APPENDIX I – PLANNING RESERVE MARGIN STUDY

Introduction

The planning reserve margin (PRM), measured as a percentage of coincident system peak load, is a parameter used in resource planning to ensure there are adequate resources to meet forecasted load over time. PacifiCorp selects a PRM for use in its resource planning by studying the relationship between cost and reliability among ten different PRM levels, accounting for variability and uncertainty in load and generation resources.[40] Costs include capital and run-rate fixed costs for new resources required to achieve ten different PRM levels, ranging from 11 percent to 20 percent, along with system production costs (fuel and non-fuel variable operating costs, contract costs, and market purchases). In analyzing reliability, PacifiCorp performed a stochastic loss of load study using the Planning and Risk (PaR) production cost simulation model to calculate the following reliability metrics for each PRM level:

- Expected Unserved Energy (EUE): Measured in gigawatt-hours (GWh), EUE reports the expected (mean) amount of load that exceeds available resources over the course of a given year. EUE measures the magnitude of reliability events, but does not measure frequency or duration.
- Loss of Load Hours (LOLH): LOLH is a count of the expected (mean) number of hours in which load exceeds available resources over the course of a given year. A LOLH of 2.4 hours per year equates to one day in 10 years, a common reliability target in the industry. LOLH measures the duration of reliability events, but does not measure frequency or magnitude.
- Loss of Load Events (LOLE): LOLE is a count of the expected (mean) number of reliability events over the course of a given year. A LOLE of 0.1 events per year equates to one event in 10 years, a common reliability target in the industry. LOLE measures the frequency of reliability events, but does not measure magnitude or duration.

PacifiCorp's loss of load study results reflect its participation in the Northwest Power Pool (NWPP) reserve sharing agreement. This agreement allows a participant to receive energy from other participants within the first hour of a contingency event, defined as an event when there is an unexpected failure or outage of a system component, such as a generator, transmission line, circuit breaker, switch, or other electrical element. PacifiCorp's participation in the NWPP reserve sharing agreement improves reliability at a given PRM level. Upon evaluating the relationship between cost and reliability in its PRM study, PacifiCorp will continue to use a 13 percent target PRM in its resource planning.

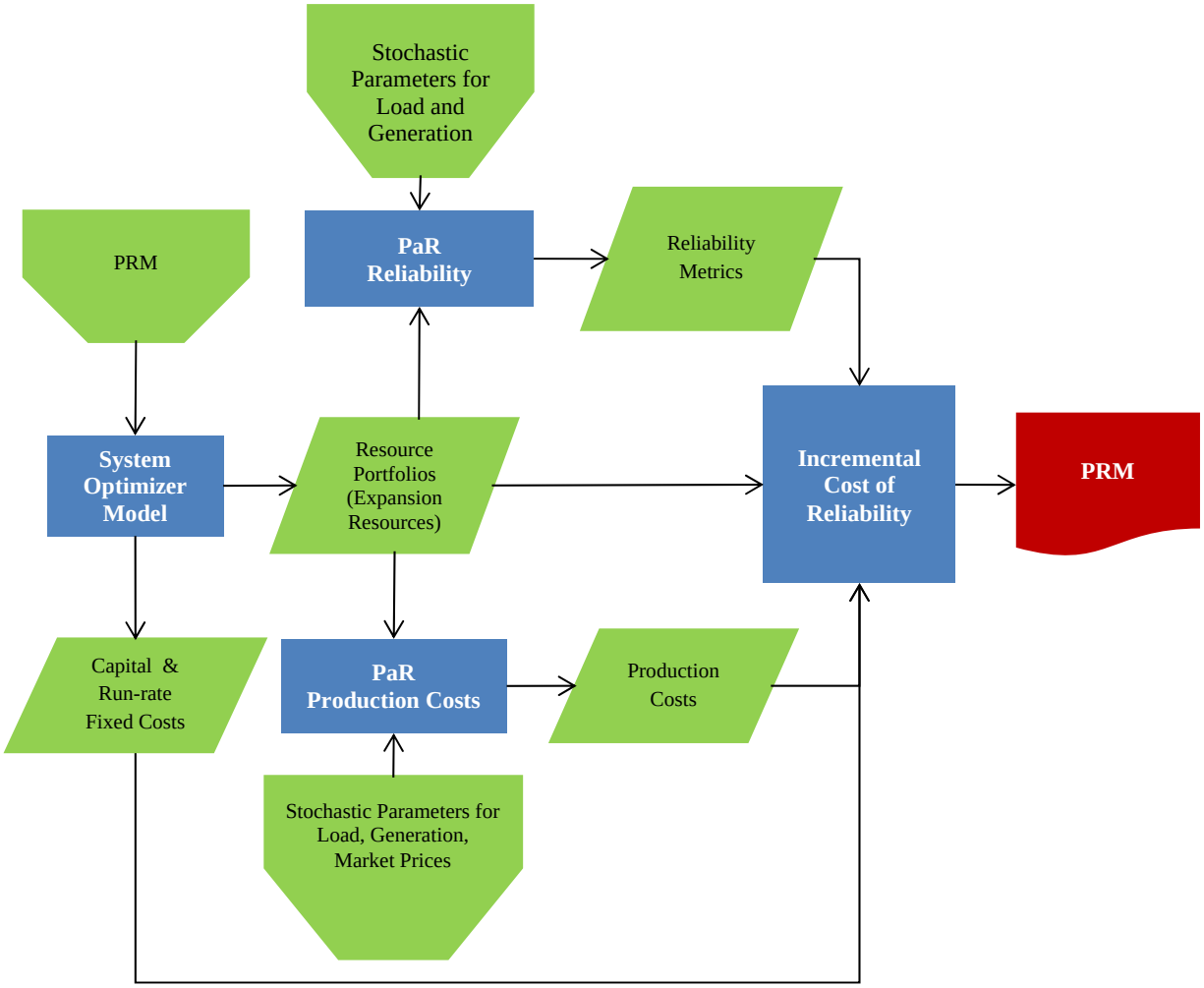
Methodology

Figure I.1 shows the workflow used in PacifiCorp's PRM study. The four basic modeling steps in the workflow include: (1) using the System Optimizer (SO) model, produce resource portfolios among eleven different PRM levels ranging between 10 percent and 20 percent; (2) using the Planning and Risk model (PaR), produce reliability metrics for each resource portfolio;

[40] Costs and reliability metrics are calculated for eleven different PRM levels, ranging from 10 percent to 20 percent. Comparative analysis among each PRM is performed for 10 different PRM levels by comparing the cost and reliability results from PRM levels ranging between 11 percent and 20 percent to those from the 10 percent PRM.

(3) using PaR, produce system variable costs for each resource portfolio; (4) calculate the incremental cost of reliability among PRM levels analyzed.

Figure I.1 – Workflow for Planning Reserve Margin Study



Development of Resource Portfolios

The SO model is used to produce resource portoflios assuming PRM levels ranging between 10 percent and 20 percent. The SO model optimizes expansion resources over a 20-year planning horizon to meet peak load inclusive of the PRM applicable to each case. As the PRM level is increased from 10 percent to 20 percent, additional resources are added to the portfolio. Resource options used in this step of the workflow include demand side management (DSM), gas-fired combined cycle combustion turbines (CCCT), and gas-fired simple cycle combustion turbines (SCCT).

Front office transactions (FOTs) are not considered as a resource expansion option in this phase of the workflow. FOTs are proxy resources used in the IRP portfolio development process that represent firm forward short-term market purchases for summer on-peak delivery, which coincides with the time of year and time of day in which PacifiCorp observes its coincident system peak load. These proxy resources are a reasonable representation of firm market purchases when performing comparative analysis of different resource portfolios to arrive at a

preferred portfolio in the IRP. However, given the seasonal and intra-day pattern of these proxy resource options, they are not as well suited for a loss of load study that evaluates reliability metrics across all hours in a given year. The contribution of firm market purchases to reliability, up to transmission and market depth limits that are identical for all scenarios, are accounted for in the loss of load study by allowing system balancing hourly purchases in the subsequent workflow step where reliability metrics are produced using PaR.

Upfront capital and run-rate fixed costs from each portfolio are recorded and used later in the workflow where the relationship between cost and reliability is analyzd. Resources from each portfolio are used in the subsequent workflow steps where reliability metrics and production costs are produced in PaR.

Development of Reliability Metrics

PaR is used to produce reliability metrics for each of the resource portfolios developed assuming PRM levels ranging between 10 percent and 20 percent. PaR is a production cost simulation model, configured to represent PacifiCorp's integrated system, that uses Monte Carlo random sampling of stochastic variables to produce a distribution of system operation. For this step in the workflow, reliability metrics are produced from a 500-iteration PaR simulation with Monte Carlow draws of stochastic variables that affect system reliability—load, hydro generation, and thermal unit outages. As discussed above, system balancing hourly purchases are enabled to capture the contribution of firm market purchases to system reliability. The PaR reliability studies are used to report instances where load exceeds available resources, including system balancing hourly purchases. Reported EUE measures the stochastic mean volume of instances where load exceeds available resources, and is mesasured in GWh. EUE measures the magnitude of reliability events. Reported LOLH is a count of the stochastic mean hours in which load exceeds available resources. LOLH measures the duration of reliability events. Reported LOLE is a count of the stochastic mean events in which load exceeds available resources. LOLE is a measure of the frequency of reliability events.

Each of the reliability metrics described above is adjusted to account for PacifiCorp's participation in the NWPP reserve sharing agreement, which allows a participant to receive energy from other participants within the first hour of a contingency event. The NWPP adjustments are made to EUE by reducing the stochastic mean volume of instances where load exceeds available resources for the first hour of a reliability event. For example, if the stochastic mean volume of EUE for a reliability event is 120 MWh, equal to 40 MWh in three consecutive hours, then the adjusted EUE is 80 MWh after removing the first hour of the event. Using this same example, LOLH would be adjusted from three to two hours, and LOLE would not be adjusted. The LOLE is only adjusted inasmuch as a given reliability event has a one hour duration.

Development of System Variable Costs

In addition to completing PaR runs to develop reliability metrics, PaR is also used to produce system variable operating costs for each of the resource portfolios developed assuming PRM levels ranging between 10 percent and 20 percent. For the system variable cost PaR runs, Monte Carlo random sampling of stochastic variables is expanded to include natural gas and wholesale market prices in addition to the stochastic variables for load, hydro generation, and thermal unit outages. Including market prices as a stochastic variable is important for this step of the

workflow because of their influence the economic dispatch of system resources, the cost of system balancing purchases, and revenues from system balancing sales. The stochastic mean of system variable costs is added to the upfront capital and run-rate fixed costs from each portfolio so that total portfolio costs are captured for each PRM level.

Calculating the Incremental Cost of Reliability

Using 2017 as the reference year, the cost of reliability is calculated as the difference in fixed and variable system costs at each PRM level relative to total costs at a 10 percent PRM. The incremental cost of reliability is calculated by dividing the cost of reliability by the difference in EUE at each PRM level relative to EUE at 10 percent PRM. This calculation yields an incremental cost per megawatt-hour (MWh) of EUE at PRM levels raninging between 11 percent and 20 percent.

Results

Resource Portfolios

Table I.1 shows new resources added to the portfolio at PRM levels ranging between 10 percent and 20 percent. Each portfolio includes a 420 megawatt (MW) CCCT. New SCCT resource capacity totals 976 MW at the 10 percent PRM, rising to 1,996 MW at a 20 percent PRM. DSM resource additions range between 1,010 MW and 1,107 MW (between 358 MW and 424 MW during system peak hours). As the PRM is increased, system capacity is largely met with additional SCCT resources. Because new SCCT resources are added in blocks indicative of a typical plant size (i.e. the model cannot add a 2 MW SCCT plant), the addition of new DSM resources does not always increase with each sequential increase in the PRM.

Table I.1 – Expansion Resources Additions by PRM

PRM (%)	DSM		SCCT (MW)	CCCT (MW)	Total at System Peak (MW)
	Maximum (MW)	Capacity at System Peak (MW)			
10	1,029	372	976	420	1,768
11	1,017	363	1,157	420	1,940
12	1,020	365	1,259	420	2,045
13	1,032	375	1,259	420	2,055
14	1,017	363	1,440	420	2,224
15	1,043	384	1,440	420	2,244
16	1,010	358	1,602	420	2,380
17	1,065	397	1,612	420	2,428
18	1,017	363	1,793	420	2,576
19	1,107	424	1,793	420	2,637
20	1,096	416	1,996	420	2,832

Reliability Metrics

Table I.2 shows EUE, LOLH, and LOLE reliability results before and after adjusting these reliability metrics for PacifiCorp's participation in the NWPP reserve sharing agreement. Each of the reliability metrics generally improve as the PRM increases and after accounting for benefits associated with PacifiCorp's participation in the NWPP reserve sharing agreement. After

accounting for its participation in the NWPP reserve sharing agreement, all PRM levels meet a one day in ten year planning criteria (LOLH at or above 2.4), and PRM levels of between 15 and 16 percent meet a one event in ten year planning criteria (LOLE at or above 0.1).

Table I.2 – Expected Reliability Metrics by PRM

	Before NWPP Adjustment			After NWPP Adjustment		
PRM (%)	EUE (GWh/yr)	LOLH (Hours/yr)	LOLE (Events/yr)	EUE (GWh/yr)	LOLH (Hours/yr)	LOLE (Events/yr)
10	301	2.60	0.87	200	1.73	0.48
11	183	2.03	0.74	116	1.29	0.41
12	197	1.78	0.50	141	1.27	0.29
13	122	1.51	0.43	87	1.08	0.29
14	84	1.24	0.35	60	0.89	0.25
15	98	1.19	0.30	73	0.89	0.22
16	32	0.34	0.20	13	0.13	0.04
17	68	0.46	0.18	41	0.28	0.07
18	17	0.30	0.12	10	0.18	0.05
19	17	0.40	0.18	9	0.22	0.08
20	13	0.27	0.12	7	0.15	0.04

The reliability metrics do not montonically improve with each incremental increase in the PRM. This is influenced by the physical location of new resources within PacifiCorp's system at varying PRM levels and the ability of these resources to serve load in all load pockets when Monte Carlo sampling is applied to load, hydro generation, and thermal unit outages. Considering that the reliability metrics are measuring very small magnitudes of change among the different PRM levels, the PaR outputs are fit to a logarithmic function to report the overall trend in reliability improvements as the PRM level increases. Table I.3 shows the fitted EUE, LOLH, and LOLE results. Figure I.2, Figure I.3 and Figure I.4 show a plot of the fitted trend for EUE, LOLH, and LOLE, respectively, after accounting for PacifiCorp's participation in the NWPP reserve sharing agreement.

Table I.3 – Fitted Reliability Metrics by PRM

	Before NWPP Adjustment			After NWPP Adjustment		
PRM (%)	EUE (GWh/yr)	LOLH (Hours/yr)	LOLE (Events/yr)	EUE (GWh/yr)	LOLH (Hours/yr)	LOLE (Events/yr)
10	294	2.78	0.90	198	1.88	0.52
11	211	2.05	0.66	142	1.38	0.38
12	162	1.62	0.53	109	1.09	0.30
13	127	1.32	0.43	86	0.88	0.24
14	101	1.08	0.36	67	0.72	0.20
15	79	0.89	0.30	53	0.59	0.16
16	60	0.73	0.25	40	0.48	0.13
17	44	0.59	0.20	29	0.38	0.10
18	30	0.46	0.16	20	0.30	0.08
19	18	0.35	0.13	11	0.22	0.06
20	6	0.25	0.10	3	0.15	0.04

Figure I.2 – Expected and Fitted Relationship of EUE to PRM

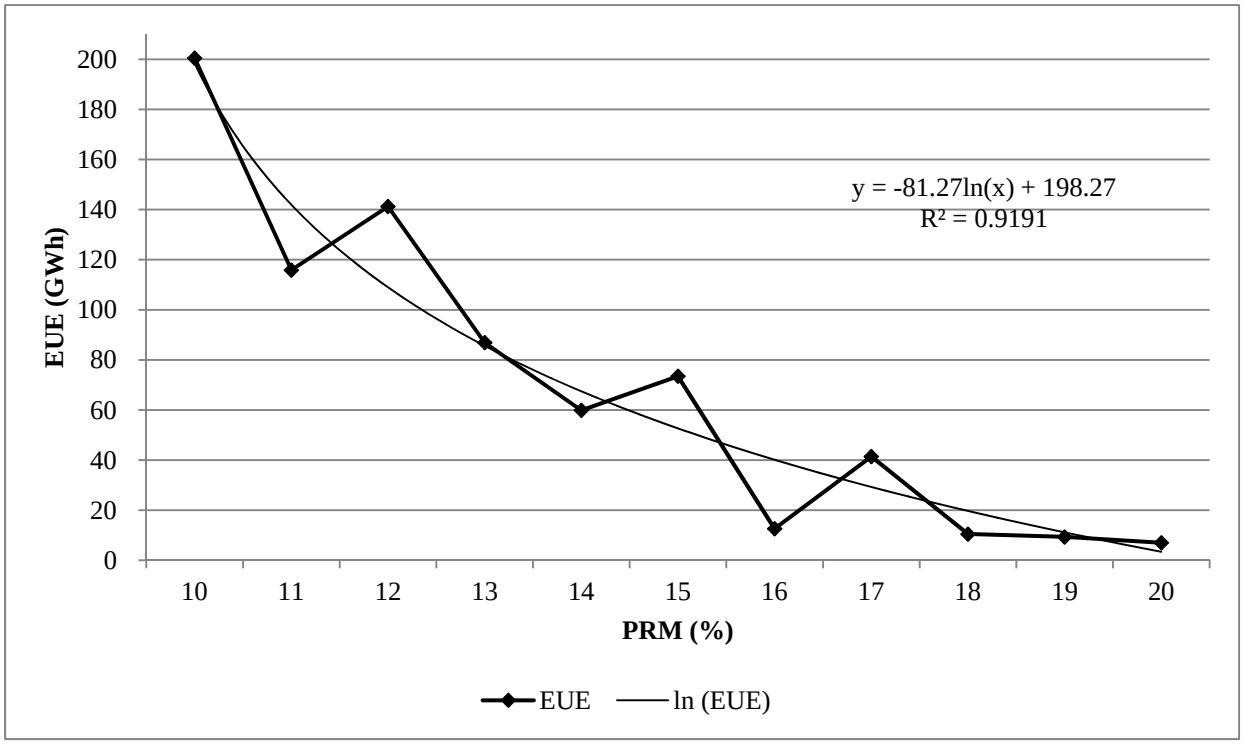


Figure I.3 – Expected and Fitted Relationship of LOLH to PRM

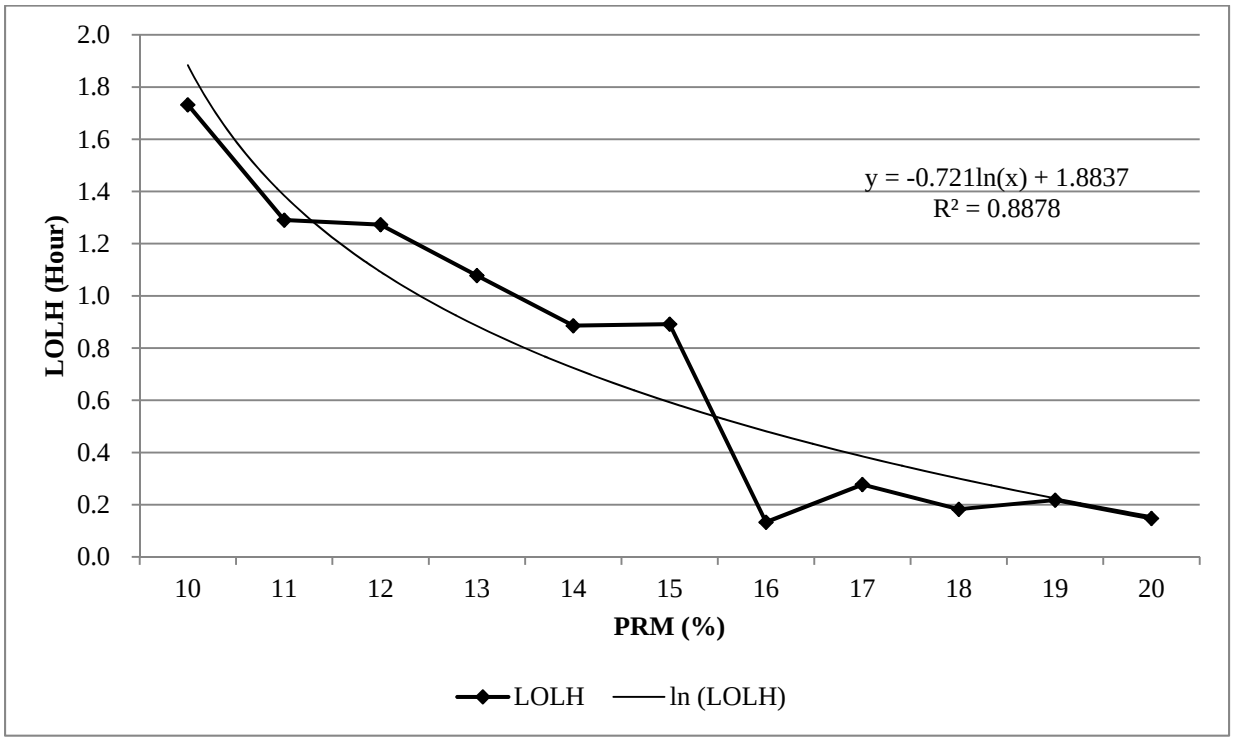
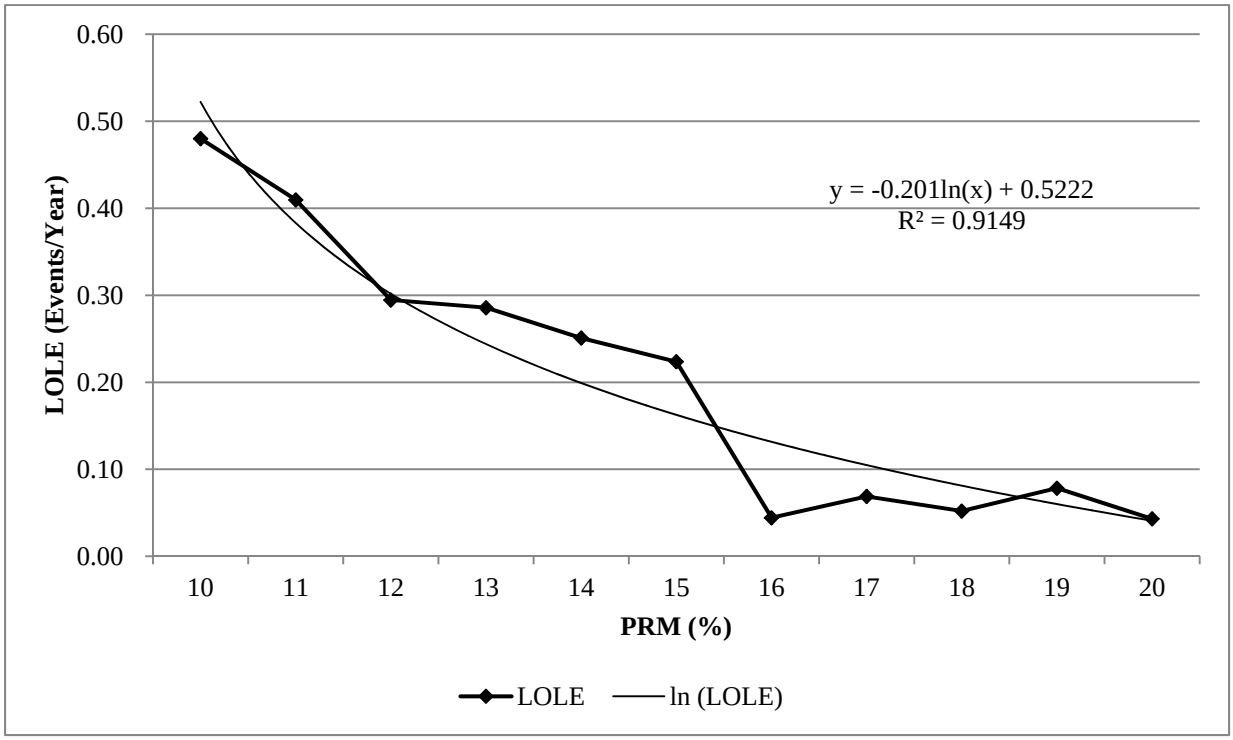


Figure I.4 – Simulated Relationship of Loss of Load Episode to PRM



System Costs

For the 2017 reference year, Table I.4 shows the stochastic mean of system variable costs and the upfront capital and run-rate fixed costs, including the cost of new DSM resources, for each portfolio developed at PRM levels ranging between 10 percent and 20 percent. The fixed costs associated with these new resource additions drive total costs higher as PRM levels increase. DSM run-rate costs increase most substantially once the PRM level exceeds 18 percent, indicating that incremental DSM resource selections for portfolios developed at the 19 percent and 20 percent PRM levels were taken from higher cost resources in the DSM supply curve.

Table I.4 – System Variable, Up-front Capital, and Run-rate Fixed Costs by PRM

PRM (%)	System Variable Costs ($ thousands)	DSM Run-rate Costs ($ thousands)	Up-front Capital & Run-rate Fixed Costs ($ thousands)	Total Cost ($ thousands)
10	1,292,361	34,498	237,119	$1,563,978
11	1,292,341	32,177	256,251	$1,580,769
12	1,288,956	32,838	276,790	$1,598,584
13	1,287,921	34,919	275,976	$1,598,816
14	1,289,097	32,181	295,108	$1,616,386
15	1,287,021	38,644	295,108	$1,620,773
16	1,289,396	30,544	314,025	$1,633,965
17	1,284,925	44,903	314,133	$1,643,961
18	1,289,300	32,177	333,265	$1,654,742
19	1,284,132	143,492	334,144	$1,761,768
20	1,283,763	141,192	363,042	$1,787,997

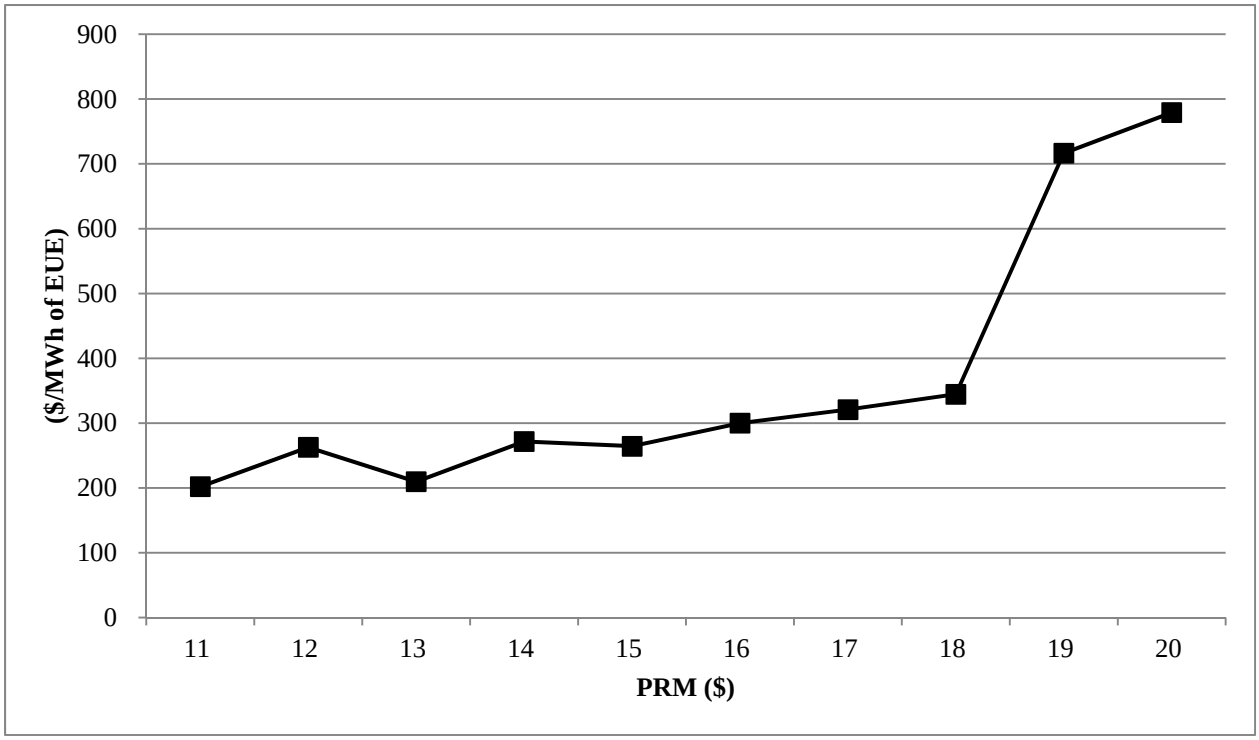
Incremental Cost of Reliability

Table I.5 shows the incremental cost of reliability at PRM levels ranging between 11 percent and 20 percent. Figure I.5 depicts this same information graphically. These results show the incremental cost of reliability rises as PRM levels increase from 15 percent and 18 percent, and increase dramatically at PRM levels above 18 percent. The incremental cost of reliability does not vary significantly at PRM levels at or below 15 percent.

Table I.5 – Incremental Cost of Reliability by PRM

PRM (%)	Reduction in Fitted EUE from EUE at 10% PRM After NWPP Adjustment (GWh)	Reduction in Total System Cost from Cost at 10% PRM ($ thousands)	Incremental Cost of EUE Relative to 10% PRM ($/MWh of EUE)
11	56	$16,791	$298
12	89	$34,606	$388
13	113	$34,838	$309
14	131	$52,408	$401
15	146	$56,795	$390
16	158	$69,987	$443
17	169	$79,983	$473
18	179	$90,764	$508
19	187	$197,790	$1,057
20	195	$224,019	$1,150

Figure I.5 – Incremental Cost of Reliability by PRM



Conclusion

Upon evaluating the relationship between cost and reliability in the PRM study, PacifiCorp will continue to use a 13 percent target PRM in its resource planning. A PRM below 13 percent would not sufficiently cover the need to carry short-term operating reserve needs (contingency and regulating margin) and longer-term uncertainties such as extended outages and changes in customer load.[41] A PRM above 15 percent improves reliability above a one event in ten year planning level, though with a 125 percent to 370 percent increase in the incremental cost per megawatt-hour of reduced EUE when compared to a 13 percent PRM. With these considerations, the selected 13 percent PRM level ensures PacifiCorp can reliably meet customer loads while maintaining operating reserves, with a planning criteria that meets one day in 10 year planning targets, at the lowest reasonable cost.

[41] PacifiCorp must hold approximately 6% of its resources in reserve to meet contingency reserve requirements and an estimated additional 4.5% to 5.5% of its resources in reserve, depending upon system conditions at the time of peak load, as regulating margin. This sums to 10.5% to 11.5% of operating reserves before even considering longer-term uncertainties such as extended outages (transmission or generation) and customer load growth.