RESOURCE ADEQUACY

Resource adequacy is the ability of the electric system to supply the energy requirements of end-use customers under all probable conditions.

The Northwest Power and Conservation Council defines resource adequacy as: "A condition in which the region is assured that, in aggregate, utilities or other load serving entities (LSE) have acquired sufficient resources to satisfy forecasted future loads reliably."

The main determining factors of resource adequacy are supply and demand. The factors that affect demand are:

1. Demand growth,
2. Demand characteristics,
3. Demand-side management, and
4. Sensitivity of demand to weather (temperature) and other factors.

The factor that affects supply is the availability of sufficient dispatchable capacity resources[1] to meet the demand.

The key challenge for long term resource planning is that supply and demand are not predictable with much certainty. The variability in supply is of particular importance, since it is so large. Therefore, City Light must use a range of possible values for supply and demand to assure reliability. As a result, at any given instance (hour), a utility is concerned with its supply being capable of meeting its demand. Resource adequacy at any given hour is the difference between the supply and the demand for a utility. The functional form of this can be represented as:

$R.A._t = S_t - D_t$, for every t, where t is an element of (1, 2, 3,..., 8760)

At any given hour, a utility desires that $S \geq D$ and consequently $R.A. \geq 0$. When, for a specific hour $R.A. < 0$, the utility needs to acquire the difference from the wholesale power market, where it will be exposed to the volatilities of power prices and uncertainty about the availability of the required amount of energy in the market over the desired time period.

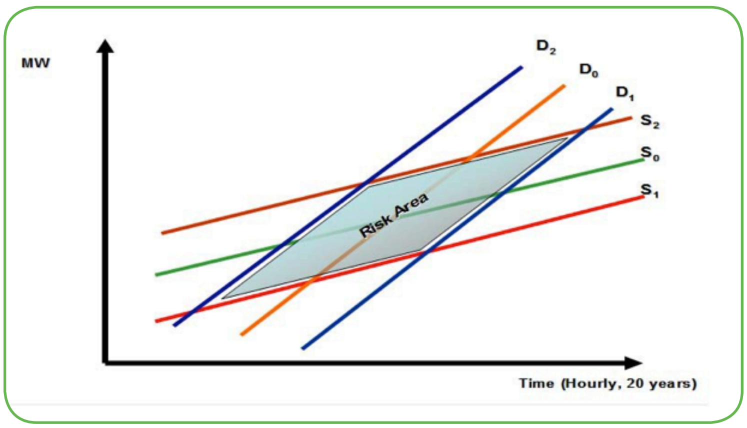
Since supply and demand factors vary from region to region or system to system, it is difficult to standardize resource adequacy criteria and methodologies. Different regions and utilities have adopted different standards and methodologies in order to optimally measure their resource adequacy as well as when to rely upon the wholesale power market or add resources.

RESOURCE ADEQUACY ANALYSIS FOR SEATTLE CITY LIGHT

City Light has elected to use the following resource adequacy standard for measuring its supply reliability: City Light plans its reliable capacity resources in order to be able to meet its highest hourly deficit at 90 percent of the time (10 percent exceedance).

City Light designed a probabilistic approach to perform risk analysis around the utility's expected hourly supply and demand. This analysis simultaneously tests the ability of the system to withstand sudden disturbances, such as unanticipated loss of system facilities or generation capabilities (supply volatilities) and sudden disturbances in load patterns (demand volatilities). This is illustrated in Figure 1.

Figure 1: Risk Analysis of Supply and Demand (MW)



The shaded area represents the logical possible disturbances that can occur to City Light's system at any given hour during the study period. City Light has developed supply and demand "risk metrics" to accurately perform a probabilistic analysis to achieve a 90 percent loss of load probability (LOLP). Risk has been evaluated for demand and supply independently[2] .

DEMAND RISK (D_T)

Heating Demand (Extreme Low Temperatures) November through February

In order to develop an accurate risk metric for City Light's demand, City Light conducted a thorough statistical analysis on hourly historical demand data (1981-2015). Based upon historical data, City Light has had annual one-hour peaks from November through February. The majority of winter peaks occurred within the months of December and January with equal frequency. Among all months, December had the highest one-hour peak. Therefore, demand volatility for the months of December and January are incorporated into the probability distribution analysis for the purposes of simulation

SUPPLY RISK (S_T)

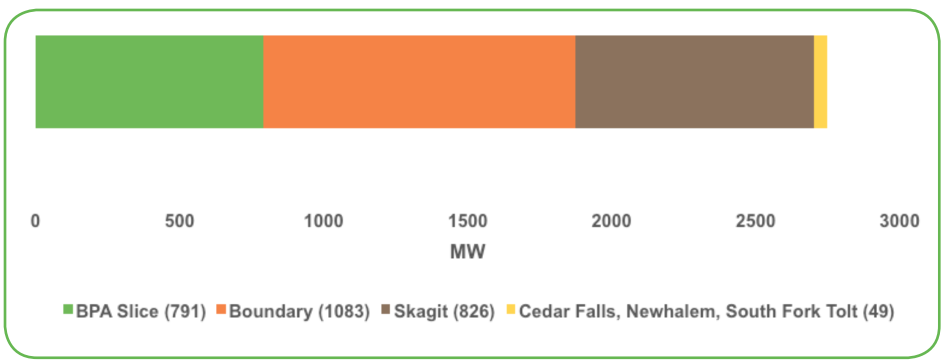
Volatilities in Dispatchable Capacity Resources

Supply risk is uncertainty in the availability of dispatchable capacity resources for any given hour. Since City Light's resource portfolio is about 90 percent hydroelectric generation, the volatility in hydro capacity resources is the largest factor of supply risk.

Hourly hydro generation is a function of stored water and forced outages. This is the capacity available for an hour and is less than or equal to the nameplate capacity. Stored water is a function of water conditions. For example, if City Light is experiencing a dry year, its ability to store water decreases, and consequently so does its generation capability. A hydro generation plant with stored water is less dependent upon water condition for the first two or three days of operation. However, as the hours of operation are prolonged, it becomes increasingly dependent on water conditions. Thus, City Light can generate the maximum output of its hydro capacity resources up to available capabilities for an hour.

In Figure 2, only dispatchable hydro capacity resources are included since other types of electric generation in City Light's resources portfolio are not dispatchable, such as wind and power contracts. Note that due to ongoing efficiency upgrades and capital improvement projects, Skagit and Boundary capabilities are continuing to change. These numbers reflect current capabilities for 2016.

Figure 2: Expected One Hour Generation Capability of Hydro Resources, December 2016.



Hydro volatility is not equal across all hydro resources due to different geographical locations and microclimate conditions associated with these resources. For example, Boundary could have dry water conditions while at the same time Skagit could have average water conditions. Therefore, "cross sectional" correlations of these resources are applied to the probability distribution analysis for the purpose of simulation.

RESULTS

Extensive statistical analyses on City Light's historical hourly demand and supply were conducted for their respective probability distributions in order to design the risk metrics used in calculating the adequacy of resources[3] .

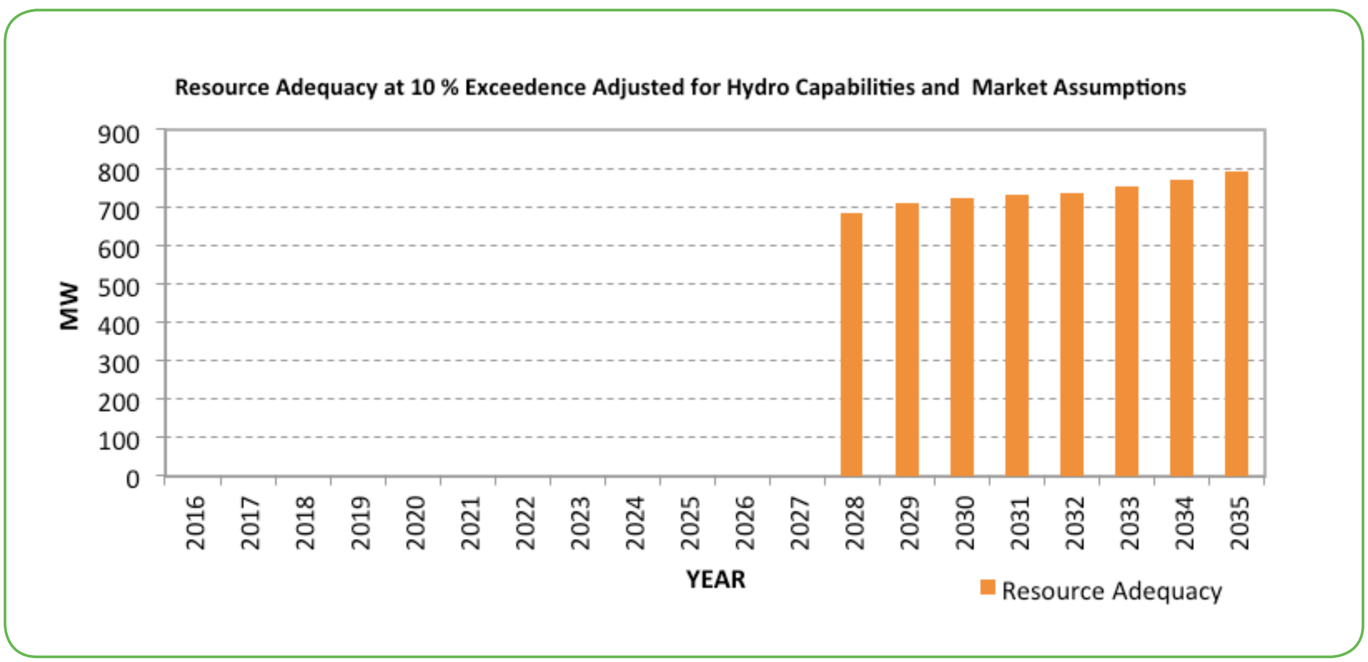
City Light has made further assumptions about the supply variables as follows:

- Existing resources continue to be operated and maintained, taking into account forced outages and scheduled maintenance (planned outages)[4] ; for instance, Skagit relicensing is assumed in 2025
- Hydro projects upgrades
- An assumption about the operating reserve requirement for City Light's resource portfolio
- Expiration of existing contracts on current schedule, including with BPA
- Adjusting City Light's hydro for extreme temperatures and shortage conditions
- 200 aMW market purchases of electricity under the most extreme temperatures and shortage conditions within the planning period

The resource adequacy analysis described above defines a measure that is used to identify the amount of energy the utility may need each year during the heating season. The simulation together with all these considerations for the study period, 2016 through 2035, led to the estimated resource requirements by year after taking into account City Light's hydro capabilities and 200 aMW of short-term market purchase assumptions (Figure 3).

Figure 3: Additional Resources Needed to Meet Resource Adequacy at 90 percent

(adjusted for hydro capabilities and 200 MW market assumptions)



[1]Dispatchable generation capacity refers to capacity resources that can be dispatched at the request of power grid operators; that is, turned on (or off) on demand. This should be contrasted with certain types of base load generation capacity, such as nuclear power, which may have limited dispatch capability.

[2]Actual Generation vs. Capability: Risk is applied to supply and demand independently. Increases in load due to lower temperatures can be met by increase in generation up to the available generation capability. For example, Boundary capacity was 1040 before recent upgrades. Now assume that one unit is out and the available capacity is reduced to 880. On average, City Light generates about 500 MW from Boundary; if demand goes up hypothetically by 400 MW then we can generate another 380 from Boundary (880 minus 500). To generate this amount, 800 SFD of stored water is required, which is often available at Boundary dam. Hence, demand changes the actual generation, but not the available capability. Therefore, the following formulaic relationship exists: CORR [Water(Available Capability), System Load] ≈ 0

[3]Resource adequacy is a function of supply and demand. In general the following abstract form for the function of resource adequacy holds:

$$R.A.=F\ (S_t, D_t)$$
$$\forall\ t \in \{1,2,3,\ldots,8760\}$$

After developing risk metrics for supply and demand, the following abstract form can be created for City Light's resource adequacy function:

$$R.A._{T_h} = F_{T_h}(SKAGIT_{(DEC_h,JAN_h)},\ BOUN_{(DEC_h,JAN_h)},\ SLICE_{(DEC_h,JAN_h)},\ D_{(DEC_h,JAN_h)})$$

Note that the subscript T_h indicates hourly time for the months of December and January.
"SKAGIT" indicates Ross, Diablo, and Gorge, "BOUN" indicates Boundary, "SLICE" indicates BPA hydro projects from which City Light receives a fixed percentage of generation and other capabilities from the Federal Columbia River System, and "D" denotes City Light's demand.

Using Auroraxmp, City Light implemented "Latin Hypercube" simulation to measure its hourly resource adequacy analysis; 1300 scenarios on hourly supply and demand have been applied simultaneously for the 20 year study period, 2016 through 2035. Figure 3 illustrates the additional resources that are needed to meet City Light's highest hourly deficit at 90 percent of the time for the month of December and consequently with the ten percent chance of exceedance.

[4]Generic planned outages schedule for City Light-owned hydro resources is developed from 2016 to 2035.