 and 3 are viable technical and financial options for the next 20 years (i.e., 2023 to 2042). After 2043, the costs begin to increase substantially due to the recommended additions of CT-hydrogen resources, a high-cost and nascent technology. Based on these results, Quanta Technology recommends the following roadmap for CWP’s future.

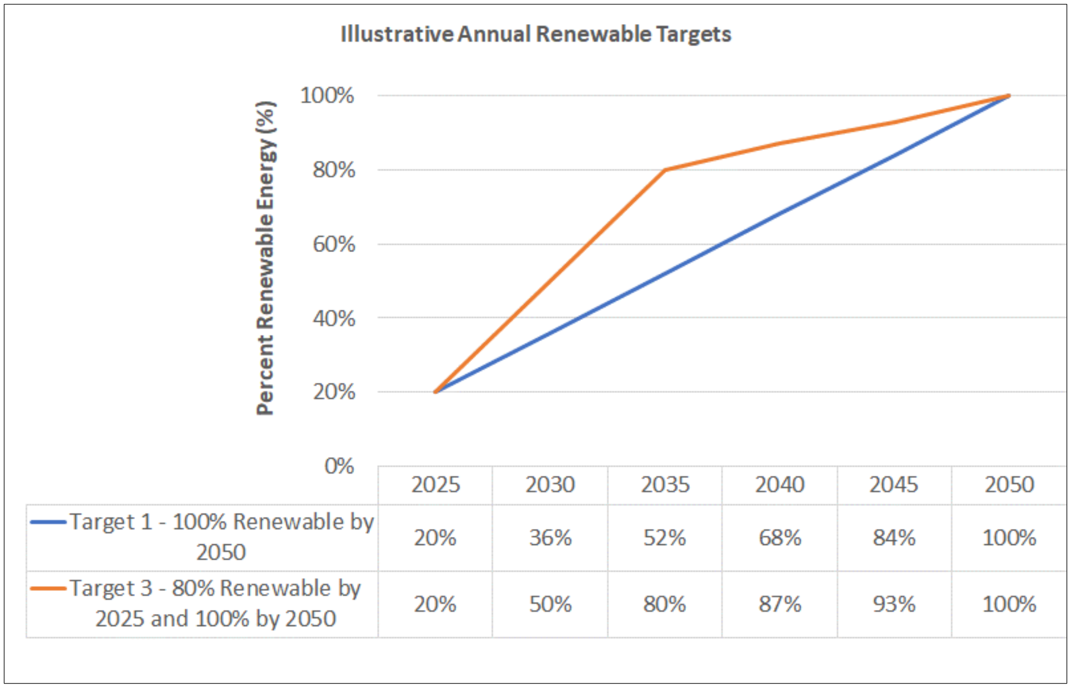
7.2.1 Next Three Months (May 2023–July 2023)

Within the next three months, Quanta Technology recommends that CWP focus on alignment, definition, and goal-setting/validation activities in the near term. Specifically, the following is recommended:

Table 8. Three-Month Recommendations

Actions	Projects
Define a clear target for CWP's clean energy supply.	• CWP would need to corral around a goal. • Establish multiple interim targets for renewable contributions before 2050 by using the findings of this report. An illustrative example of renewable goals to achieve Targets 1 and 2 is shown in Figure 30.
Start CWP IRP program.	• A program manager will likely be needed to coordinate all aspects of reaching the goal. • Reporting templates should be developed • Timeframe of reporting to citizens should be established.

For example, some potential annual renewable targets may be considered below.



	2025	2030	2035	2040	2045	2050
Target 1 - 100% Renewable by 2050	20%	36%	52%	68%	84%	100%
Target 3 - 80% Renewable by 2025 and 100% by 2050	20%	50%	80%	87%	93%	100%

Figure 30. Illustrative Annual Renewable Targets

7.2.2 Next 18 Months (August 2023–February 2025)

Within the next 18 months, Quanta Technology recommends that CWP focus its attention on TOU, DR, and EE and prioritize utility-scale renewable purchases over rooftop solar for PV assets, as well as a number of other actions. Specifically, the following is recommended:

Table 9. 18-Month Recommendations

Actions / Theme	Projects
Develop TOU, DR, and EE programs	• Complete a load research study and consider and appliance saturation survey to gather better data to assess and design TOU, EE, and DR programs for CWP, Residential, and Business customers. • Develop forecasts of the load impacts of the future appliance and end-use electrification.
Prioritize utility-scale renewable purchases over solar PV on city rooftops	• Utility-scale solar project ownership: prioritize project and PPA negotiations to support CWP's choice of renewable target plan. • Continue to look for opportunities to pool CWP requirements and partner with FMPA and other Florida utilities for renewable and storage project power purchases and project development. • Complete a study of all CWP assets to prioritize which CWP facilities should or should not be included in future plans to add solar and storage to CWP assets. Consider an RFI for City-owned assets to understand costs and options for all possible facilities. • Complete an EV adoption study better to quantify the expected impacts of EV adoption in CWP.
Analyze warehouse rooftop PV installation	• Understand the need for individual building monitoring • Create a roadmap for monitoring and control. • Engage in discussions with vendors to develop an understanding of software in the marketplace.
Explore CWP utility bill financing	• Explore avenues in which CWP guarantees can help with financing solar of customer rooftop solar and storage additions. • Create a billing template to reflect customer savings and contribution to the goal.
Plan CWP IRP updates	• Consider assignment of a project manager to provide regular updates on the program • Update the current plan to complete a revised CWP IRP after the development of EE and DR programs are developed, and results from the load research study are available. • Commit to regular, periodic updates of IRP, which include a resource technology maturity assessment of new and existing technologies to provide information to adapt CWP's plan to evolving technology capabilities and costs.

7.2.3 Next 48 Months (March 2025–April 2027)

Within the next 48 months, Quanta Technology recommends that CWP focus on implementing programs (EE and TOU). Specifically, the following is recommended:

Table 10. 48-Month Recommendations

Actions	Projects
Update IRP and technology maturity assessments.	• Create a roadmap for technology upgrades such as DERMs to support CWP. • Create a roadmap for the implementation of CWP-owned Battery Storage for resiliency.
Create a plan for CWP vehicle electrification	• Complete a study and plan for the electrification of all CWP-owned vehicles.
Implement rate changes	• Create and implement TOU rates with energy costs and demand rates that represent actual energy and demand costs. • Change the NEM rate credited to customers to a cost-based TOU rate that evolves as CWP TOU costs evolve. • New future NEM credit for any excess flow from the customer back to the system should reflect only the actual TOU wholesale energy value to CWP. • The value of NEM backflow power from distributed solar will ultimately go to zero and be of negative value in future years as CWP wholesale solar production exceeds noontime CWP demand, after which CWP will need to purchase energy storage to store the excess solar or interrupt the excess solar.

7.2.4 Beyond 48 Months (Beyond April 2027)

Quanta Technology recommends that CWP follow the course of action with regular project management updates on meeting the renewable targets adopted in Section 7.2.1.

APPENDIX A: TERMS AND DEFINITIONS

Table 11. Report Terms

Term	Definition
100% Renewable	● All energy originates from some form of renewable technology.
Bioenergy or Biomass	● Energy technologies that use biomass as a fuel. ● Biomass is a solid or gaseous renewable energy resource derived from plant- and algae-based materials that include: ▪ Crop wastes ▪ Forest residues ▪ Purpose-grown grasses ▪ Woody energy crops ▪ Microalgae ▪ Urban wood waste ▪ Food waste ● Even though biofuels are considered renewable, burning biofuels emit carbon and other elements. ● When burned as a fuel for electric production, biofuels only release the carbon the plants take from the air and soil during their growth cycle. The process is comparable to moving carbon in and out of the atmosphere and soil but does not contribute incremental increases to the atmospheric carbon. ● The biomass energy technologies considered in this study are dispatchable, and their ability to operate continuously, just like a fossil-fueled plant, is only limited by the continuity of the fuel supply to the site and onsite fuel storage.
Electrification	● The process of changing appliances and end uses that use fossil fuels to electric, e.g., changing a natural gas space heater to an electric heat pump or changing a gasoline-fueled vehicle to an electric vehicle.
Energy Neutral	● A CWP or customer facility that generates sufficient annual energy from their distributed energy resources to offset the annual consumption of the facility.
Green Hydrogen	● Green hydrogen is considered a green and renewable fuel source. Green hydrogen is created without emissions or the use of fossil fuels. The typical method considered the likely future source of large quantities of green hydrogen is renewable energy resources supplying power to electrolyzers that split water into pure oxygen and pure hydrogen. ● Green hydrogen differs from other types of hydrogen that use different fossil-fueled processes to separate hydrogen from the fuel source.
Net Energy Metering	● A rating program currently in effect in CWP where customers with distributed energy resources are credited at full retail, variable rates for any excess energy (i.e., the energy that exceeds the customer's instantaneous needs) that flows back into the CWP system.
Net-Zero Carbon	● Net zero refers to a state in which the greenhouse gases going into the atmosphere are balanced by removal from the atmosphere. Generally, utilities plan to achieve net-zero carbon by reducing their carbon emissions and acquiring renewable energy credits or other carbon offsets, which counterbalance carbon removal of any remaining carbon emissions resulting from their electric energy production.
Net-Zero Energy	● Sufficient energy is produced from solar PV or other renewable sources to offset the annual energy consumption.

Term	Definition
Renewable Energy	• Energy is generated only from technologies considered to be renewable, including wind, solar, ocean energy, geothermal, hydroelectricity, technologies that burn fuels derived from biomass, and green hydrogen (i.e., hydrogen generated from processes that use water and renewable energy). • Hydroelectricity is a renewable technology but is treated differently than other forms of renewable energy in some states due to its other environmental impacts.
Renewable Energy Credit	• A renewable energy credit (REC) is a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. • When one megawatt-hour (MWh) of electricity is generated and delivered to the grid from a renewable energy resource, RECs are issued. • The ownership of the REC is a certificate that can be owned, sold, or traded separately from the electrical energy that served as the source of the REC creation.
Zero Carbon	• All energy is created with technologies that do not emit carbon into the atmosphere. • "Real Zero" is a new term recently invented and trademarked by FPL to differentiate its emission goal from other utilities' net-zero carbon goals, though Real Zero is identical in definition to zero carbon. • For electric generation, zero-carbon energy resources include all forms of generation technology that do not emit carbon (e.g., nuclear and renewable technologies that do not emit carbon into the atmosphere). • Even though biofuels and geothermal are considered renewable, they are not zero-carbon resources since both generally emit carbon into the atmosphere.

APPENDIX B: LIST OF ABBREVIATIONS AND ACRONYMS

Table 12. Report Abbreviations and Acronyms

Term	Definition
ATB	Annual technology baseline
Biomass	Biomass fuel generation
CAPEX	Capital expenditures
CapPurch	Capacity purchases from the Florida energy market, which is assumed to be 100% fossil generation
CE	Internal Combustion Engine fueled with diesel
CT	Combustion turbine generator
CT-Hydrogen	Green hydrogen-fueled combustion turbine
CWP	City of Winter Park
DEF	Duke Energy Florida
Dsolar-CommGround	Distributed solar PV at CWP facility open land
Dsolar-CommRoof	Distributed solar PV on CWP facility rooftops
DR	Demand response
EE	Energy efficiency
EES-4	Battery electric energy storage system with a 4-hour energy capacity
ELCC	Effective load-carrying capability
EV	Electric vehicle
FGBC	Florida Green Building Coalition
FL	Florida
FMPA	Florida Municipal Power Agency
FPL	Florida Power & Light
FY	Fiscal year
GHG	Greenhouse gas
GRU	Gainesville Regional Utilities
GW	Gigawatt
IBR	Inverter-based resources
IRP	Integrated resource plan
pIRP	Probabilistic integrated resource plan
JEA	Jacksonville Electric Authority
KW	Kilowatt

Term	Definition
LCOE	Levelized cost of energy
LDV	Light-duty vehicle
LP	Linear program
MW	Megawatt
NREL	National Renewable Energy Laboratory
OUC	Orlando Utilities Commission
PPA	Power purchase agreement
PSC	Public Service Commission
PV	Photovoltaic
REC	Renewable energy credit
RPS	Renewable portfolio standards
SAP	Sustainable action plan
SFH	Single-family homes
T&D	Transmission & Distribution
TAL	Tallahassee
TECO	Tampa Electric Company
TYSP	Ten-year site plan
USolar	Utility-scale solar PV
VRE	Variable renewable energy

APPENDIX C: BATTERY LIFECYCLE CONSIDERATIONS

Two key factors dictate the life of battery-based energy storage systems:

- Capacity fading due to age
- Capacity fading due to charge-discharge cycles

Lithium-ion storage capacity typically fades or degrades with time and use, at 2%–3% per year, if used at an average rate of one full cycle per day. The storage system is designed to deliver a maximum lifetime of around 4000–6000 full cycles before the capacity fades below 70%–80% of its initial capacity. The number of cycles a battery system delivers depends strongly on the depth of discharge in each cycle. The lifecycles increase as the cycle depth of discharge decreases. In addition to lifecycles, lithium-Ion batteries typically have a shelf life of around 15 years.

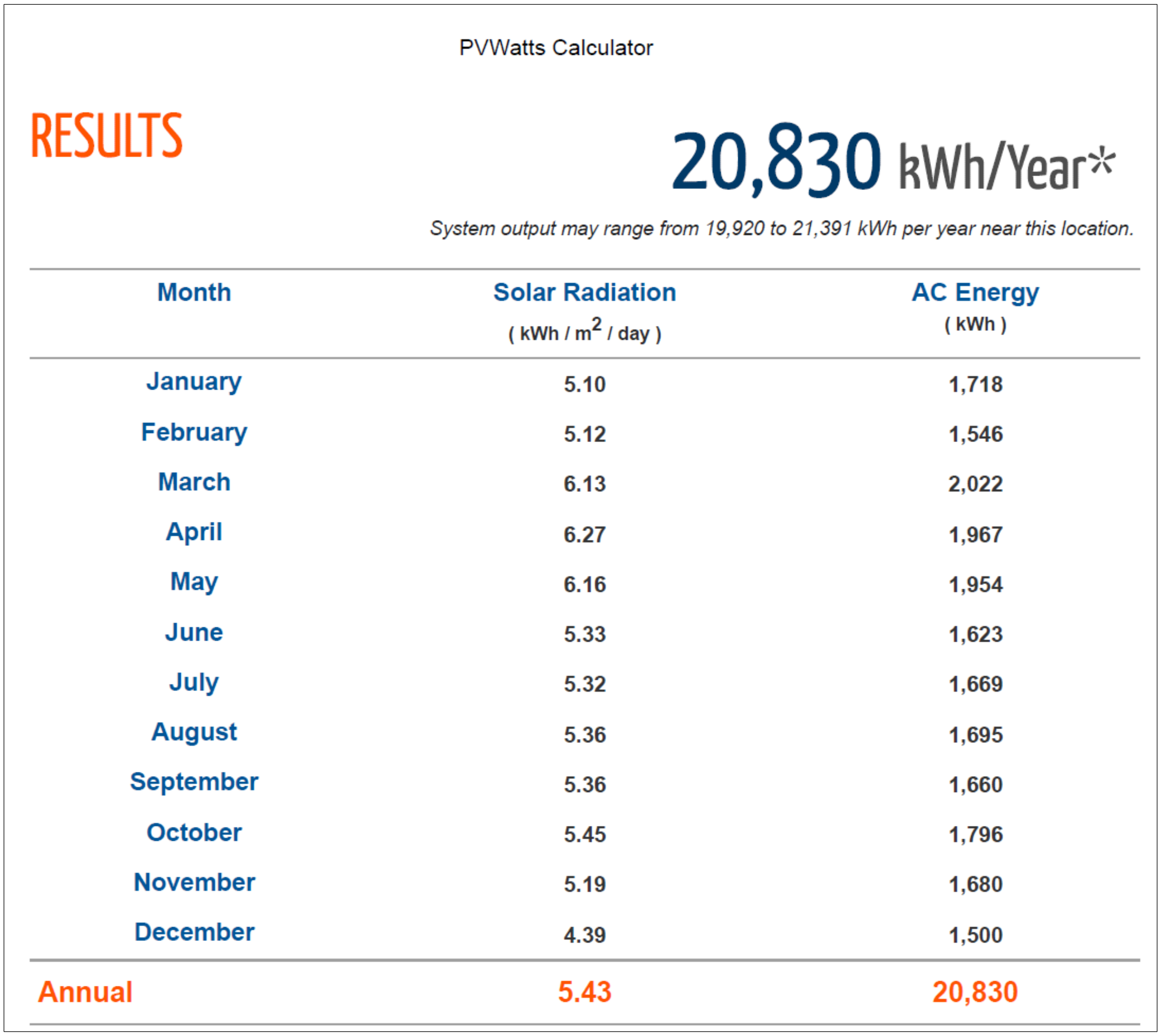
To maintain a battery over its life, operators usually implement an asset management plan that includes annual inspections and capacity augmentations.

However, its modules must be replaced and recycled at the end of a battery system's life. Many components of the battery systems will remain functional, including the housing/containers, electrical balance of the plant, and interconnections. The bi-directional inverters are also replaced every 10–15 years.

The chemistry of lithium-Ion batteries differs between technologies and manufacturers. Some use toxic compounds and rare metals (such as cobalt or cadmium), while others use safer, non-toxic, and relatively common materials (such as manganese oxide or phosphate). Unlike lead-acid batteries that recycle 100% of the lead used in their ecosystem, the state of recycling lithium-ion batteries is still evolving. Recycling uses complex and energy-demanding processes that include pyrometallurgy and hydrometallurgy. In pyrometallurgy, battery components are smelted in a high-temperature process that burns and separates a mixed metal alloy of cobalt, copper, iron, and nickel. Hydrometallurgy recovers the desired metals by treating the cathode material with an acidic or basic solution. Multiple companies throughout North America are already in the business of reusing or recycling batteries, and many of these have partnered with car companies to aid in the recycling of their electric vehicle batteries. Most companies specializing in this process claim to recover up to 95% of the raw materials, including cobalt, nickel, and lithium. Tesla also recycles batteries independently, claiming to recover 92% of the battery's raw materials.

From a financial point of view, the cost of recycling after 15 years is not certain. Assuming a value of at least $50/kWh in today's dollars is prudent.

APPENDIX D: NREL PVWATTS SOLAR PRODUCTION ESTIMATE



PVWatts Calculator

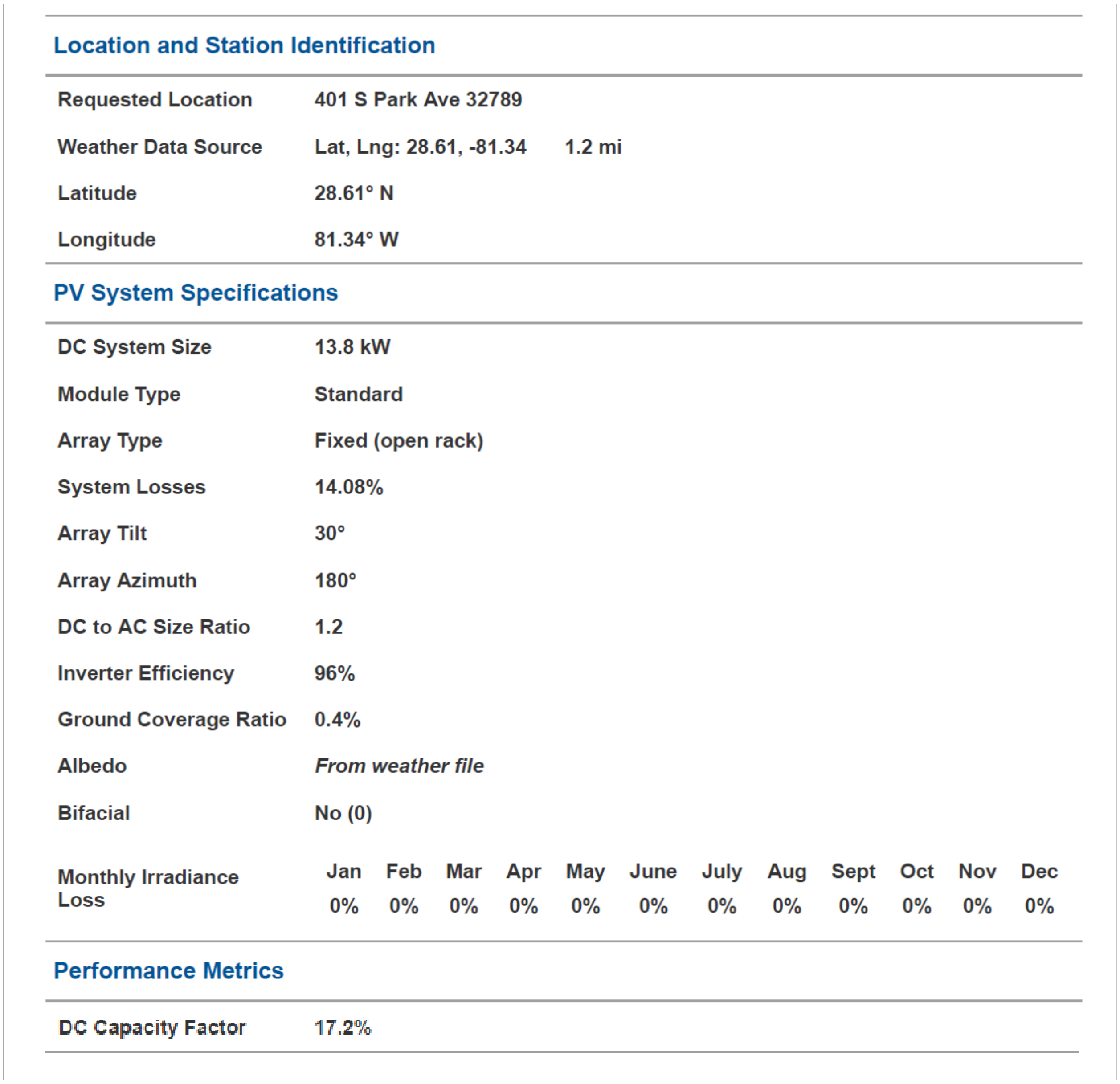
RESULTS

20,830 kWh/Year*

System output may range from 19,920 to 21,391 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	5.10	1,718
February	5.12	1,546
March	6.13	2,022
April	6.27	1,967
May	6.16	1,954
June	5.33	1,623
July	5.32	1,669
August	5.36	1,695
September	5.36	1,660
October	5.45	1,796
November	5.19	1,680
December	4.39	1,500
Annual	**5.43**	**20,830**

Figure 31. PVWatts Calculator



Location and Station Identification

Requested Location	401 S Park Ave 32789
Weather Data Source	Lat, Lng: 28.61, -81.34 1.2 mi
Latitude	28.61° N
Longitude	81.34° W

PV System Specifications

DC System Size	13.8 kW
Module Type	Standard
Array Type	Fixed (open rack)
System Losses	14.08%
Array Tilt	30°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4%
Albedo	*From weather file*
Bifacial	No (0)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Monthly Irradiance Loss	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	17.2%

Figure 32. PVWatts Information and Metrics

APPENDIX E: RESIDENTIAL ROOFTOP SOLAR AND BATTERY FORECASTS

Table 13. Residential Rooftop Solar PV And Battery Forecasts

Year	Expected		High		Low	
	Residential Distributed Solar (MWh)	Residential Battery (MWh)[14]	Residential Distributed Solar (MWh)	Residential Battery (MWh)[11]	Residential Distributed Solar (MWh)	Residential Battery (MWh)[11]
2025	650	5	1,037	8	387	0
2026	1,297	7	2,069	11	772	0
2027	2,591	8	4,132	13	1,542	0
2028	3,878	10	6,186	16	2,308	0
2029	5,809	12	9,266	19	3,457	0
2030	7,730	13	12,330	21	4,601	0
2031	10,291	15	16,417	24	6,126	0
2032	12,840	17	20,483	27	7,643	0
2033	15,376	18	24,528	29	9,152	0
2034	18,550	20	29,591	32	11,041	0
2035	21,707	22	34,628	35	12,920	0
2036	25,499	23	40,676	37	15,177	0
2037	29,922	25	47,732	40	17,810	0
2038	34,973	27	55,789	43	20,816	0
2039	39,349	28	62,769	45	23,421	0
2040	43,052	30	68,678	48	25,625	0
2041	46,087	32	73,519	51	27,432	0
2042	49,107	33	78,336	54	29,229	0
2043	51,462	35	82,093	56	30,631	0
2044	53,805	37	85,830	59	32,025	0
2045	55,486	38	88,512	62	33,026	0
2046	57,159	40	91,181	64	34,022	0
2047	58,823	42	93,836	67	35,012	0
2048	59,829	43	95,440	70	35,611	0
2049	60,830	45	97,037	72	36,207	0
2050	60,526	47	96,552	75	36,026	0

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[14] Battery energy forecasts are based on 80% of rated battery energy capacity.

APPENDIX F: FORECAST OF ROOFTOP AND GROUND MOUNT SOLAR PV ON CWP-OWNED PROPERTY

Table 14. Forecast Of Rooftop And Ground Mount Solar PV On CWP-Owned Property

Year	Expected	
	CWP-Owned Property Rooftop PV (MWh)	CWP-Owned Property Ground Mount PV (MWh)
2025	1,202,606	87,161
2026	1,196,593	173,887
2027	1,251,426	347,340
2028	1,272,390	519,926
2029	1,266,029	778,810
2030	1,267,122	1,036,400
2031	1,318,279	1,379,863
2032	1,405,424	1,721,609
2033	1,863,194	2,061,646
2034	1,853,878	2,487,144
2035	2,014,147	2,910,515
2036	2,107,862	3,418,930
2037	2,129,793	4,011,964
2038	2,119,144	4,689,195
2039	2,408,994	5,275,878
2040	2,396,949	5,772,466
2041	2,434,720	6,179,411
2042	2,437,856	6,584,320
2043	2,504,856	6,900,043
2044	2,492,332	7,214,188
2045	2,921,870	7,439,601
2046	3,043,854	7,663,887
2047	3,028,635	7,887,052
2048	3,013,492	8,021,939
2049	2,998,424	8,156,152
2050	2,983,432	8,115,371

APPENDIX G: RESIDENTIAL LDV EV FORECASTS

Table 15. Residential LDV EV Forecasts

Year	Expected		High		Low	
	Resident-Owned LDV EV	Resident LDV EV Charging Energy (MWh)	Resident-Owned LDV EV	Resident LDV EV Charging Energy (MWh)	Resident-Owned LDV EV	Resident LDV EV Charging Energy (MWh)
2023	403	797	624	1,235	302	597
2024	542	1,224	840	1,898	407	918
2025	714	1,766	1,107	2,737	536	1,325
2026	942	2,483	1,460	3,849	707	1,862
2027	1,222	3,381	1,894	5,240	917	2,536
2028	1,556	4,469	2,413	6,927	1,167	3,352
2029	1,953	5,775	3,026	8,951	1,464	4,331
2030	2,417	7,327	3,747	11,356	1,813	5,495
2031	2,799	8,638	4,569	14,100	2,211	6,822
2032	3,241	10,002	5,430	16,757	3,191	9,848
2033	3,753	11,582	6,453	19,915	4,172	12,874
2034	4,346	13,411	7,670	23,669	5,152	15,900
2035	5,032	15,529	9,115	28,130	6,133	18,926
2036	5,827	17,981	10,833	33,431	7,113	21,952
2037	6,747	20,821	12,875	39,732	8,094	24,977
2038	7,812	24,109	15,301	47,221	9,074	28,003
2039	9,046	27,917	18,185	56,121	10,055	31,029
2040	10,475	32,326	21,613	66,698	11,035	34,055
2041	12,129	37,431	21,651	66,816	12,016	37,081
2042	14,044	43,342	21,689	66,934	12,996	40,107
2043	16,262	50,186	21,728	67,052	13,977	43,132
2044	18,831	58,112	21,766	67,171	14,957	46,158
2045	21,804	67,289	21,804	67,289	15,938	49,184
2046	21,843	67,408	21,843	67,408	16,918	52,210
2047	21,882	67,527	21,882	67,527	17,899	55,236
2048	21,920	67,647	21,920	67,647	18,879	58,262
2049	21,959	67,766	21,959	67,766	19,860	61,287
2050	21,998	67,886	21,998	67,886	20,840	64,313

APPENDIX H: ANNUAL SCHEDULE OF CAPACITY PURCHASES

Table 16. Scenario 1A: Annual Capacity Purchases (MW)

Year	Utilty Scale Solar (Usolar)	4-hr Battery Energy Storage System (ESS-4)	Biomass	Internal Combustion Engine - Fossil (CE)	Hydrogen Fuel Combustion Turbine (CT Hydrogen)	Demand Response (DR)	Energy Efficiency (EE)	City Property Rooftop Solar (Dsolar-Comm Roof)	City Property Ground Mount Solar (Dsolar-Comm Ground)	FL System Purchase (Cap Purch)
2023	20.0	0.0	15.0	5.0	0.0	5.0	3.0	0.0	0.0	75.5
2024	20.0	0.0	15.0	5.0	0.0	5.0	4.0	0.0	0.0	74.7
2025	20.0	0.0	15.0	5.0	0.0	5.0	5.0	0.0	0.0	73.7
2026	20.0	0.0	15.0	5.0	0.0	5.0	5.0	0.0	0.0	73.4
2027	20.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	73.1
2028	20.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	72.9
2029	20.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	72.4
2030	30.8	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	70.3
2031	38.4	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	68.2
2032	56.1	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	64.8
2033	64.4	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	62.7
2034	70.8	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	60.7
2035	70.8	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	59.7
2036	70.8	20.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	49.1
2037	70.8	40.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	39.4
2038	70.8	60.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	30.3
2039	70.8	76.4	15.0	5.0	0.0	5.0	5.0	1.0	3.0	23.0
2040	70.8	93.7	15.0	5.0	0.0	5.0	5.0	1.0	3.0	15.4
2041	89.3	93.7	15.0	5.0	0.0	5.0	5.0	1.0	3.0	13.8
2042	89.8	93.7	15.0	5.0	0.0	5.0	5.0	1.0	3.0	15.0
2043	89.8	93.7	15.0	5.0	0.0	5.0	5.0	1.0	3.0	16.3
2044	89.8	93.7	15.0	5.0	0.0	5.0	5.0	1.0	3.0	17.8
2045	89.8	93.7	15.0	5.0	6.8	5.0	5.0	1.0	3.0	13.0
2046	89.8	93.7	15.0	5.0	7.4	5.0	5.0	1.0	3.0	13.2
2047	89.8	93.7	15.0	5.0	7.4	5.0	5.0	1.0	3.0	13.9
2048	89.8	93.7	15.0	5.0	7.4	5.0	5.0	1.0	3.0	14.5
2049	89.8	93.7	15.0	5.0	16.2	5.0	5.0	1.0	3.0	7.0
2050	78.9	93.7	15.0	0.0	41.2	0.0	5.0	1.0	3.0	0.0

Table 17. Scenario 2A: Annual Capacity Purchases (MW)

	Utilty Scale Solar (Usolar)	Biomass	Internal Combustion Engine - Fossil (CE)	Renewable Energy Credits (REC)	Hydrogen Fuel Combustion Turbine (CT Hydrogen)	Demand Response (DR)	Energy Efficiency (EE)	City Property Rooftop Solar (Dsolar-Comm Roof)	City Property Ground Mount Solar (Dsolar-Comm Ground)	FL System Purchase (Cap Purch)
2023	20.0	15.0	5.0	0.0	0.0	5.0	3.0	0.0	0.0	75.5
2024	20.0	15.0	5.0	0.0	0.0	5.0	4.0	0.0	0.0	74.7
2025	20.0	15.0	5.0	0.0	0.0	5.0	5.0	0.0	0.0	73.7
2026	20.0	15.0	5.0	0.0	0.0	5.0	5.0	0.0	0.0	73.4
2027	20.0	15.0	5.0	0.0	0.0	5.0	5.0	1.0	0.0	73.1
2028	20.0	15.0	5.0	0.0	0.0	5.0	5.0	1.0	0.0	72.9
2029	20.0	15.0	5.0	14.1	0.0	5.0	5.0	1.0	0.0	72.4
2030	20.0	15.0	5.0	29.9	0.0	5.0	5.0	1.0	0.0	71.9
2031	20.0	15.0	5.0	43.7	0.0	5.0	5.0	1.0	1.0	71.0
2032	20.0	15.0	5.0	68.7	0.0	5.0	5.0	1.0	1.0	70.2
2033	20.0	15.0	5.0	84.5	0.0	5.0	5.0	1.0	1.0	69.4
2034	20.0	15.0	5.0	105.5	0.0	5.0	5.0	1.0	1.0	68.3
2035	20.0	15.0	5.0	121.4	0.0	5.0	5.0	1.0	1.0	67.3
2036	20.0	15.0	5.0	146.9	0.0	5.0	5.0	1.0	2.0	66.7
2037	20.0	15.0	5.0	176.6	0.0	5.0	5.0	1.0	2.0	67.0
2038	20.0	15.0	5.0	192.6	0.0	5.0	5.0	1.0	2.0	68.0
2039	20.0	15.0	5.0	208.3	0.0	5.0	5.0	1.0	3.0	68.8
2040	20.0	15.0	5.0	225.0	0.0	5.0	5.0	1.0	3.0	69.9
2041	20.0	15.0	5.0	242.5	0.0	5.0	5.0	1.0	3.0	71.0
2042	20.0	15.0	5.0	260.9	0.0	5.0	5.0	1.0	3.0	72.3
2043	20.0	15.0	5.0	280.4	0.0	5.0	5.0	1.0	3.0	73.6
2044	20.0	15.0	5.0	300.9	0.0	5.0	5.0	1.0	3.0	75.1
2045	20.0	15.0	5.0	323.7	0.0	5.0	5.0	1.0	3.0	76.7
2046	20.0	15.0	5.0	340.1	0.0	5.0	5.0	1.0	3.0	77.4
2047	20.0	15.0	5.0	341.0	0.0	5.0	5.0	1.0	3.0	78.1
2048	20.0	15.0	5.0	345.8	0.0	5.0	5.0	1.0	3.0	78.8
2049	20.0	15.0	5.0	361.9	0.0	5.0	5.0	1.0	3.0	79.4
2050	20.0	15.0	5.0	412.1	0.0	5.0	5.0	0.0	1.5	80.4

Table 18. Scenario 3A: Annual Capacity Purchases (MW)

Year	Utilty Scale Solar (Usolar)	4-hr Battery Energy Storage System (ESS-4)	Biomass	Internal Combustion Engine - Fossil (CE)	Hydrogen Fuel Combustion Turbine (CT Hydrogen)	Demand Response (DR)	Energy Efficiency (EE)	City Property Rooftop Solar (Dsolar-Comm Roof)	City Property Ground Mount Solar (Dsolar-Comm Ground)	FL System Purchase (Cap Purch)
2023	20.0	0.0	15.0	5.0	0.0	5.0	3.0	0.0	0.0	75.5
2024	20.0	0.0	15.0	5.0	0.0	5.0	4.0	0.0	0.0	74.7
2025	20.0	0.0	15.0	5.0	0.0	5.0	5.0	0.0	0.0	73.7
2026	20.0	0.0	15.0	5.0	0.0	5.0	5.0	0.0	0.0	73.4
2027	20.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	73.1
2028	20.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	72.9
2029	35.7	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	70.0
2030	60.7	0.0	15.0	5.0	0.0	5.0	5.0	1.0	0.0	65.8
2031	85.7	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	61.1
2032	110.7	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	56.6
2033	133.0	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	52.4
2034	144.1	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	49.7
2035	144.1	0.0	15.0	5.0	0.0	5.0	5.0	1.0	1.0	48.7
2036	144.1	20.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	38.1
2037	144.1	40.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	28.4
2038	144.1	60.0	15.0	5.0	0.0	5.0	5.0	1.0	2.0	19.3
2039	144.1	80.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	10.2
2040	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	1.3
2041	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	2.4
2042	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	3.7
2043	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	5.0
2044	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	6.5
2045	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	8.1
2046	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	8.8
2047	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	9.5
2048	144.1	100.0	15.0	5.0	0.0	5.0	5.0	1.0	3.0	10.1
2049	128.5	100.0	15.0	5.0	12.9	5.0	5.0	1.0	3.0	1.2
2050	103.5	100.0	15.0	0.0	37.9	0.0	5.0	1.0	3.0	0.0