Appendix M Model Analysis

M-1 Overview

The Los Angeles Department of Water and Power (LADWP) is developing an action plan to assure that the future energy needs of its customers are reliably met at the least cost, and are consistent with the City of Los Angeles' (City's) commitment to environmental excellence.

LADWP has developed the following Policy Goals:

1. Achieve a goal of meeting load with 20 percent renewables by 2010 and increasing up to 35 percent by 2020.
2. Reduce Greenhouse Gases (GHGs) by 35 percent from the 1990 level by 2030.
3. Maintain electric rates lower than California Investor Owned Utilities (IOUs).
4. Continue to be self-sufficient in meeting customer load.

It is possible that some of these goals are mutually exclusive. For example, the cost of meeting some of the goals may make it impossible to maintain the 15 percent electric rate advantage goal.

In order to investigate these matters in detail, LADWP performed comprehensive computer based modeling that evaluates a large number of possible future generation resource portfolios in a number of possible future environments. Through this analysis, LADWP developed a robust understanding of the issues involved so that LADWP's power system staff has a full understanding of the ramifications of the action plan it chooses to put in place with respect to resource acquisition.

The study horizon for the modeling is the 20 year period 2010 through 2030. In performing this modeling, it is necessary to assume certain actions are taken in each of the next 20 years. However, it must be understood that the Integrated Resource Plan (IRP) is an ongoing process. A new IRP is developed every two years. Between each 2-year interval, the most recent IRP is modified if appropriate. The key results from this IRP analysis is the action plan that will be put in place for the next 1 to 5 years. The balance of the 20 years is being studied because many of the actions taken in the next 1 to 5 years may have a long term impact on LADWP. Long-term actions modeled in this IRP will not be taken until future IRPs confirm the continuing appropriateness of these actions.

This Appendix presents the Model Analysis and is organized as follows:

- Section M.2, Model Description, provides a description of the model selected by LADWP to simulate the operation of its power system under different futures and with different resource portfolios.
- Sections M.3, Load Forecast, and M.4, Current Resources, look at expected future loads and existing and committed resources to determine what additional resources, if any, need to be secured to meet the load.
- Section M.5, Gap Analysis, describes the determination of additional needs.
- Section M.6, Options, identifies the major supply side options available to meet load requirements.
- Sections M.7, Resource and Financial Assumptions and M-8, Candidate Portfolios, define the objectives of candidate portfolios, establish the renewables needed, and identify the available renewable resources and financial parameters. Technology

characteristics are then presented for biomass, geothermal, solar, and wind, and the portfolio selection methodology is described.

M.2 Model Description

LADWP has chosen a widely used and industry accepted hourly chronological unit commitment and dispatch model to simulate the operation of the LADWP power system under different futures and with different resource portfolios. The model is the Planning & Risk model (PaR) licensed from Ventyx (an Atlanta based software firm). It uses the PROSYM unit commitment and dispatch algorithm.

PROSYM is designed for performing planning and operational studies, and as a result of its chronological structure, accommodates detailed hour-by-hour investigation of the operations of electric utilities. Because of its ability to handle detailed information in a chronological fashion, planning studies performed with PROSYM closely reflect actual operations. PROSYM considers a complex set of operating constraints to simulate the least-cost operation of the utility. This simulation, respecting chronological, operational, and other constraints, is the essence of the model.

This model looks at the LADWP load for each hour and then dispatches LADWP generation supplies on an economic basis (lowest variable cost units first) until the load is met. The model output reflects all the variable costs incurred in meeting the load for each study performed. The fixed costs for the resources are added to the modeled variable costs to develop the total power cost incurred in meeting the load.

The model is also capable of representing certain transmission constraints on a utility system. LADWP load is generally confined to the geographic area of Los Angeles. An IRP would not generally be a replacement for transmission planning activities needed in the service area. However, LADWP does have generation outside of Los Angeles and has transmission rights to other areas of the Western Interconnect. To better represent the constraints and opportunities related to these remote facilities, the modeling topology depicted on Figure M-1 was developed for this IRP.

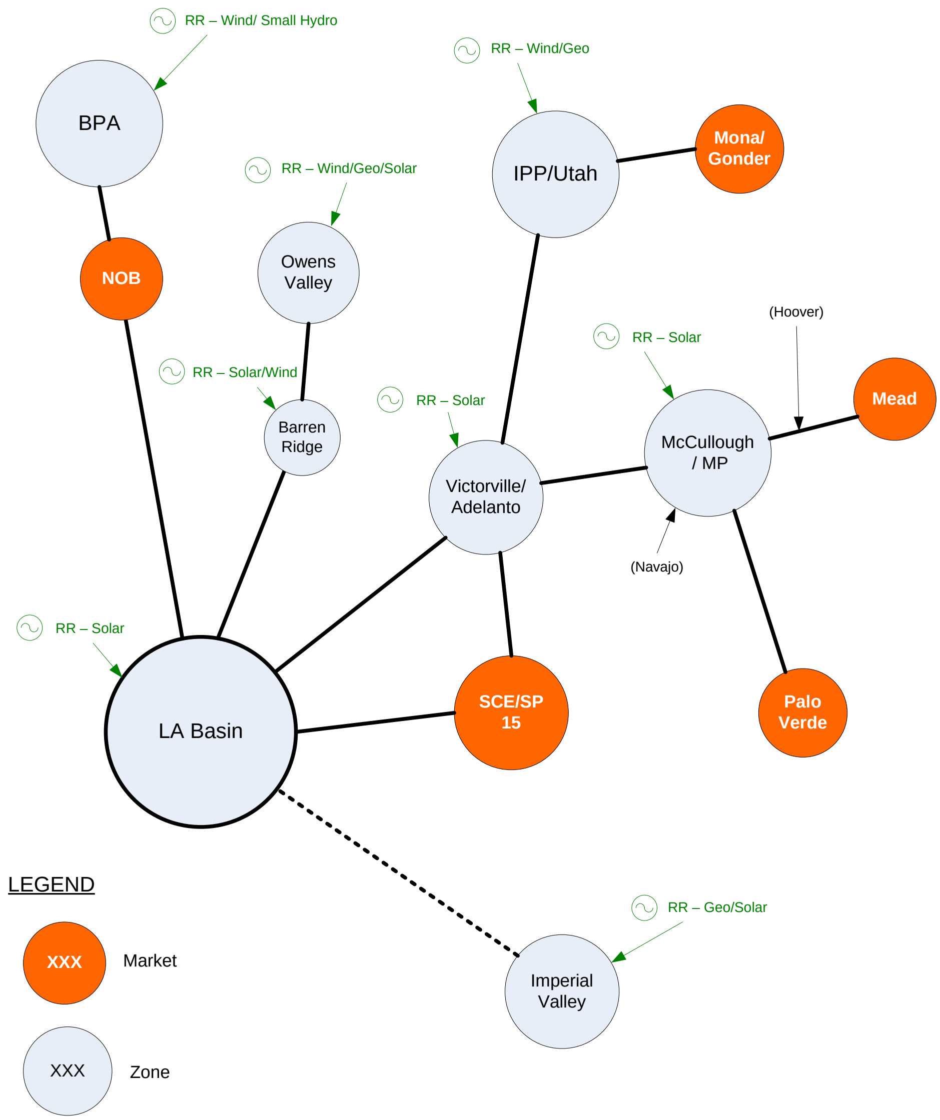

Fig M-1: LADWP Modeling Topology

On a day-to-day basis, LADWP will buy power in spot markets if such a purchase can be done both without causing a reliability problem and if the price of the spot market power is less than the operating cost of its own power plants. Similarly, on a day-to-day basis, LADWP will sell power in spot markets if the price of power in the spot market is greater than the cost of operating an LADWP resource and the power is not needed to meet LADWP load. In an IRP analysis, it may or may not be desirable to attempt to reflect spot market activity. For this IRP, much of the analysis was done without including spot markets. However, the models were set up to allow sensitivity analysis to see if future candidate portfolio preferences might be different if the spot market is included in the analysis.

M.3 Load Forecast

For this IRP, the April 2010 load forecast was used. (See Section 2 and Appendix A of this report).

M.4 Current Resources

LADWP has a number of existing resources. Some of these are expected to continue to be available through the forecast period; others may not. The expected availability of existing and planned resources as of the timing of this analysis was incorporated into the base case of the planning scenarios. Some of the supply side actions were addressed in a preliminary matter for purposes of this IRP through special runs of the PaR Model as follows:

1. South Coast Air Quality Management District (SCAQMD). Haynes 5&6 and Scattergood 3 and are the subject of a SCAQMD Settlement Agreement requiring a reduction in air emissions by 2014 and 2016, respectively.
2. State Water Resources Control Board, (SWRCB). The SWRCB is responsible for water quality principles, guidelines, and objectives deemed essential for water quality control. As such, the SWRCB is interested in the environmental effects of the use of ocean water in a "Once Through Cooling" (OTC) mode for power plants in California. Current units at Haynes, Scattergood, and Harbor use OTC technology. Recently adopted OTC rules could force LADWP to eliminate the use of OTC or shut down units that still use OTC.

In order to determine how to treat these units in the IRP, separate studies were made to look at the alternatives for these units. Since the units are located in a local resource adequacy zone in the greater Los Angeles vicinity, the studies needed to take into account local resource needs when looking at options for these plants.

LADWP also needs to deal with certain constraints associated with California SB 1368. SB 1368 prohibits an electricity provider from entering into long term power purchase agreements unless the baseload generation complies with GHG emission performance standards. These standards cannot be any higher than 1100 lb/MWh, roughly equivalent to the greenhouse gas emission rate from a baseload combined-cycle natural gas fired plant. For purposes of the gap analysis, the IRP assumes that LADWP will be SB1368 compliant.

The resources that are assumed to exist or be committed to in this IRP are described in Appendix F:

M.5 Gap Analysis

The gap analysis in this IRP evaluated both a Resource Adequacy need as well as a need to meet certain goals for renewables as a percentage of billed energy (renewable need). The Resource Adequacy need compares available generation supplies to the load that needs to be served. For LADWP, this comparison was based on the annual peak load plus a planning reserve margin. In addition to a system wide demonstration of Resource Adequacy, there is a need to have a certain amount of generation on in the Los Angeles service territory to assure local reliability. Section 2.4.9 of this report discusses the LADWP approach to Resource Adequacy.

Figure M-2 presents the resource adequacy gap analysis based on the loads and existing and committed resources.

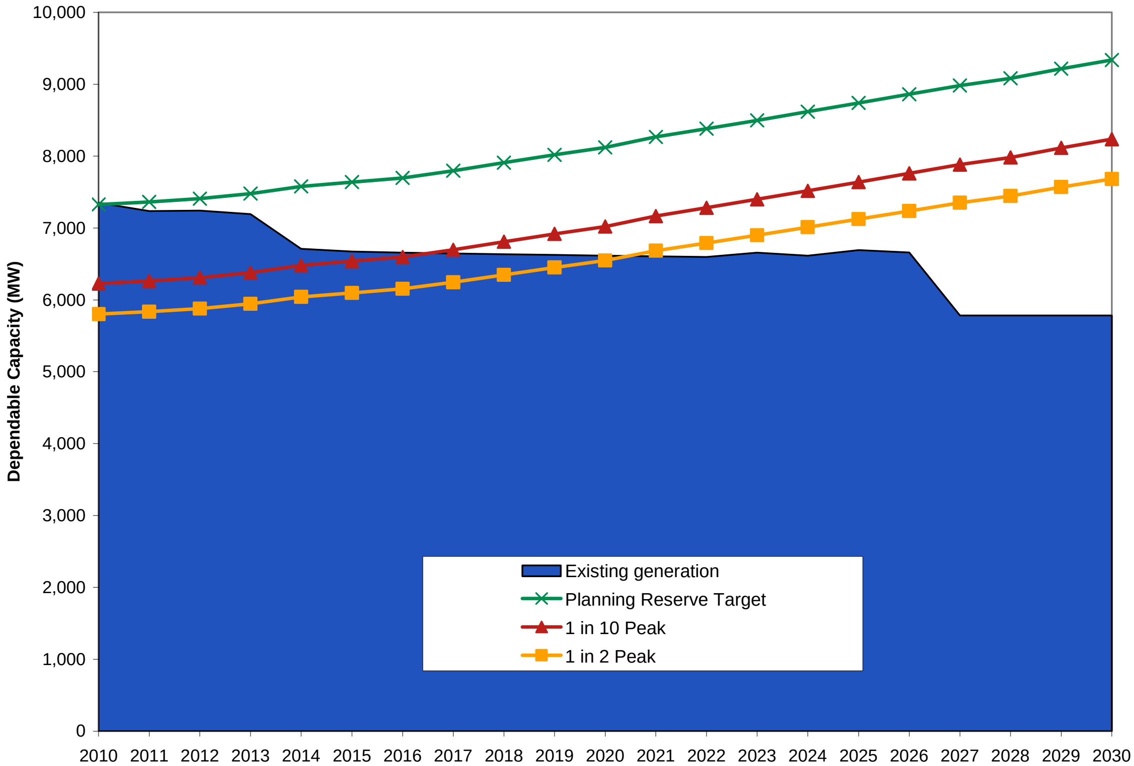

Figure M-2: Resource Adequacy Gap Analysis

M.5.1 Amount of Renewables Needed

To determine the amount of renewable energy necessary to meet future targets, forecasts were made for the future power demand and the amount of existing renewable capacity available to meet these requirements. The difference between the projected amount required and the amount currently being utilized is the net short that will need to be acquired to meet RPS guidelines. A description of the methodology undertaken to define the future renewable needs is outlined below.

LADWP Renewable Net Short

The net short is the generation target to be met with resources identified in this project. The calculation for the net short was performed using the following equation.

Net Short(GWh) = (Forecasted Energy Sales) x (Annual Renewable Percent Goal) – (Operating Renewable Resources – Under Construction and Pre-construction Renewable Resources - Renewable Energy Purchases)

LADWP has projected its renewable supply though 2020, consisting of existing renewables, projected contribution from future projects, estimated California Solar Initiative (CSI) contribution, and efficiency goals. The net short versus the possible 35 percent renewables scenarios by 2020 is presented on Figure M-3. Without additional procurement of additional renewables resources, LADWP will be roughly 3,800 GWh/yr short of a 35 percent renewables target by 2020, and 5,900 GWh/yr short by 2030.

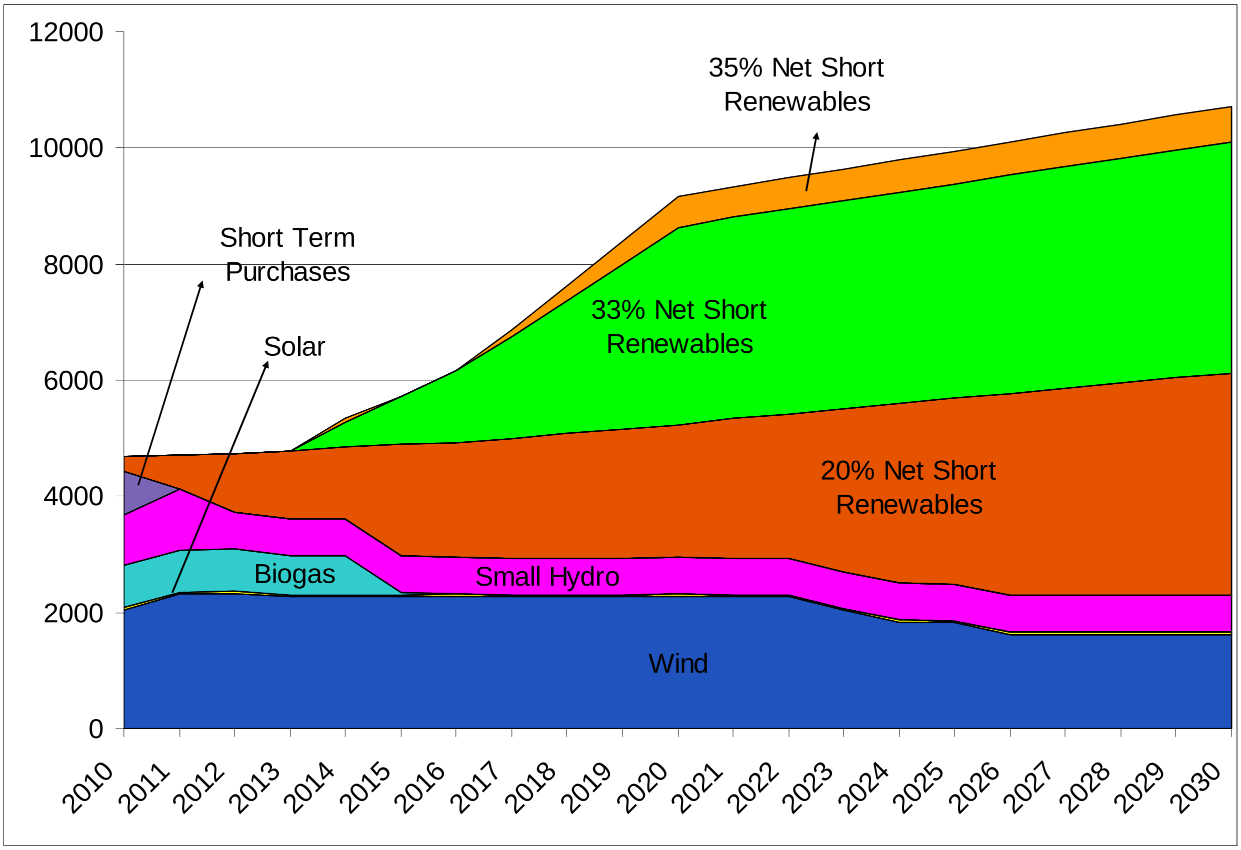

Figure M-3: LADWP Renewable Target Net Short

LADWP existing renewable resources include:

- Solar: Approximately 37 GWh/yr of local solar
- Wind: Approximately 2,050 GWh/yr of LADWP owned or purchased wind power. Between 2022 and 2025, 645 GWh/yr of wind power purchase agreements will expire. These will be replaced by other renewable resources.
- Hydro: 880 GWh/yr of hydroelectric power, including Sepulveda, Water System, Aqueduct, Owens Valley, Powerex, and Owens Gorge projects. The Powerex agreement will expire in 2012 and is expected to be replaced by other renewable resources.
- Biogas: 83 GWh/yr of in-state and out-of-state purchases. Existing agreements will be replaced by other renewable resources as they expire.

LADWP has a number of other resources that are currently being negotiated or considered for future renewable energy procurement. Because of the level of uncertainty for these projects, they were not included in the firm future capacity forecast. The intent of the IRP process is to identify the additional projects that can help meet the renewable energy goals at the lowest cost.

M.6 Options

There are a large number of options that LADWP can consider for filling the gaps. An IRP does not typically evaluate specific plants, but instead examines the implication of resource technology types and locations to give guidance to power system staff in the type of technology and locations that should be pursued.

Demand side options include Energy Efficiency (EE) programs which reduce energy consumption during many hours of the year and Demand Side Management (DSM) programs, which are programs that the utility can call on to interrupt load during peak periods if necessary for reliability purposes. The supply curve for future EE and DSM is typically determined by performing a comprehensive study of EE and Demand Response potential. LADWP is in the process of updating its 2006 study of EE and DSM potential. That work was not available for this IRP, but it will be incorporated into next year's IRP update. For purposes of this IRP, it was assumed that LADWP performs sufficient EE to meet the intent of Assembly Bill 2021 of reducing total forecasted electricity consumption by 10 percent over the 10 year period 2007-2016. The assumption is that LADWP reduces its load by 1 percent each year for each of those 10 years.

Major supply side options available to meet load include the following:

- Geothermal
- Western US Wind:
- Large Central Station Solar
- Distributed Solar
- Biomass and Biogas
- Hydroelectric
- Gas Fired Combustion Turbines
- Combined Cycle gas fired resources

While there are other renewable technologies that LADWP would want to acquire, it is expected that these will be in small quantities and thus were not analyzed in depth as part of this IRP.

M.7 Resource and Financial Assumptions

M.7.1 Overview

In order to perform the computer-based modeling, a significant amount of model input data was developed and prepared. General assumptions and price inputs included

- Load

  The hourly loads used in the modeling are based on the load forecast described in Section 2, "Load Forecast and Resources."

- Existing supply-side resources

  The expected availability of existing and planned resources was incorporated into an initial forecast of resource needs. A summary of the major assumptions made for renewable resources is shown in Table M-1.

Table M-1: Summary of supply-side resource assumptions

Resource	Levelized Cost ($/MWh)	Capacity Factors	Dependable Capacity
Solar Photovoltaic - PPA	$140	25%	27%
Solar Photovoltaic – LA Solar – Public/Private Partnership In-Basin	$200	21%	27%
Solar Photovoltaic – LA Solar Public/Private Partnership Owens	$153	25%	27%
Solar Customer - Net-Metered	$190	19%	27%
Solar Feed-In Tariff	$190	20%	27%
Wind	$90	35%	10%
Geothermal	$120	90%	90%
New Combined Cycle Gas (310 MW)	$80	87%	100%
New Simple Cycle Gas (50/100 MW)	$124	< 10%	100%

- Demand side resources

  Existing and new LADWP EE programs are incorporated within the load forecast itself. New DR programs are included as capacity resources in the model.

- Candidate demand and resource options

  Resources used to meet peak demand and renewable energy goals include projected generation from future projects including customer-installed solar, as well as generation from existing projects.

- Financial metrics

  The modeling assumed general inflation of 1.5 percent over the forecast period, a discount rate, and a levelized fixed charges rate. Table M-2 shows the assumed value of each of these financial metrics.

Table M-2: Assumed financial metrics

Metric	Rate (Percent)
Inflation	1.50
Discount Rate	5.50
Levelized Fixed Charges Rate	6.70

M.7.2 Gas Fired Resource Assumptions

The assumptions used for the various gas fired technologies are shown on Table M-3.

Table M-3 : Gas Fired Resource Assumptions

Asset Type	Combined Cycle		Combustion Turbine	
Model Designation	1 x 1 GE 7FA	2 x 1 GE 7FA	LMS 6000	LMS 100
Generation Fuel	Gas	Gas	Gas	Gas
Start Fuel	Gas	Gas	Gas	Gas
Installed Cost (Includes Owners Costs and IDC, $/kW)				
US, Representative	$1,265	$1,200	$1,290	$1,290
Heat Rate				
Average Heat Rate at Maximum Capacity	6686	-	9675	9190
Capacity (MW)	312	-	50	100
Summer Rating	-	6,870	-	-
Capacity	-	260	-	-
Winter Rating	-	6,820	-	-
Capacity	-	260	-	-
Variable O&M ($/MWh)	$4.00	$4.00	$4.49	$4.49
Fixed O&M ($/kW-year)	$6.90	$6.90	$15.99	$15.99
Maintenance Rate (hours per year)	0%	6%	3%	3%
Forced Outage Rate (hours per year)	5%	2%	4%	4%
Start Costs				
Cash Start Costs ($/start) incl MM	0	0	0	0
Fuel Start Costs (MMBtu start fuel/start)	0	0	0	0
Emission Rates (with controls) (lbs/MMBtu)				
CO2	117	117	117	117
SO2	0.0007	0.0007	0.0009	0.0009
NOx	0.01	0.01	0.0116	0.0116
Hg	0	0	0	0

M.7.3 Renewable Resources Available

Most renewable resources that were considered in the analysis were those identified as part of the Western Governor's Association Western Renewable Energy Zones (WREZ) project. This was supplemented by analysis of other resources that would be suitable for LADWP to meet future renewable goals at suitable resource adequacy. In Phase 1 of the WREZ initiative, Qualified Resource Areas (QRAs) were defined as areas of high quality and dense renewable energy resources with enough capacity to potentially justify the construction of a high voltage transmission line for interstate transmission of renewable energy. QRAs needed to meet size, resource quality, environmental and technical criteria. The WREZ Zone Identification and Technical Analysis (ZITA) working group developed the economic and technical criteria to identify QRAs. The WREZ Environment & Lands (E&L) working group developed the environmental criteria to identify QRAs.

These two sets of criteria in geospatial analyses of the entire WREZ study area were used to filter vast renewable energy resource potential to the highest quality and most developable renewable energy resources. The resulting resource areas were called Candidate Study Areas (CSAs). The screening criteria developed by the ZITA and E&L working groups are defined in the WREZ report and carried forth to this analysis.

Fifty-three QRAs were identified across the WREZ study area, with nearly 200,000 MW of renewable energy resources theoretically capable of generating over 560 terawatt hours (TWh) of energy per year. Over 2,200,000 MW of non-QRA resources were also identified across the study area. These resources were screened to reflect only resources located near transmission available to LADWP.

M.7.3.1 Technology Characteristics

Assumptions were made for the cost and performance of each technology used to convert the renewable resources to electricity. A summary of the main assumptions made for biomass, geothermal, solar, and wind are highlighted below. These assumptions were used in calculating the levelized cost of electricity and rank cost that was used in evaluating different technology portfolios. Specifics for the resource valuation methods are covered in section M.8.

Biomass

Combustion of biomass fuel was assumed to take place in a stoker or fluidized bed steam generator with a standard steam power cycle. Assumed emissions control equipment included selective non-catalytic reduction (SNCR) for NOx control and a baghouse/electrostatic precipitator for particulate control. This combination represents conventional technology which has been proven over many years of operation.

Geothermal

Input from the private sector, research institutions, and government agencies was used to compile a resource map and power production table for the WREZ project that shows the varied and significant potential of geothermal resources across the Western Interconnection.

Estimation of geothermal generation potential for specific areas has relied on volumetric estimation of heat in place wherever sufficient information was available to justify this approach. The methodology has been described in detail in a study of California and Nevada geothermal resources for the CEC PIER program. In brief, the heat-in-place approach entails estimation of the area, thickness, and average temperature of the geothermal resource. Recovery factors based on industry experience are applied to estimate the proportion of heat that can be recovered as electrical energy over an assumed project life of 30 years. Uncertainty in the input parameters is handled by a probabilistic approach that yields a range of possible generation values and associated probabilities. The modal value of the probability distribution is considered the “most likely value” of generation potential for the project concerned.

Where there is insufficient resource information to apply the heat-in-place method, estimates of generation potential have been made by analogy to better-known projects in similar geologic environments. If the only public information about a project is that it contains geothermal leases or has been the subject of a geological reconnaissance study, the project size has been estimated at a minimum size of 10 MW (gross). Larger estimates of capacity can be justified even in the absence of published resource data if there is evidence of active geothermal development efforts.

Solar Photovoltaic

The solar resource assessment identified solar resources potentially developable as utility-scale solar projects. A direct normal insolation (DNI) level of 6.5 $kWh/m^2/day$ was assumed to be an appropriate overall minimum DNI threshold that could be cost-effectively developed on a utility scale. Besides utility-scale assessments, a rough potential for solar PV projects on residential and commercial rooftops in the LADWP service territory was also estimated.

For solar PV technologies, 12x24 production profiles and capacity factors were calculated for the centroid of each utility scale resource area and applied to all resources inside that location. For a solar photovoltaic project, capacity factor is the ratio of its AC delivered energy over a year and its AC energy output if it had operated at full nameplate capacity the entire time.

Data and models used were developed by the National Renewable Energy Laboratory (NREL) as a basis for the capacity factor analysis for photovoltaic modules. NREL provided high resolution solar irradiance data in GIS format. This data included global horizontal, latitude tilt and direct normal monthly irradiance values for 10km x 10km grid squares. NREL derived the solar irradiance data from many years of satellite images covering the United States.

A proprietary tool was used to calculate energy production. The inputs for this tool included the NREL solar irradiance data, temperature data, geographical location, day and hour. The tool outputs average hourly energy production by month for both tracking crystalline silicon and fixed tilt thin film technologies. An annual degradation in performance of 1 percent was included in the cost of energy calculations.

For local solar resources, information was collected for commercial rooftops and complimented by data from the California Energy Commission[10] (CEC) and UC San Diego[11] (UCSD) for residential rooftop potential. For commercial potential, a Google Earth assessment of large rooftops in the Los Angeles area was performed to estimate the total space available. This was scaled to act as a proxy for the entire LADWP service territory, with the amount of space discounted to reflect undevelopable areas. Data from the CEC for Los Angeles County and from UCSD for California metro areas scaled to the size of Los Angeles County was used as a rough assessment of the residential potential. Growth of the metro area was estimated per the methodology used in the CEC and UCSD analysis.

Solar Thermal

Thermal plants consist of two major subsystems: a collector system that collects solar energy and converts it to heat, and a power block that converts heat energy to electricity. Concentrating solar thermal power plants (CSP) produce electric power by collecting the sun's energy to generate heat using various mirror or lens configurations. For solar thermal electric systems, the heat is transferred to a turbine or engine for power generation. Other solar thermal systems, like the solar chimney, collect solar heat without the aid of concentrators.

All CSP systems make use of the direct normal insolation (DNI) component of solar radiation, that is, the radiation that comes directly from the sun. Global radiation, which is reflected radiation, is present on sunny and cloudy days but is unusable by CSP systems. Since all CSP systems use DNI and concentration of DNI allows a solar system to achieve a high working fluid temperature, there is a need for the collector systems to track the sun. Parabolic trough and CLFR systems use single-axis trackers to focus radiation onto a linear receiver, while dish-Stirling and power tower CSP systems use two-axis trackers.

The WREZ analysis used for renewable energy technology selection did not consider solar thermal due to the projection of higher cost relative to solar PV. However, the higher capacity factor and capacity credit

[10] "California Rooftop PV Assessment and Growth Potential By County", CEC-500-2007-048, September 2007.
[11] Anders, S., and Bialek, T., "Technical Potential For Rooftop Photovoltaics in the San Diego Region", available at www.sandiego.edu/EPIC/.../060309_ASESPVPotentialPaperFINAL.pdf

brings grid stability issues valued by LADWP, especially as more intermittent renewable energy is brought into the system.

Wind

The US wind resource assessment carried out as part of WREZ identified wind resources potentially developable as utility-scale wind projects. NREL wind power Class 3 was assumed to be an appropriate overall minimum wind power threshold that could be cost-effectively developed on a utility scale, although higher minimum wind power class thresholds were applied to wind resources in different states. This differentiation was made due to the vast disparities in the quality and quantity of wind resources across the western US and Baja. States such as Wyoming have large quantities of potentially developable, high quality (Class 5) wind, while states such as Utah and Washington may not. A minimum threshold was applied in an effort to focus the analysis on resources that would most likely be developed for export across state lines.

To calculate the wind resource capacity potential (in MW) inside each grid square for the US portion of the study area, it was assumed that each square kilometer of eligible wind power class resource contained five MW of generation potential. Using this assumption, the acreage of each eligible, segregated wind power class in each grid square was quantified and converted to generating capacity. The wind power capacity identified in each grid square was discounted by 75 percent to account for unknown developability constraints.

To calculate the annual wind energy generating potential (in GWh/yr) inside each grid square, a capacity factor was calculated for each grid square. In the US, this was calculated based on the capacity factors of the areas of each wind power class in each grid square. A representative capacity factor was assigned to each wind power class, shown in Table M-5. The capacity factor for each grid square was calculated as the capacity-weighted average capacity factor of the wind power classes in each grid square.

Table M-5. Assumed Wind Capacity Factor by Wind Class.

Wind Power Class	Capacity Factor (percent)
Class 3	28
Class 4	31
Class 5	35
Class 6	40
Class 7	42
Source: Analysis of NREL mesoscale SCORE-lite modeled capacity factors.	

Production profiles were created for US wind resources using NREL mesoscale modeled data within 50 miles of the centroid of each initial resource area; modeled projects were 30 MW each. These profiles were used to determine the capacity and energy value of wind energy based on the resource available. Although the modeled projects were 30 MW, the resulting annual production profiles were appropriate for application to all wind resources in the area.

M.8 Candidate Portfolios

A candidate portfolio is a selection of renewable and non-renewable resources that will fill the gap (i.e. the Resource Adequacy need and the need for renewable resources). Given the large number of available renewable and non-renewable technologies, a large number of candidate portfolios can meet this need. Several candidate portfolios were selected for detailed modeling. The candidate portfolios to be analyzed are selected in order to provide a broad spectrum of possible portfolios so that the analysis will provide power system staff guidance on which portfolio types are likely to be the most desirable. This process is to first identify candidate renewable portfolios to meet policy goals. For each candidate renewable portfolio, a determination of the contribution of that candidate renewable portfolio toward Resource Adequacy is determined. Then the residual Resource Adequacy need is met with a combination of peaker and combined cycle gas fired generation as necessary.

M.8.1 Renewable Portfolio Selection Methodology

Because only a limited number of portfolios could be run in the modeling software, portfolios were developed to reflect certain boundary situations. After review of the available resources, the following initial cases were developed as potential ways to meet the renewable net short:

- Geothermal only
- Large (utility-scale) solar only
- Wind only, with focus on specific regions of the West
- WREZ optimal (lowest cost resources defined by the WREZ model)
- Balanced (even geothermal, solar, and wind to fill the net short)
- Local distributed solar

For each case except the local distributed solar, the resource model developed by the WREZ project was used to determine the renewable resources that would meet the requirements of each portfolio. While most cases involved only one resource type, the “WREZ optimal” portfolio could include any resource in the model, with the final selections based on the lowest cost. The “balanced” portfolio was evenly split among the lowest cost wind, geothermal, and solar resources to meet the net short.

For each of these portfolios, after the appropriate constraints were applied, resources were selected based on lowest rank cost and transmission availability until the net short was reached. To assess and rank projects consistently, a method must be developed to measure the economics of all resources on a consistent basis. Renewable technologies all have different characteristics, with different cost requirements and energy delivery patterns. Resource valuation is a way to measure different renewable resources on a comparable basis.

A valuation process designed to provide a single ranking value to a resource was developed to identify those resources with the combination of lowest cost and highest value. The valuation approach is similar to the bid evaluation process many utilities use when procuring renewable resources.

Table M-6. Resource Valuation.

Ranking Cost = Cost – Value	
Costs: Generation Costs + Integration Costs	**Value:** Energy Value + Capacity Value

M.8.1.1 Renewable Generation Cost

The cost of generation is calculated as a levelized cost of energy ("LCOE") at the point at which the project will interconnect to the existing transmission system. The LCOE for a project is the total life-cycle cost of generating electricity at the facility normalized by the total generation from the facility and is calculated in terms of dollars per megawatt hour ($/MWh). LCOE provides a consistent basis for comparing the economics of disparate projects across all technologies and ownership.

For each project or resource class, a pro forma financial analysis was conducted to determine the life-cycle cost. This pro forma model uses input assumptions for key project variables to determine expected revenues, costs, and year-by-year after-tax cash flow over the project life. The pro forma model used is consistent with the model used in CEC's Cost of Generation model, as well as those used in WREZ and California's Renewable Energy Transmission Initiative. It is also very similar to the model used by the CPUC to calculate the Market Price Referent (MPR), with the necessary modifications to make the calculations appropriate for renewable resources, including the modeling of tax incentives, accelerated depreciation, and other incentives.

The analysis included appropriate assumptions for each project. Some assumptions were tailored to be technology specific, such as financing terms and appropriate tax incentives. Other assumptions such as capacity factor and capital cost depended on geography and the available natural resource. Specific costs included in the generation costs were:

- Capital costs
- Generation interconnection costs ("gen-tie")
- Fixed operation and maintenance
- Variable operation and maintenance
- Heat rate (if applicable)
- Fuel costs (if applicable)
- Incentives
- Net plant output
- Capacity factor
- Economic life

M.8.1.2 Renewable Integration Cost

The integration cost of a project is the indirect operational cost to the transmission system to accommodate the generation from the project into the grid. The addition of substantial amounts of intermittent and as-available renewable resources could result in substantial generation swings on the transmission system, and the grid operator must accommodate these swings by ensuring there is sufficient regulation service, modifications to current daily ramps, additional reserve capacity, and voltage support. Additional integration costs will include wear-and-tear on resources if they are required to repeatedly cycle to adjust for the intermittent resource output.

M.8.1.3 Renewable Resource Adequacy Contribution (Capacity Value)

The capacity value of a generating resource is based on its ability to provide dependable and reliable capacity during peak periods when the system requires reliable resources for stable operation. Resources that can provide firm capacity will have a higher capacity value than resources that cannot. In the WREZ model, the ability of a renewable resource to generate power during the top 10 percent of the model's yearly load was used as the capacity credit. LADWP uses a more conservative approach by only considering the peak hour in each day of the summer hours, then including an exceedance factor of 90 percent.

The baseline value of capacity is the cost of the next most likely addition of low-cost capacity, defined as the fixed carrying costs of a simple cycle gas turbine generator. This includes the capital costs, fixed operations and maintenance costs, and other fixed charges associated with the gas turbine generator capacity, expressed as a dollar per kilowatt per year ($/kW-year). The capacity value does not include variable costs, such as fuel purchases. The WREZ carrying cost is estimated at $114/kW-yr.

For new projects, the capacity factor is derived from the projected generation profile for the resource. The formula for calculating capacity value ($/kW-yr) is:

$$\textit{Capacity Value (\$/MWh)} = \textit{(Capacity Credit) x (Baseline Capacity Value)/} \\ \textit{(Project Capacity Factor *8760/1000)}$$

M.8.1.4 Renewable Energy Value

The energy value of a resource assesses the value of its hourly output to the energy markets. Resources that produce more power during high-price, peak demand periods will have a higher energy value than resources that provide power primarily during low demand periods.

The value of the energy generated by a project was based on a 2015 Los Angeles market price forecast developed using a production cost model. In this model, the CO_2 price is assumed to be $35/ton, and the natural gas cost is $10/MMBTU. The formula for calculation of energy value is:

$$\textit{Energy Value (\$/MWh)} = \\ \Sigma\ \textit{[(Energy Value in Time Period) x (Energy Output in Time Period)] / Total Energy Output}$$

M.8.1.5 Transmission Limits and Costs

Constraints were placed on the transmission lines entering LADWP's service territory to reflect existing or future capacity estimates. Resources selected in the model were limited by this availability.

M.8.1.6 Model Information and Inputs

The following spreadsheets present various LADWP projects and initiatives and their inputs and constraints used during modeling. All projects and initiatives are subject to change.

Table M-7: Project capital costs for the Recommended Case

Program	Project	Type	COD	Capacity (MW)	Capacity Factor	Average Generation (GWh)	Capital Cost 2011-2020 (B$)	Capital Cost 2021-2030 (B$)	Capital Cost 2011-2030 (B$)
r	Haynes 5&6 Repowering	Combustion Tubine	1/1/2012	600	3%	151	$ 0.74	$ -	$ 0.74
r	Scattergood 3 Repowering	312MW CC & 200MW CT	1/1/2016	312; 200	84%; 11%	2,294; 184	$ 0.71	$ -	$ 0.71
r	Haynes 1&2 Repowering	312MW CC & 150MW CT	1/1/2027	312; 50/100	91%; 1%	2,498; 1/7	$ -	$ 0.76	$ 0.76
r	TOTAL						$ 1.45	$ 0.76	$ 2.21
	DR_Phase 1	Demand Response	1/1/2011	50			$ 0.05	$ -	$ 0.05
	DR_Phase 2	Demand Response	1/1/2012	50			$ 0.05	$ -	$ 0.05
	DR_Phase 3	Demand Response	1/1/2013	50			$ 0.05	$ -	$ 0.05
	DR_Phase 4	Demand Response	1/1/2014	50			$ 0.05	$ -	$ 0.05
	DR_Phase 5	Demand Response	1/1/2018	50			$ 0.05	$ -	$ 0.05
	DR_Phase 6	Demand Response	1/1/2019	50			$ 0.05	$ -	$ 0.05
	DR_Phase 7	Demand Response	1/1/2020	50			$ 0.05	$ -	$ 0.05
	DR_Phase 8	Demand Response	1/1/2021	50			$ -	$ 0.05	$ 0.05
	DR_Phase 9	Demand Response	1/1/2022	50			$ -	$ 0.05	$ 0.05
	DR_Phase 10	Demand Response	1/1/2023	50			$ -	$ 0.06	$ 0.06
	Energy Efficiency Program	EE		434		1962	$ 0.83	$ 0.31	$ 1.14
	TOTAL						$ 1.18	$ 0.47	$ 1.65
wth	GenericCT_21	Combustion Tubine	1/1/2021	100	5%	45	$ -	$ 0.15	$ 0.15
wth	GenericCC_24	Combined Cycle	1/1/2024	312	59%	1625	$ -	$ 0.49	$ 0.49
wth	GenericCT_26	Combustion Tubine	1/1/2026	100	2%	15	$ -	$ 0.16	$ 0.16
wth	GenericCT_29T2	Combustion Tubine	1/1/2029	200	3%	45	$ -	$ 0.33	$ 0.33
wth	TOTAL						$ -	$ 1.13	$ 1.13
	Navajo Replacement	Combined Cycle	1/1/2014	500	52%	2,297	$ 0.28	$ -	$ 0.28
	IPP Replacement	520MW CC & 600MW CT	1/1/2027	520; 600	60%; 6%	2,711; 338	$ -	$ 1.56	$ 1.56
	TOTAL						$ 0.28	$ 1.56	$ 1.84
	Generic RPS 1	Generic Renewable	1/1/2023	80	80%	569	$ -	$ 0.49	$ 0.49
	Generic RPS 2	Generic Renewable	1/1/2025	80	80%	569	$ -	$ 0.50	$ 0.50
	Geo_PG1	Geothermal	1/1/2015	80	90%	633	$ 0.43	$ -	$ 0.43

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Program	Project	Type	COD	Capacity (MW)	Capacity Factor	Average Generation (GWh)	Capital Cost 2011-2020 (B$)	Capital Cost 2021-2030 (B$)	Capital Cost 2011-2030 (B$)
RPS	Geo_PG2	Geothermal	1/1/2017	80	80%	569	$ 0.44	$ -	$ 0.44
RPS	Geo_PG3	Geothermal	1/1/2018	80	80%	569	$ 0.45	$ -	$ 0.45
RPS	Geo_PG4	Geothermal	1/1/2020	80	80%	569	$ 0.46	$ -	$ 0.46
RPS	Solar_FIT	Solar	1/1/2012	150	20%	263	$ 0.53	$ -	$ 0.53
RPS	Solar_PPA1	Solar	7/1/2015	50	25%	110	$ 0.21	$ -	$ 0.21
RPS	Solar_PPA2	Solar	7/1/2018	50	25%	110	$ 0.21	$ -	$ 0.21
RPS	Solar_PPA3	Solar	7/1/2021	50	25%	110	$ -	$ 0.21	$ 0.21
RPS	Solar_PPA4	Solar	7/1/2024	50	25%	110	$ -	$ 0.21	$ 0.21
RPS	Solar_PPA5	Solar	7/1/2027	50	25%	110	$ -	$ 0.21	$ 0.21
RPS	Solar_PPA6	Solar	7/1/2030	50	25%	110	$ -	$ 0.21	$ 0.21
RPS	Solar_DWP_Built (In-Basin)	Solar	1/1/2010	120	21%	216	$ 0.66	$ -	$ 0.66
RPS	Solar_DWP_Built (Owens)	Solar	1/1/2013	200	25%	440	$ 0.88	$ -	$ 0.88
RPS	Solar_Customer_Net-metered	Solar	1/1/2010	225	19%	371	$ 0.26	$ -	$ 0.28
RPS	Wind_PG1	Wind	1/1/2012	101	34%	300	$ 0.26	$ -	$ 0.26
RPS	Wind_PG2	Wind	1/1/2014	101	34%	300	$ 0.27	$ -	$ 0.27
RPS	Wind_PG3	Wind	1/1/2019	130	35%	400	$ 0.37	$ -	$ 0.37
RPS	Wind_PG4	Wind	1/1/2026	98	35%	300	$ -	$ 0.31	$ 0.31
RPS	Wind Pine CYN	Wind	1/1/2016	141	32%	395	$ 0.35	$ -	$ 0.35
RPS	TOTAL						$ 5.78	$ 2.14	$ 7.94
Trans	Transmission						$ 1.21	$ 0.43	$ 1.64
TOTAL	TOTAL						$ 9.90	$ 6.49	$ 16.41

Table M-8: Capital costs for natural gas unit installations and upgrades for the Recommended Case

Natural Gas Units

Project	Type	COD	Capacity (MW)	Capacity Factor	Average Generation (GWh)	Capital Cost
Haynes 5&6 Repowering	Combustion Tubine	1/1/2012	600	3%	151	$ 742
Navajo Replacement	Combined Cycle	1/1/2014	500	52%	2,297	$ 637
Credit for Navajo Asset Sale	-	1/1/2014				$ (360)
Scattergood 3 Repowering	312MW CC & 200MW CT	1/1/2016	312; 200	84%; 11%	2,294; 184	$ 714
GenericCT_21	Combustion Tubine	1/1/2021	100	5%	45	$ 152
GenericCC_24	Combined Cycle	1/1/2024	312	59%	1625	$ 486
GenericCT_26	Combustion Tubine	1/1/2026	100	2%	15	$ 164
Haynes 1&2 Repowering	312MW CC & 150MW CT	1/1/2027	312; 50/100	91%; 1%	2,498; 1/7	$ 758
IPP Replacement	520MW CC & 600MW CT	1/1/2027	520; 600	60%; 6%	2,711; 338	$1,560
GenericCT_29T2	Combustion Tubine	1/1/2029	200	3%	45	$ 334
Total						$5,186

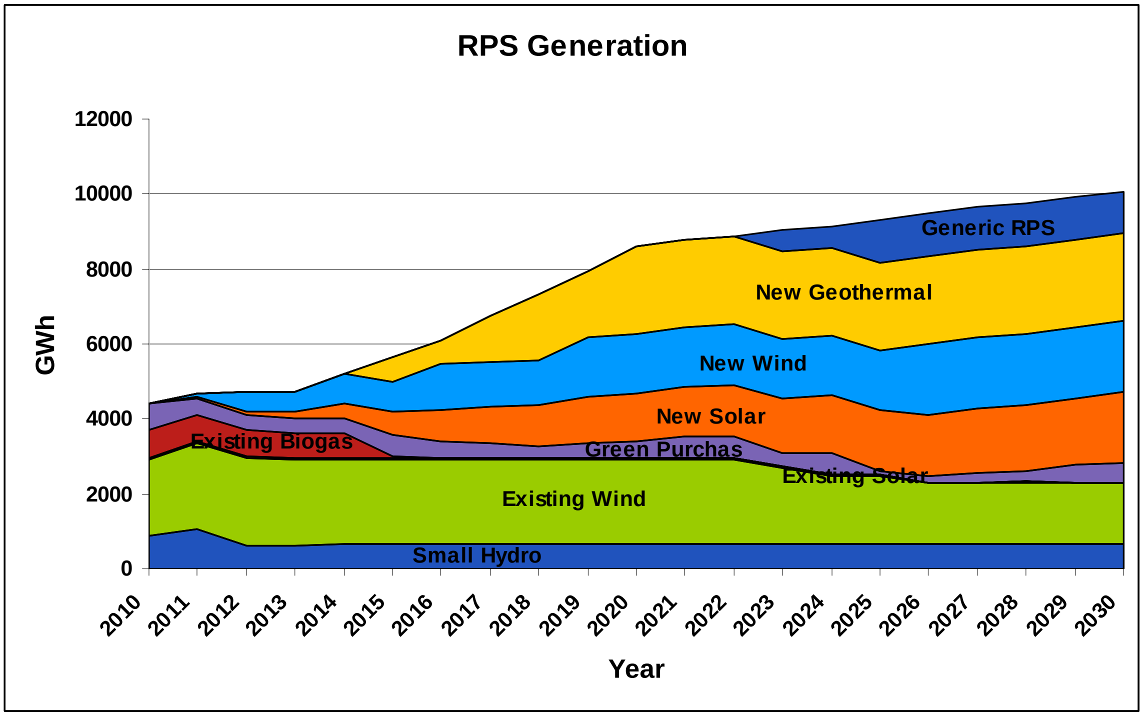
Table M-9: PPA costs for the Recommended Case

PPA Units

Project	Type	COD	Capacity (MW)	Capacity Factor	AVG Annual Generation (GWh)	Equivalent Capital Cost for PPAs ($M)
Wind_PG1	Wind	1/1/2012	101	34%	300	$ 405
Wind_PG2	Wind	1/1/2014	101	34%	300	$ 417
Wind_PG3	Wind	1/1/2019	130	35%	400	$ 600
Wind_PG4	Wind	1/1/2026	98	35%	300	$ 499
Solar_FIT	Solar	1/1/2012	150	20%	263	$ 529
Solar_PPA1	Solar	7/1/2015	50	25%	110	$ 213
Solar_PPA2	Solar	7/1/2018	50	25%	110	$ 213
Solar_PPA3	Solar	7/1/2021	50	25%	110	$ 213
Solar_PPA4	Solar	7/1/2024	50	25%	110	$ 213
Solar_PPA5	Solar	7/1/2027	50	25%	110	$ 213
Solar_PPA6	Solar	7/1/2030	50	25%	110	$ 213
Geo_PG1	Geothermal	1/1/2015	80	90%	633	$ 431
Geo_PG2	Geothermal	1/1/2017	80	80%	569	$ 444
Geo_PG3	Geothermal	1/1/2018	80	80%	569	$ 451
Geo_PG4	Geothermal	1/1/2020	80	80%	569	$ 464
Generic RPS 1	Generic Renewable	1/1/2023	80	80%	569	$ 485
Generic RPS 2	Generic Renewable	1/1/2025	80	80%	569	$ 500

M.8.1.7 Recommended Case Renewable Generation Mix

The following figure presents the renewable generation mix of the Recommended Case.



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