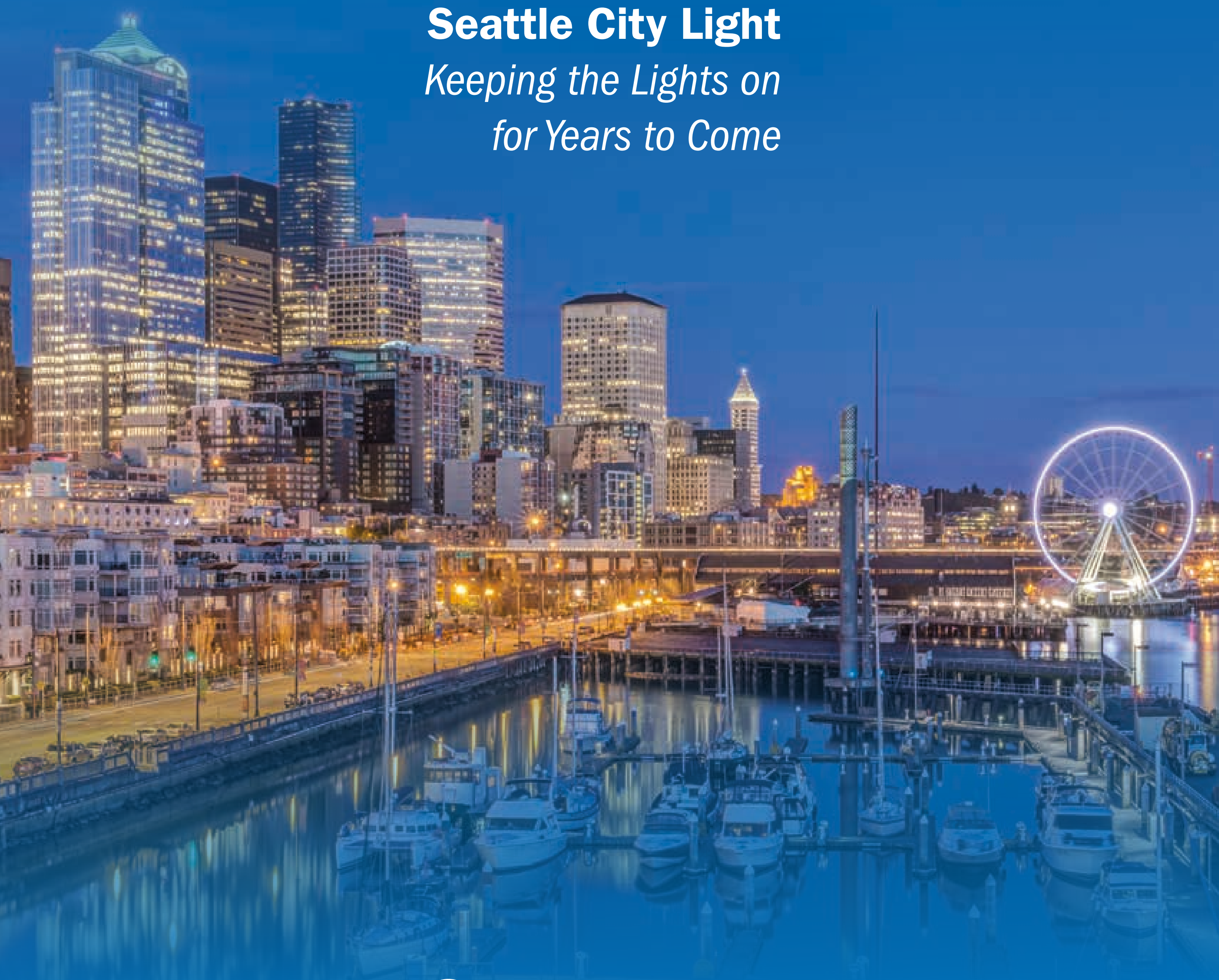
2016 INTEGRATED RESOURCE PLAN



Seattle City Light

Keeping the Lights on for Years to Come

Seattle City Light

ACKNOWLEDGMENTS

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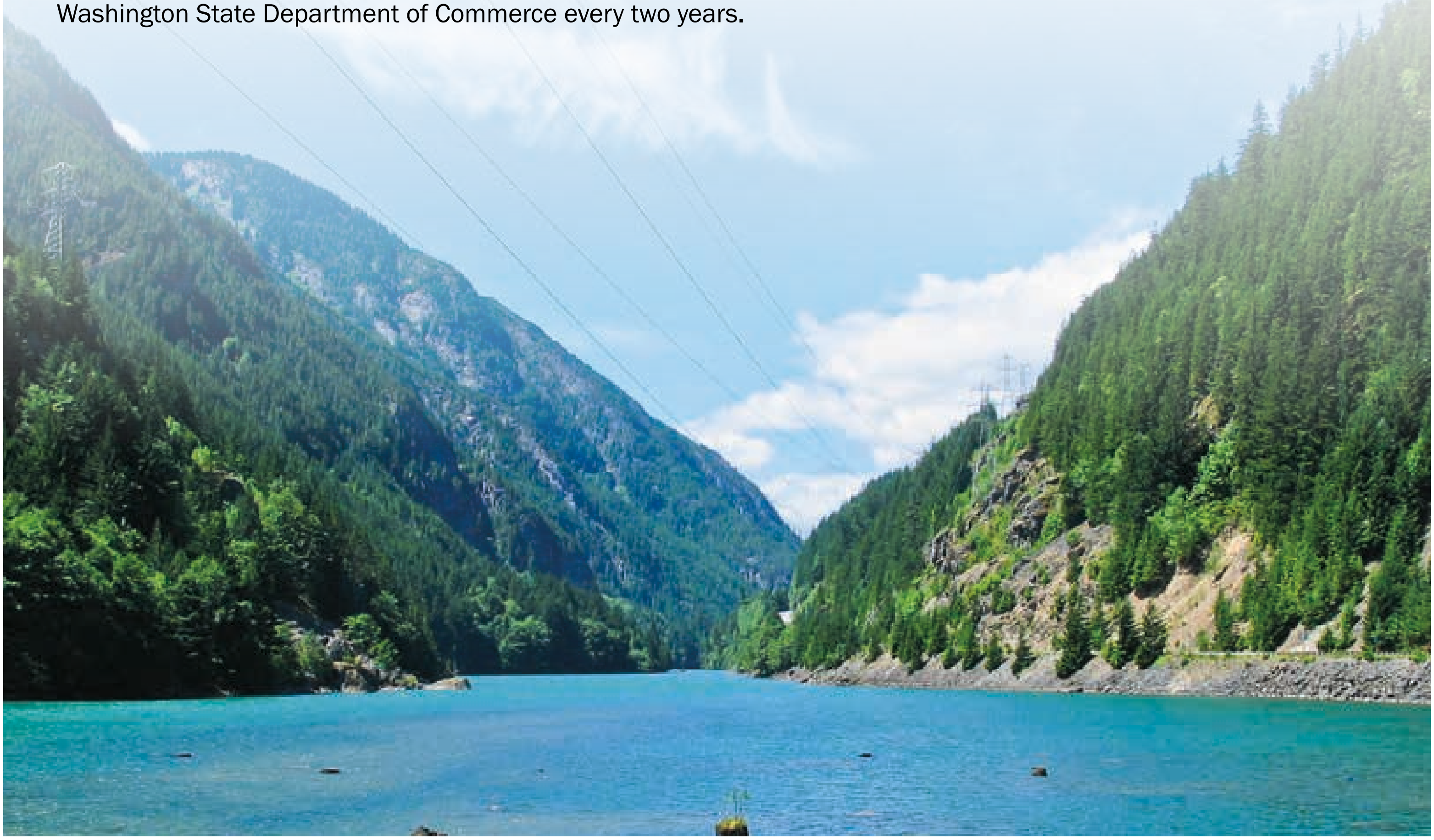
INTRODUCTION

Seattle City Light has provided its customers with reliable, safe and affordable clean energy since 1910. As the utility continues this work and plans for the future, it must account for the power supply demands of its growing customer population and also the increasing trend of energy efficiency.

Seattle City Light and the citizens of Seattle with their shared environmental values continue to make the utility a national leader, balancing power supply needs with the environmentally friendly power supply resources required to meet those needs. Seattle City Light has been a consistent voice for generating electricity with clean renewable resources and promoting energy efficiency with its customers, limiting negative impacts on the environment and reducing the need for costly new power generation. Since 2005, City Light has been greenhouse gas neutral – the first electric utility in the nation to achieve that distinction.

Seattle City Light's 2016 Integrated Resource Plan (IRP) outlines how the utility will meet anticipated customer needs under changing market dynamics, evolving policies and future uncertainties over the next 20 years. The IRP requires a constant review of conditions which affect its power supply needs, costs and risks. These considerations include evaluation of energy efficiency potential and new resource opportunities to ensure the utility's reliability, environmental stewardship, and Washington State mandated renewable resource requirements are achieved.

The IRP is created as part of good utility practice and is developed with guidance from the Mayor, City Council, and legislation from Washington State. State law requires electric utilities to develop IRPs and provide them to the Washington State Department of Commerce every two years.



The basic job inherent in developing an Integrated Resource Plan is:

- Forecast the energy and capacity needed to meet customer demand.
- Determine the utility's capability to supply those needs and ensure flexibility for when those needs fluctuate.
- Define the capability and cost of current and prospective resources.
- Evaluate potential future City Light portfolios based on reliability, cost, risk and environmental impact; and recommend a plan.

To decide whether the utility needs to alter its mix of resources, it does rigorous research, forecasting and analyses and considers input and feedback from technical stakeholders, customers, the Mayor, and City Council.

City Light reported its findings to the City Council for the 2016 IRP review. After a public hearing in front of the Council's Energy and Environment Committee, the full City Council passed the 2016 IRP and its recommendations on August 1, 2016.

City Light: Way Back in the Beginning


Photo credit: Seattle Municipal Archive

On March 4, 1902, three-fifths of Seattle voters approved $500,000 in bonds to fund construction of a municipal hydroelectric dam and plant at Cedar Lake. The project was entrusted to the Seattle Water Department and a young engineer named James D. Ross (1872-1939). The Seattle Lighting Department, or City Light, was created in 1910 and Ross became its superintendent in 1911 and held the post until his death in 1939.

A municipal power plant was not a common idea in those early days, but due to growing resentment of private interests controlling electrical services and streetcars, voters consistently sided with public ownership advocates through a series of additional bond elections. Ross is credited with decisions that built City Light with ample electricity capacity that has lasted a century. The reigning in of the area's vast hydro supplies as a Municipal utility is considered one of the best investments passed on from Seattle forefathers. The new Cedar Falls power plant began delivering power to Seattle on January 10, 1905.

EXECUTIVE SUMMARY

The Integrated Resource Plan (IRP) is Seattle City Light's 20-year forecast of what electricity demands its customers will have and what mix of resources will best meet these needs. The four evaluation criteria used in this IRP are reliability, cost, risk and environmental impact. The 2016 IRP reflects the results of the past two years' research, planning and analyses to reassess customer demands, to review generation needs, and to consider market conditions and evolving policies and regulations.

KEY RECOMMENDATIONS: The 2016 Integrated Resource Plan recommends staying the course with energy efficiency, hydro and renewable resources as outlined in previous plans. While the region is growing, customer energy demand is expected to grow at a pace lower than forecasted in prior Integrated Resource Plans. As a result, City Light does not forecast any new power supply resource additions for the proposed 20 year timeline as a result of increased customer demand. The study does show minor changes in its resource additions resulting from the replacement of contracts that are expiring. It also shows that in most cases demand growth can be met cost-effectively with new energy efficiency programs. This does not mean that the circumstances could not change, City Light will continue to evaluate every two years whether its plans should be altered.

The current two-year action plan recommends City Light continue supporting programs to reduce energy use as its primary path in meeting the forecast demand and forestall new generation development. The IRP action plan also calls for monitoring technology options, as they develop, to determine the most cost-effective means to meet customer needs.

KEY FINDINGS

- **Seattle City Light expects continued modest load growth despite the building surge visible in the utility's service area.**

Over the course of the Integrated Resource Plan's 20-year study, City Light expects to experience modest average annual load growth of about 0.4% under conditions of normal weather and before the impact of City Light sponsored energy efficiency programs available to its customers. This demand growth is at a slower pace than in the past. Despite the visible construction, there is no dramatic jump in expected power needs. The reason can be tracked to a customer base which has increased its energy efficiency, ever-improving technological efficiencies and stringent building codes.

New energy efficiency programs are not included in the above forecast, because they are considered one of the energy supply resources that City Light considers as part of the Integrated Resource Plan. Overall, City Light's energy efficiency programs protect the environment and act as a major supply resource – they save customers money by avoiding the cost of building several large power plants. The recommended pace of new City Light sponsored energy efficiency programs is forecast to meet all projected growth in electric demand during the 20-year study.

- **Seattle City Light should continue its pursuit of cost-effective new energy efficiency.**

Energy efficiency through new energy efficiency programs and targets is considered to be the resource of choice. The 2006 statewide citizens' Initiative 937 (I-937), "The Energy Independence Act" requires utilities to add cost-effective energy efficiency and renewable resources to meet a portion of load. Future energy efficiency programs included in this IRP are forecasted to be more cost-effective than available renewable resources for meeting the remaining power supply needs. The recommended portfolio in the 2016 IRP continues a high energy efficiency strategy. As a consequence of reducing load, energy efficiency also reduces the amount of renewable resources and renewable energy credits (RECs) the utility must add to comply with I-937.

- **City Light can expect to meet its power supply needs without adding costly new generation resources.**

For the next decade, City Light expects to meet its resource needs with a combination of its existing resources, its new energy efficiency programs, use of generation flexibility in existing hydro resources, and short-term wholesale market purchases as deemed reliable and necessary.

The significant increase in power supply resources shown in the 2016 IRP in 2028 compared to the 2012 IRP and the 2014 IRP update comes from including an assessment of the expiration of City Light's power purchase contract with the Bonneville Power Administration (BPA). The IRP analysis shows that to meet its obligations to be a reliable, environmentally responsible and cost-effective utility, a new BPA contract is expected to be part of the preferred resource portfolio along with additional renewable resources.

- **Seattle City Light should continue to add renewable energy credits and renewable resources as necessary to meet renewable portfolio standard (RPS) requirements mandated by I-937.**

In 2020, City Light's RPS requirement jumps to serving 15% of annual load with eligible renewable generation from its current level of 9%. Based on the existing renewable mix in City Light's resources portfolio and previously acquired RECs, the utility expects to meet its RPS obligations through 2023. Because City Light does not have power supply needs before 2028, RECs are expected to be the most cost-effective way to satisfy I-937.

- **The utility should continue to seek existing and new opportunities to maximize economic benefits from its clean and reliable hydro resources.**

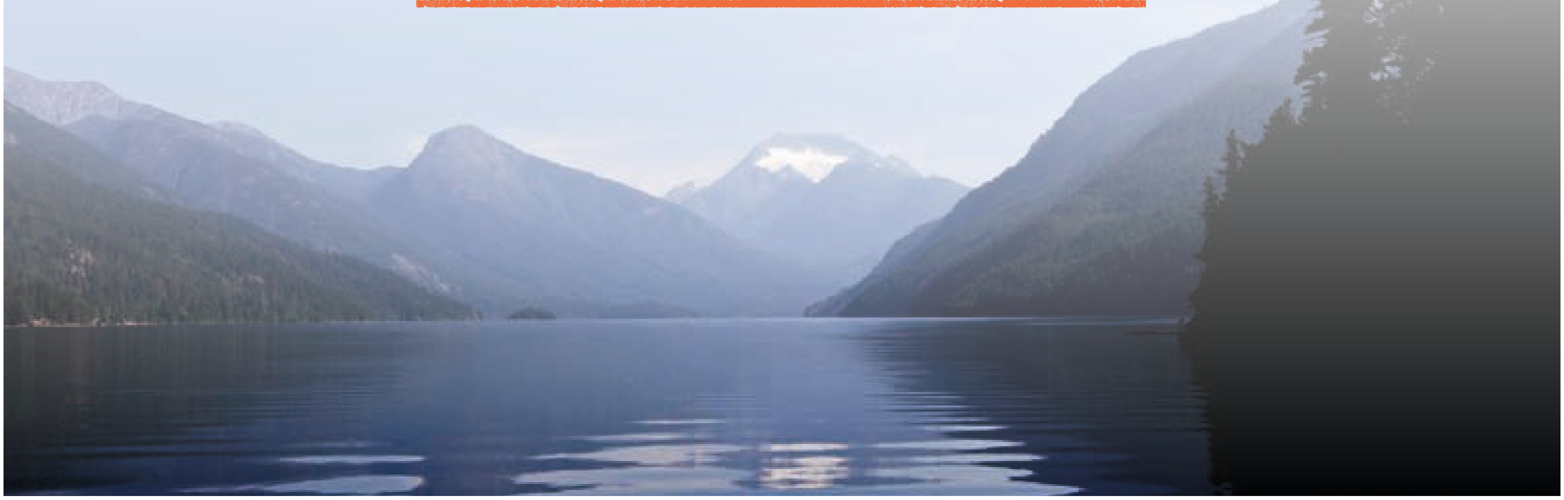
City Light's flexible and abundant hydro resources gives it an ability to withstand fluctuations in energy demand and supply and have surpluses to sell in the wholesale energy markets. City Light will continue to maintain its strategic resources sell its surplus power to offset the cost to serve demand, purchase power when needed, and explore new market opportunities for reliability and economic benefits.

- **Seattle City Light has been a leader in environmental stewardship for more than 30 years, making it ready – even a model – for responding to the increased impacts and changes which may be caused by climate change.**

City Light has instituted energy efficiency programs for almost four decades, and its energy efficiency goals are nationally respected. With its abundant hydropower resources, the utility is committed to the protection of aquatic ecosystems and fish and wildlife habitat, environmental education, and maintaining the beauty and recreational opportunities that are critical to the quality of life in the Northwest. Additionally, the utility is one of the first in the country to attain carbon neutrality and is a leader in studying its climate vulnerability.

City Light's 2016 Integrated Resource Plan includes an early review and analysis of climate change impacts on City Light's water resources used for electricity generation and for meeting electricity demand. The future projected climate change impacts appear similar to changes City Light already has encountered due to severe weather fluctuations, dramatic shifts in market conditions, emergency conditions, or other circumstances faced in the past. What is changing today is the formulation of specific climate change legislation, policies and plans which have been promulgated recently or are in the works nationally, regionally, and locally.

City Light offers reduced price, energy efficient LED light bulbs for sale at participating retailers, http://www.seattle.gov/light/homelighting/. Each year City Light customers who attend public meetings or work on special projects for energy efficiency or education are often given LED light bulbs as tokens of appreciation for their time and work.



PUBLIC INVOLVEMENT

Over the next 20 years, City Light will track its power supply needs, new and traditional resources and I-937 compliance choices. These power supply choices require investing hundreds of millions of dollars of customer funds, as well as dramatically affecting future operating costs, reliability and the City's environmental footprint for decades to come. As a publicly owned utility, customer input on the Integrated Resource Plan is essential.

City Light conducted three IRP stakeholder meetings and one webinar with representatives that included customers, environmental organizations, regional energy related governmental organizations, and academic specialists.

In addition, City Light shared information and collected comments about its IRP process through its website, social media, neighborhood council meetings, and a live and interactive Public Online Open House, which is available for viewing on the IRP website.

In summarizing the views of the stakeholder and public participants, their commitment to the environment is clear.

1) There is broad support for an aggressive environmental stewardship program.
2) The focus continues to be the investment by the utility in the aggressive pursuit of energy efficiency with an interest in how new technologies such as solar, electric vehicles and other distributed resources may impact the utility and how the utility interacts with customers in the adoption of these resources.

But public participation in meetings is not the only way City Light customers show their preference for power supply resources and production. Its customers are active participants in taking steps offered by the utility to show their environmental stewardship. Customers and City Light advance these initiatives together through:

1) Programs offering discounted light bulbs at local stores resulting in hundreds of thousands of new LED light bulbs being installed every year.
2) Four community solar projects sharing the benefits of solar energy with a wide range of customers.
3) Public participation in the Green Up program where customers voluntarily add extra money when paying their electric bill to be used for educational and demonstration projects to support renewable resource development.
4) Plans to install public electric vehicle charging stations as Seattle continues to lead the country in transforming renewable energy to electric fuel for cars.
5) Salmon, steelhead and bull trout fish habitat restoration and water quality programs which are continually advocated for by customers.
6) Support for new building codes every time new technologies are developed and proposed, making Seattle the city with one of the highest standards for energy efficient growth.

PLANNING AND REGULATORY REQUIREMENTS

City Light's goal is to exceed customer expectations in producing and delivering power that is environmentally responsible, safe, affordable and reliable. Since 2005 City Light has been a greenhouse gas neutral utility. In planning for the future, it does this in the backdrop of a complex industry, new technological advances, and changing policies and regulations.

City of Seattle Policies and Regulations

City Light has a 30 year plus history of environmental stewardship with policies, programs and planning efforts driving how the utility makes decisions. Environmental and climate protection initiatives are woven throughout several City policies.

Climate change is not a stand-alone issue separate from the other issues that the City faces. It is rooted in land use, transportation, energy use and consumption patterns that have evolved over generations.

In 2000 City Council passed a ground breaking resolution (30144) that established City Light as a global leader in climate protection. It was the basis for City Light to meet load growth with cost-effective energy efficiency and renewable resources and offset all of its greenhouse gas emissions from fossil fuels. City Light first achieved greenhouse gas neutrality in 2005 and has maintained that standard since. Most recently in 2016, City Council confirmed its resolve opposing the use of fossil fuels altogether in Resolution 31667. This resolution guides resource strategies to support clean and safe electricity production, opposing the use of fossil fuels and new nuclear energy in the generation of electricity. City Light's existing power supply resources, operations, and planning processes reflect the City's values to address climate change and be a good steward of the environment.

The City of Seattle is pursuing a goal of carbon neutrality by 2050 and the Seattle Climate Action Plan is the first step toward achieving that goal. (http://www.seattle.gov/environment/climate-change)

To support the Mayor's Drive Clean Seattle Initiative to combat climate change, City Light will implement three electric charging infrastructure pilot programs over the next several years. Starting in 2017, City Light will begin installing 10 to 20 public DC fast charging stations within its service territory, which will triple current availability. Also beginning in 2017, City Light will install Level II, 240V, stations in customers' homes and create a service that lowers the initial cost and uncertainly of installing at-home charging. Lastly, the City has committed to reduce greenhouse gas emissions from the municipal fleet 50 percent by 2025 through a significant investment in electric vehicles.

The current City Light portfolio is expected to be sufficient to meet increases in electric vehicle demand. Based on third-party projections, resulting load from plug-in electric vehicles for 2016 will be less than 3 average megawatts with load projections through 2030 totaling 14 average megawatts.

State Policies & Regulations

Washington State has always had been a strong voice for new laws and citizens' own initiatives regarding environmental priorities. Two examples impacting electric utilities are Electric Utility Resource Plans and the Energy Independence Act.

Electric Utility Resource Plans

The State, through ESHB 1010 (Chapter 195, Laws of 2006, Revised Code of Washington (RCW), Chapter 19.280) passed legislation in 2006 which requires certain Washington utilities, including City Light, to regularly prepare Integrated Resource Plans (IRPs). Under this law, IRPs must describe the mix of power supply resources and the energy efficiency needed to meet projected needs using available technologies, particularly renewable resource technologies. All of these must be balanced to offer the lowest reasonable cost to its ratepayers.

This process results in the formal Integrated Resource Plan that City Light reconsiders and updates every two years. The IRP is then reviewed by the public and stakeholders before going to the Seattle City Council where it is officially considered, discussed in public hearings, and adopted. Upon adoption, an action plan within the IRP sets into motion the new adjustments to City Light's electric portfolio.

The Energy Independence Act (Initiative 937)

A statewide citizen initiative (I-937) in 2006 passed another mandate that is now in state law, "The Energy Independence Act" (RCW, Chapter 19.285), requiring that City Light must acquire all cost-effective energy efficiency and also add higher levels of renewable resources to its portfolio.

For renewable resources, City Light has targets to serve 9% of retail load with eligible renewable generation by 2016 and 15% of retail load by 2020.

To meet I-937 requirements, eligible renewable energy must be sourced from within the Pacific Northwest or be purchased outside the Pacific Northwest and delivered to Washington on a firm transmission path, in real time, without integration services. Utilities may comply with I-937 by purchasing RECs.

RECs are energy certificates: non-tangible energy commodities that represent proof that one megawatt hour (MWh) of electricity was generated from naturally replenishing (renewable) resources such as modern biomass, wind, solar, geothermal and biofuels. Washington State law specifically excludes hydropower as an eligible resource, but hydro efficiency upgrades can create qualifying renewable energy under I-937.

Regional Policies and Regulations

Similar to the City of Seattle and State of Washington, many states and localities have placed priorities on energy efficiency and renewable energy. City Light like other utilities throughout the West require renewable energy resources and renewable energy credits to meet state renewable portfolio standards.

Some of the most aggressive renewable portfolio standards today are in California and Oregon. Based on 2011 legislation, California electricity retailers are required to serve 20% of retail sales from renewable resources by the end of 2013, 25% by the end of 2016, and 33% by the end of 2020. In October 2015, new legislation increased the 2030 requirement from 33% to 50%. In Oregon, large utilities are expected to serve 25% of retail load with renewable resources in 2025, with the target recently increased to 50% of retail load by 2040.

Increases in renewable resource generation and low natural gas prices as a result of technological advances are reducing the energy prices in wholesale electricity markets. Additionally, as renewable generation technology has become more established and less costly, renewable generation has been built in advance of utilities' near-term renewable generation requirements, driving down the cost of renewable energy credits. These same technological advancements have also been driving down the cost of renewable generation, particularly utility-scale solar.

Federal Policies and Regulations

Electric utilities are regulated by numerous federal regulations including the Clear Air Act, Clean Water Act and rules regulating electricity transmission and wholesale electricity sales. The federal government also licenses hydropower plants and ensures compliance. City Light's Boundary and Skagit Dams are licensed by the Federal Energy Regulatory Commission. Many of the regulations that fall under the Clean Air Act and Clean Water Act have significant impacts on the design, operation, and maintenance of fossil fuel power plants. These regulations impact utilities resource decisions.

With climate change, federal regulation under the Clean Air Act is now targeting carbon dioxide pollution regulation. For many years utilities have speculated about when federal regulation of carbon dioxide emissions would occur. In 2013 President Obama announced his Climate Action Plan. Under this Plan, the president set new goals to establish carbon pollution standards for power plants. In 2014, the U.S. Environmental Protection Agency (EPA) released its Clean Power Plan proposed rule. The Clean Power Plan rule set targets to reduce carbon pollution from the power sector 32 percent below 2005 levels by 2030. On February 9, 2016 the Supreme Court stayed implementation of the Clean Power Plan after 15 states filed a complaint arguing the EPA overstepped its authority. Many states including Washington State are still continuing discussions to develop a plan for implementation. Unlike many other utilities, City Light will not have to alter its resource mix to comply with carbon regulation. Its resource mix does not include fossil fuels and City Light purchases offsets for its greenhouse gas emissions including those resulting from wholesale market purchases. City Light continues to anticipate that federal carbon regulation will change the resource mix for many utilities across the United States, making renewable resources more advantageous.

THE 2016 IRP PLANNING PROCESS

The following steps describe the process:

1. **Existing Resource Portfolio:** Review existing supply to predict how well it will meet future demand. This includes representing impacts from operational constraints resulting from hydro license requirements; forecasting operations and maintenance and upgrade plans; and updating the analysis to include new contracts and contract renewals completed.

2. **Load Forecast:** Forecast customers' future energy demand considering population, employment, and the economy, amongst other factors.

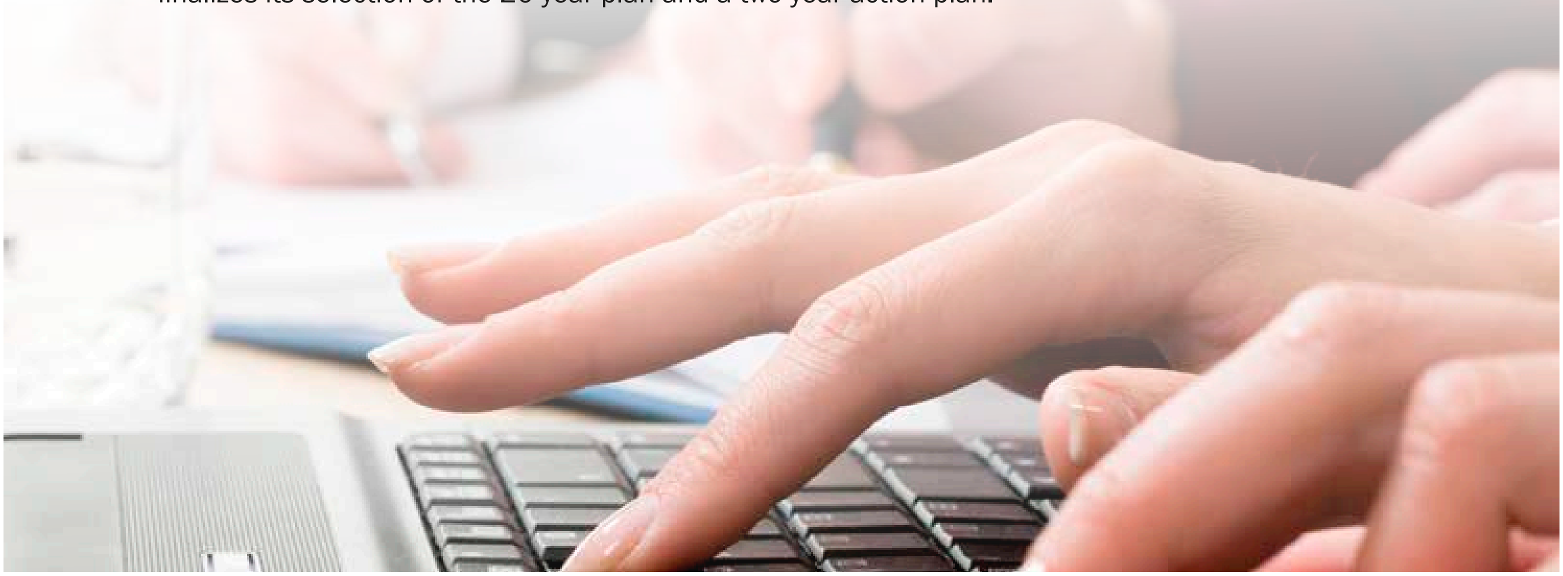
3. **Identification of Resource Need:** Identify future supply needs over the next 20 years by evaluating the ability of existing supply to meet future forecasted demand, regulatory requirements and uncertainty in supply and demand. To help identify these needs City Light performs a resource adequacy assessment and forecasts its needs to comply with I-937.

4. **Resource Choices:** Identify a wide range of commercially available utility-scale generating resources to meet future supply needs and forecast resource costs.

5. **Candidate Portfolio Development:** Because the utility may need new supply over time, City Light is likely to add resources at different times over the 20 year study horizon. Portfolios are developed that add individual resources over time as needed. Candidate portfolios are constructed on a least-cost basis to meet reliability and I-937 requirements.

6. **Portfolio Analysis:** Evaluates what resources City Light should use to meet customer demands based on how well those resources deliver reliability, environmental responsibility and cost efficiency while limiting risk.

7. **Selection of the IRP Plan:** After concluding the portfolio risk analysis, feedback from technical stakeholders, the public, the City Council's Energy and Environment Committee, and the Mayor is incorporated and allows City Light to select and present an Integrated Resource Plan. The Seattle City Council by Council Resolution finalizes its selection of the 20 year plan and a two year action plan.



EXISTING RESOURCE PORTFOLIO

City Light's existing resource portfolio has been cultivated to be among the most environmentally responsible and low cost in the nation. Energy efficiency programs have contributed to reducing City Light's customer energy use, and currently equate to the addition of several large power plants.

This portfolio includes many past investments in energy efficiency, City Light owned hydropower resources, existing hydropower and renewable contracts from regional partners, and wholesale market purchases.

Figure 1 is a map of City Light's existing resources. City Light's power resources are 90 percent hydropower, approximately 50 percent of which is supplied by five hydroelectric projects owned and operated by the utility. Most of the remaining hydropower is purchased from the Bonneville Power Administration (BPA), a nonprofit federal power marketing agency. Beyond generating hydropower, City Light has the responsibility to operate its hydroelectric projects for flood control, fish management, and reservoir recreation. Additionally, in coordination with Seattle Public Utilities, two projects are operated for municipal water supply.

City Light Generation

- Located on the Pend Oreille River in northeastern Washington, Boundary Dam is City Light's largest resource. While the Boundary Project produces the most power and has substantial operational flexibility, it has only modest storage capacity.
- The Skagit Project includes the Ross, Diablo, and Gorge dams in the North Cascades. The Skagit Project has generous storage capacity.
- Additional power is provided by small hydro projects including Newhalem, South Fork Tolt, and the Cedar Falls dam.

Location of City Light's owned and contracted resources

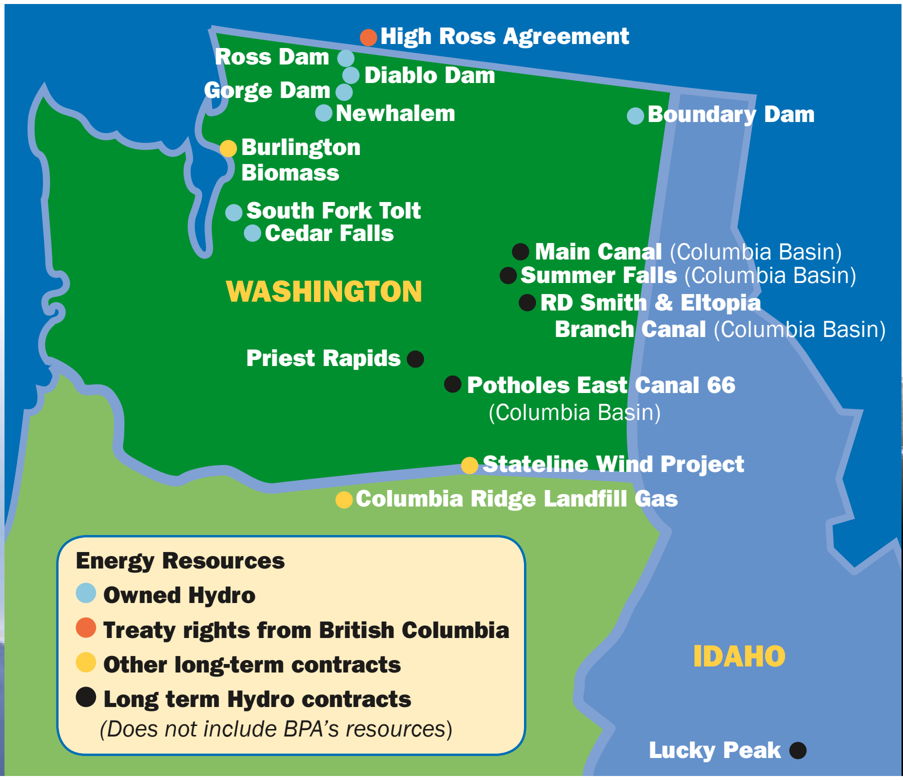


Figure 1. Map of City Light's Owned and Contracted Resources

Contracted Resources

City Light's largest power purchase comes from BPA and is approximately 40 percent of City Light's supply. BPA markets wholesale electrical power from 31 federal hydroelectric projects in the Northwest, one nonfederal nuclear plant and several small nonfederal power plants. As one of BPA's "preference customers," City Light is entitled to a substantial amount of power from these sources. The current contract with BPA runs through September 2028. In this IRP, City Light analyzed the competitiveness of the BPA contract relative to other resource options.

The remaining contracts include:

- Under an 80-year agreement with the Canadian province of British Columbia, City Light abandoned plans to raise the height of Ross Dam in exchange for power purchases from British Columbia Hydro.
- City Light has contracted with Lucky Peak, a hydro project located near Boise, Idaho for over 30 years.
- City Light purchases power from the Priest Rapids Project under a 2002 agreement with Grant County Public Utility District.
- The Columbia Basin contracts include power from five Columbia River Basin hydroelectric projects. The projects are part of three irrigation districts, so electric generation is mainly in the summer months.
- Under an exchange agreement with the Northern California Power Agency (NCPA), City Light delivers energy to NCPA in the summer. In exchange, NCPA delivers energy to City Light in the winter.
- The Stateline Wind Project, on the Washington and Oregon border outside Walla Walla, Washington, provides wind-generated electrical energy and associated environmental attributes. This project meets I-937 requirements.
- City Light receives small amounts of biomass and landfill gas through Burlington Biomass, Columbia Ridge Landfill Gas Project, and King County West Point Wastewater Treatment Plant. These small projects qualify under I-937 as renewable energy.
- Seattle City Light also purchases power in the wholesale market to supplement its owned generation and contracted resources.

OWNED AND PURCHASED POWER RESOURCES FOR 2016				
	Nameplate Capability (MW)	Energy Available Under Average Conditions (MWh)	Year FERC License Expires	Year Contract Expires
OWNED RESOURCES				
BOUNDARY PROJECT	1,119	3,423,010	2055	N/A
SKAGIT PROJECT				
Gorge	207	985,370	2025	N/A
Diablo	182	818,494	2025	N/A
Ross	450	828,565	2025	N/A
SMALL HYDRO PROJECTS	49	135,264	Varies	N/A
CONTRACTED RESOURCES				
BPA Block	N/A	2,349,845	N/A	2028
BPA Slice	N/A	2,682,195	N/A	2028
Priest Rapids	6	23,470	2052	2052
Columbia Basin	64	240,039	2030/2032	2022/2027
High Ross	N/A	310,271	N/A	2066
Lucky Peak	101	293,359	2030	2038
Stateline	175	371,162	N/A	2021
Small Renewables	20	205,772	N/A	Various

Figure 2. City Light's 2016 Sources of Power

Market Resources

City Light makes market sales and purchases in the wholesale electric power market. Market participation is particularly important to City Light because 90 percent of City Light's current resource portfolio is hydroelectric, which is highly variable, based on water availability and operating restrictions. Water conditions vary by season and year. Under average conditions, City Light has surplus energy throughout most of the year that can be sold in the electric market to offset costs. When there is not enough hydropower to meet demand, City Light makes market purchases for those instances.

Dry months or years can reduce water flows and cause the need to buy power, raising costs. At the same time, wet seasons or years may result in surplus water flow. City Light must also contend with a mismatch between the demand for hydropower and hydro's production peak. Spring snow melt drives hydropower production to peak in May. Yet Seattle's electricity demand peaks in the winter. Keeping sufficient power generation to meet winter demand can mean excess generation the rest of the year. In addition to this seasonal variation, precipitation may vary significantly from year to year, worsening the imbalance.

Figure 3 below shows how annual and monthly hydro generation for City Light's primary supply resources can vary significantly from year to year. Each line represents a single year between 1929 and 2008. The generation has been adjusted for today's operating constraints and shows the range of what could be generated with City Light's three largest resources: the Skagit Project, Boundary Dam and BPA Slice all combined.

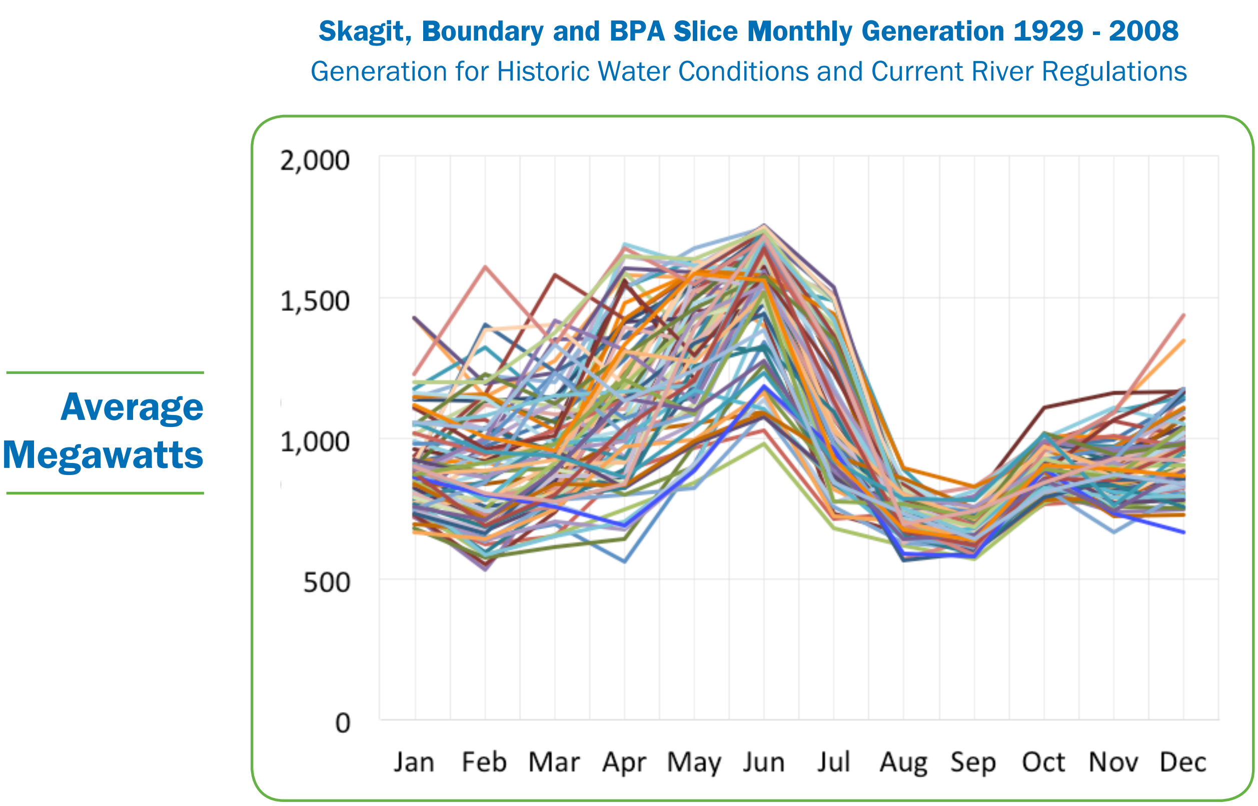


Figure 3. Seasonal and Annual Variability in City Light's Hydro Resources

Energy Efficiency

Energy efficiency was introduced into City Light's resource mix more than 30 years ago and has remained the utility's first-choice in meeting load growth. Energy efficiency programs encourage customers to use power more efficiently and allow the utility to defer the acquisition of expensive new resources, including those that negatively affect the environment. Energy efficiency is low cost and has low environmental impacts, including no greenhouse gas emissions. Integral to developing the IRP, energy efficiency programs will help City Light maintain its status as a greenhouse gas neutral utility, support the City's environmental and climate change policy goals, and meet the requirements of I-937.

For example, the average City Light residential customer today uses 8,000 kilowatt hours of electricity a year compared to 10,300 kilowatt hours per year in 2000.

Energy efficiency programs are designed for all customer classes and address specific energy end-uses such as lighting, water heaters, laundry appliances, HVAC, motors, and manufacturing equipment. These programs provide energy efficiency information and financial incentives that encourage customers, for example, to insulate their homes, install energy efficient appliances, or install efficient lighting in commercial and industrial establishments.

Seattle's Energy Code: Saves Money, Saves Electricity, Saves the Environment

The Seattle Energy Code has been consistently ranked among the most progressive codes in North America since its inception 36 years ago. Code concepts developed in Seattle are routinely incorporated into the Washington State Energy Code and increasingly into national standards. This code is one of the major reasons that City Light can plan on using its existing resources instead of adding new and costly electricity generation from other resources.

The Seattle Energy Code requires energy efficiency levels at least 20% better than the current national standard. This drives down energy costs by making high-performance buildings the local "business as usual".

New code provisions are vigorously debated and refined through a series of public meetings with local stakeholders to address cost-effectiveness and environmental stewardship.

Highlights of the 2015 Seattle Energy Code include:

- *High-performance heating systems for commercial buildings*
- *Prohibition of simultaneous heating and cooling in any one space*
- *Daylight-responsive lighting controls in all daylight zones*
- *Dimming of lighting in unoccupied stairwells and parking garages*
- *Controlled receptacles in offices, classrooms and other spaces*
- *Significant lighting power reductions, responding to the proliferation of LED lighting*
- *Small photovoltaic array and larger "solar-ready" roof area required on commercial projects*
- *Sub-metering and user dashboards required for medium and large-sized buildings*
- *Energy upgrades in substantial renovation projects nearly to the efficiency levels required in new construction*

LOAD FORECAST

The most critical step in future power planning is the determination of future power supply needs. For the purpose of the IRP, this involves an assessment of how much total energy City Light customers are expected to consume over a period of time (load), what is the maximum amount they are expected to consume instantaneously (peak demand) and how rapidly they are expected to change their instantaneous needs (flexibility or ramp).

The first step in assessing the need for additional resources is forecasting Seattle's future electricity demand and establishing a target for the desired level of resource adequacy. The Integrated Resource Plan's long-range forecast calls for continued load growth trends in electricity demand for the service area. This growth is primarily driven by projected economic and population growth for the region. Relative to previous IRP's, load growth is forecast to grow at a slower pace, due in part to changing regulations, building codes, and customer behaviors. This is similar to regional and national trends.

It should be noted that the IRP treats energy efficiency as a supply resource and evaluates energy efficiency in the same way as it evaluates other supply resources. As such, the graph below in Figure 4 shows the load forecast with historic energy efficiency, but without the impacts of new energy efficiency.

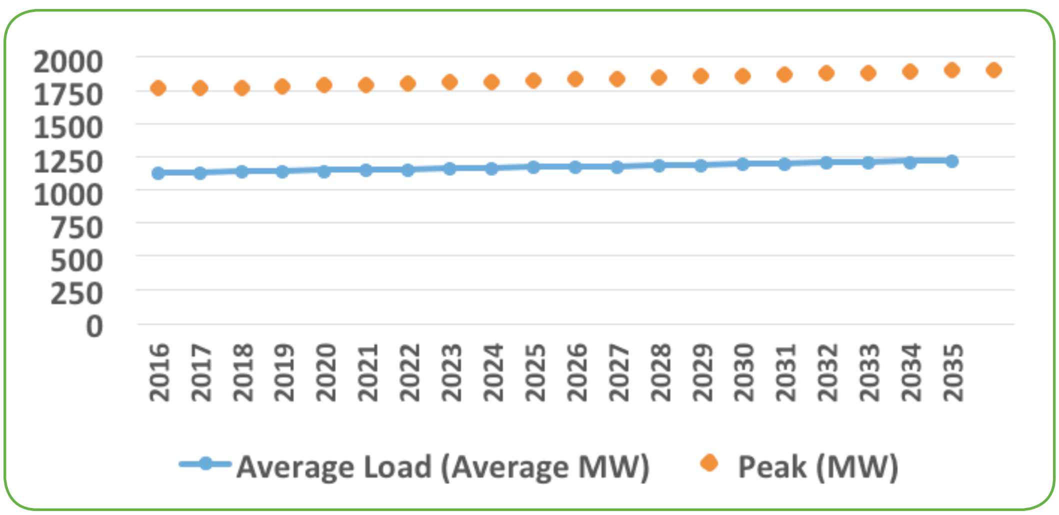
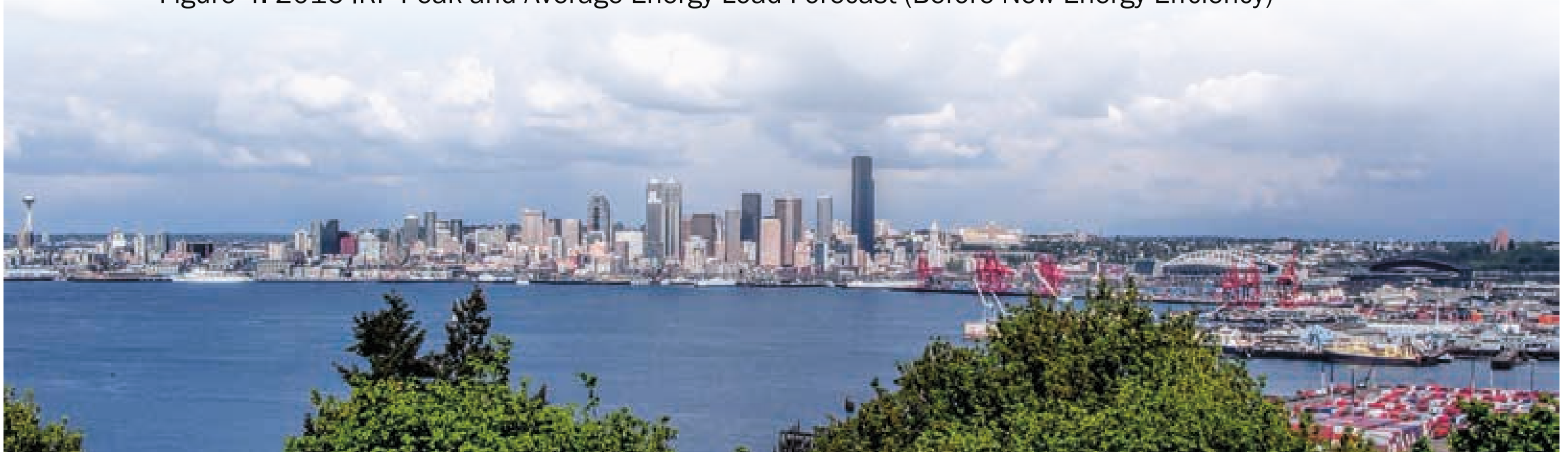


Figure 4. 2016 IRP Peak and Average Energy Load Forecast (Before New Energy Effciency)



IDENTIFICATION OF RESOURCE NEEDS

As part of the IRP process, City Light identifies future supply needs for the next 20 years based on the ability of existing supply to meet future forecasted demand, regulatory requirements, and uncertainty in supply and demand. To help identify these needs City Light performs a resource adequacy assessment and forecasts how much eligible renewable generation will be needed to comply with I-937.

Resource Adequacy

Combining information about forecasted demand and existing resources, City Light determines whether it needs additional power supply resources for reliability. This is determined through a resource adequacy study. As a utility that relies on hydro generation, City Light established that it must have a high confidence measure of meeting resource needs to cover all circumstances which might develop – especially in high demand hours during the winter season. The 2016 IRP high confidence level is based on a 90% probability of being able to meet winter deficit conditions. It considers historical load variability, hydro generation variability, and the collective plans for maintenance and turbine overhauls, before appropriately adjusting its resource adequacy studies to account for circumstances that push the limit of City Light's capacity to meet every energy need.

City Light has maintained a high level of resource reliability, including the ability to serve demand even when hydro generation capability is low by using its option to purchase from the wholesale electricity market. City Light's analysis has determined reliance on 200 megawatts of short-term market purchases is appropriate. In an average water year (with normal temperatures) City Light has substantial surplus power available to sell in the wholesale power market, even during the winter months.

In addition to serving system load on an annual average basis, City Light must also have sufficient resources on a monthly, weekly and hourly basis. The greatest threat to City Light's resource reliability is the combination of low water and high customer demand for power. Low generation capability is usually due to drought conditions in the Pacific Northwest. High customer demand is usually due to extremely low temperatures in the winter. City Light's annual peak demand most often occurs in December or January. Including the decision to test the competitiveness of a future BPA contract and 200 megawatts of short-term market purchases, the 2016 IRP forecasts the utility will not need resources until 2028.

Figure 5 shows the load resource balance under expected conditions. The resource adequacy analysis identifies the amount of additional energy and capacity required to serve load. While this figure shows annual average need, City Light's flexibility with its hydro resources allow it to reshape generation to follow changes in load throughout the day. Additionally, the decision to allow a modest 200 megawatts of market purchases ensures City Light can meet peak winter demands under all probable cases.

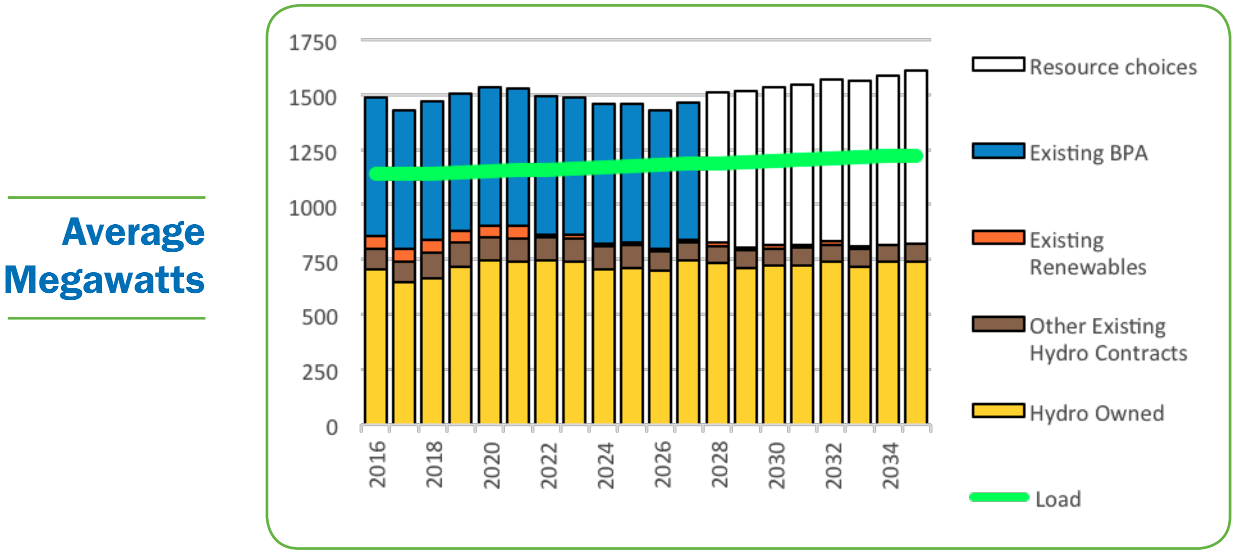


Figure 5. Expected Load Compared to Existing Resource Generation from 2016-2035

City Light will be demonstrating two projects to gain a better understanding of how these potential resources may play a role in meeting the needs of City Light's distribution network.

- In partnership with BPA, City Light is conducting a targeted demand response demonstration project using residential hot water heaters. This will help City Light and the region better understand demand response's potential for both peak shaving and renewables integration. Starting in 2017, approximately 100 customers will install a communications device capable of modifying energy consumption of their hot water heater. The communications device will receive a radio signal during demand response events and send data back via the customer's Wi-Fi network. City Light will target the customer recruitment in a tight geographic areas where there is a constraint on its distribution system.

- Seattle City Light will create a microgrid at a designated emergency shelter, powered by solar energy and a battery storage system. During an emergency, this stand-alone power grid will meet critical loads and keep the shelter operating.

I-937 Compliance

Under I-937, City Light must acquire all cost-effective energy efficiency and also add higher levels of renewable resources to its portfolio.

In 2013 City Light assessed the potential for energy efficiency to set a 2014-2015 energy efficiency target at 207,437 megawatt hours. Actual achievement was exceeded by over 60%. For the 2016-2017 biennium, City Light updated the target to 224,431 megawatt hours. This reflects a higher potential savings over the previous biennium.

For renewable resources, City Light has eligible renewable generation targets of 9% of retail load by 2016 and 15% of retail load by 2020. City Light expects to easily reach its 9% retail load goal with its Stateline Wind, biomass and landfill gas contracts, hydro efficiency upgrades at the Boundary and Gorge dams, and its multiple renewable energy credit contracts. To supplement this generation, City Light has also secured enough renewable energy and credits to ensure it will reach the 15% requirement by 2020. City Light's analysis forecasts it will be able to meet its renewable energy obligations for I-937 compliance through 2023.

RESOURCE CHOICES

City Light makes its resource decisions based on its citizens' priorities: low cost and low risk electricity generation, environmental stewardship, and reliability. City Light's customers, stakeholders, City Council and Mayor all express interest in reliance on energy efficiency and renewable resources in the utility's resource mix.

To meet the area's power supply needs as well as meet City Light goals (reliability, low-cost, low risk, and environmentally responsible), it's critical to understand the differences among the available resources in today's market. In many cases non-renewable resources are more reliable and cost-effective than renewable resources, but are less environmentally sensible.

Renewable Generation: Renewable resources satisfy the need for power and avoid the consumption of fossil fuels. In addition, renewable generation tends to avoid the emission of air and water pollution that endangers the environment and human health. The drawback of most renewable generation is the availability of fuel (water, sun, wind) as a result of weather fluctuations, making these resources less reliable. However, hydroelectric generation with storage provides reliability and flexibility in meeting resource needs.

Approximately 90% of City Light's power is generated by hydropower, including its hydroelectric facilities here in Washington State. However, for meeting I-937, freshwater electricity generation is excluded unless it results from qualifying hydro generation efficiency improvements.

Non-Renewable Generation: Non-renewable resources generally satisfy the need for power through the consumption of fossil fuels such as coal, oil and natural gas. City Light is required by RCW 19.280.030 to evaluate non-renewable generation as well as renewable generation. Most fossil fuel resources have the reliability advantage of being readily available to serve demand regardless of the weather. The most effective fossil fuel resource that can follow load is the natural gas combustion turbine. Natural gas combustion turbines can also provide necessary integration services to intermittent renewable generation, improving reliability of electric service.

City Light benefits from receiving clean hydro power from BPA power and transmission contracts; however, costs to produce and deliver this electricity have been rising and could alter the relative economics of future contracts and resource alternatives.

Market: Market purchases satisfy the need for power on a short-term basis to successfully meet reliability. City Light has the option of purchasing electricity from the wholesale western electricity market as needed.

Energy Efficiency: Energy efficiency is using less energy to provide the same service by using a different or upgraded technology. Figures 6 and 7 show the residential and commercial uses of energy where City Light expects to achieve the greatest savings through its energy efficiency programs. City policy and I-937 require energy efficiency choices. Certain energy efficiency measures can improve the load shape because their greatest effect is in the winter when electricity use tends to be greatest. Energy efficiency is the mainstay in both rounds of portfolio analyses, which examined base and high levels of achievement.

City Light benefits from receiving clean hydro power and being able to deliver electricity to demand from BPA power and transmission contracts; however, costs to produce and deliver this electricity have been rising and could alter the relative economics of future contracts and resource alternatives.

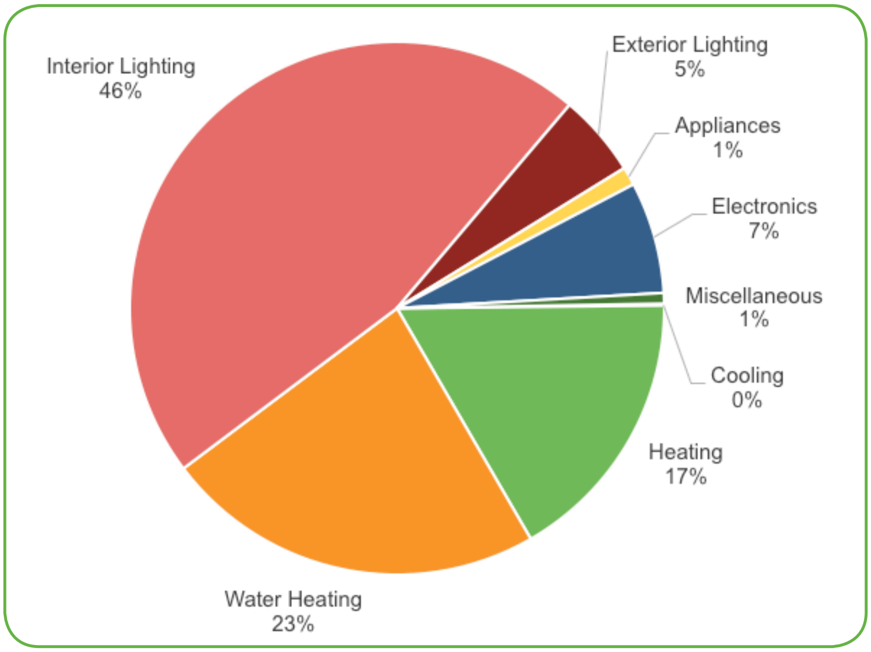


Figure 6. Achievable Residential Potential by End-use

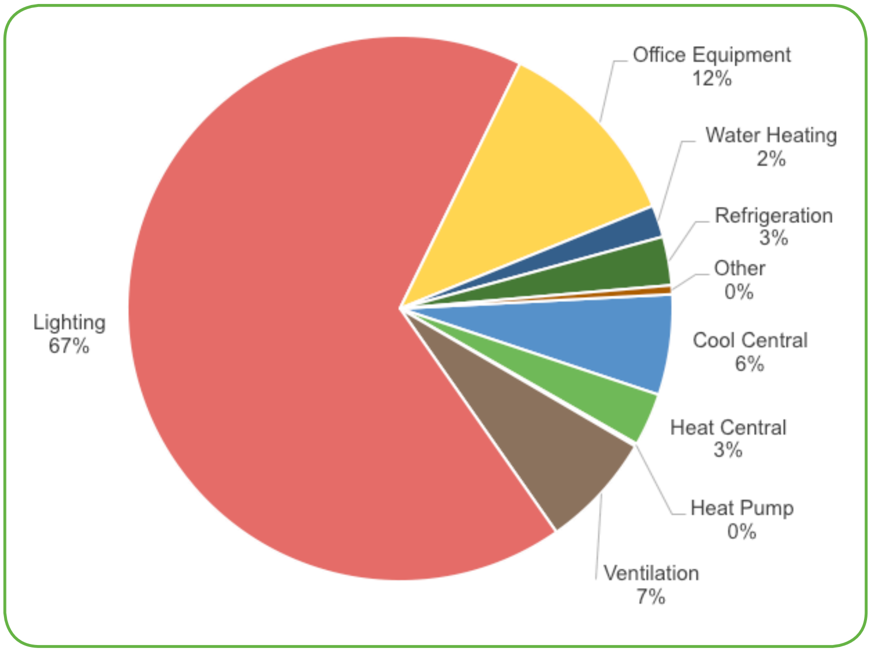


Figure 7. Achievable Commercial Potential by End-use

Resources Choices for the 2016 IRP

For the 2016 IRP the resources identified in Figure 8 are commercially available and proven technologies with reasonable costs and low environmental impact. This figure shows a relative comparison of each technology on an equivalent basis in dollars per megawatt hour. It represents a forecast of the annual cost per unit of energy produced for twenty years that City Light may expect to pay. Also, it includes recovery of the capital investment, operations, maintenance, emissions costs, shaping, and delivery of that energy to City Light. Many of these resource costs have been rapidly changing with technology advancements and adoption. City Light will continue to monitor developments in resource technologies for cost and commercial availability.

Seattle City Light 2016 New Resource Cost Projections

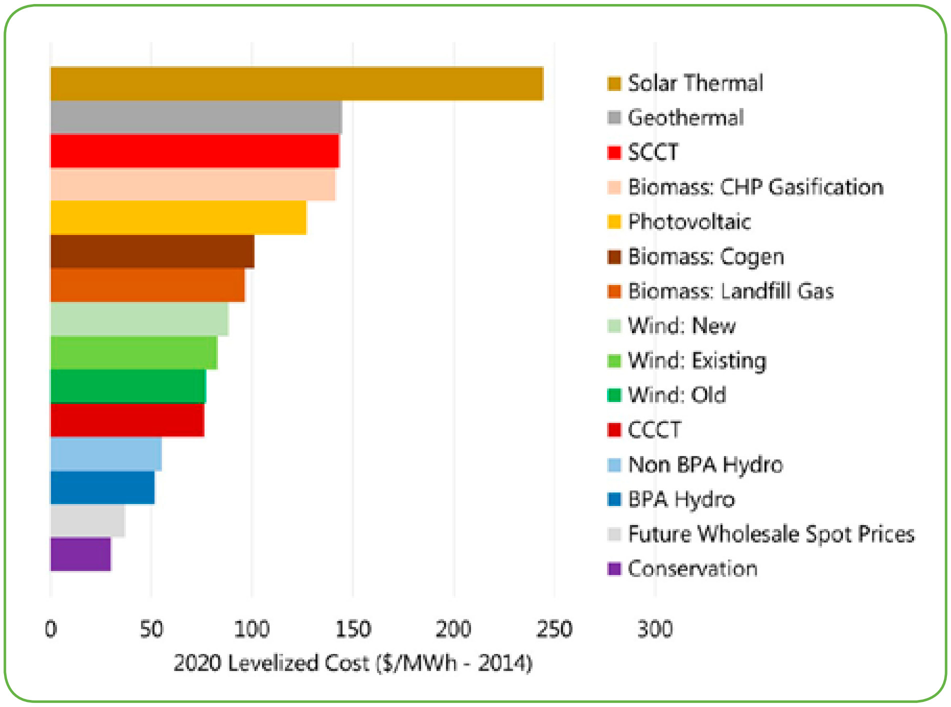


Figure 8. 2016 IRP New Resource Choices and Cost Projections – Projections From Early 2015

CANDIDATE PORTFOLIO CONSTRUCTION

The utility may need new supply over time, making a single resource option unrealistic. City Light may prefer to add resources as needed and when economically beneficial over the next 20 years or to meet environmental stewardship goals. To reflect the ability to add resources incrementally over time, candidate portfolios are developed that add individual resources over time. After portfolios are created, the utility performs analyses of each future candidate portfolio to measure the cost and financial risk.

In the case of this IRP, nine portfolios were constructed using a portfolio optimization tool to meet multiple objectives. Each portfolio was constructed to meet reliability and renewable resource levels to satisfy I-937. Additionally the portfolios reflect City of Seattle policies while testing the required broad range of resources required by the state rules for Integrated Resource Planning.

Figure 9 provides a summary description of each of the nine future IRP portfolios.

RESOURCE OPTIONS	IRP Candidate Portfolios								
	#1	#2	#3	#4	#5	#6	#7	#8	#9
ENERGY EFFICIENCY									
Base	✓	✓		✓	✓	✓	✓	✓	✓
High Achievement			✓						
RENEWABLES									
RECs	✓	✓	✓	✓				✓	
Wind		✓	✓		✓		✓	✓	✓
Other renewables				✓	✓	✓	✓		✓
MARKET PURCHASE FLEXIBILITY									
Yes	✓	✓	✓	✓				✓	
No					✓	✓	✓		✓
BPA									
Existing contract as is								✓	✓
New BPA contract	✓	✓	✓	✓	✓	✓	✓		
NATURAL GAS (INCLUDES EMISSIONS COSTS)									
Yes	✓				✓	✓			✓
No		✓	✓	✓			✓	✓	

Figure 9. Comparison of Mix of Resources in IRP Resource Portfolio Options

PORTFOLIO ANALYSIS

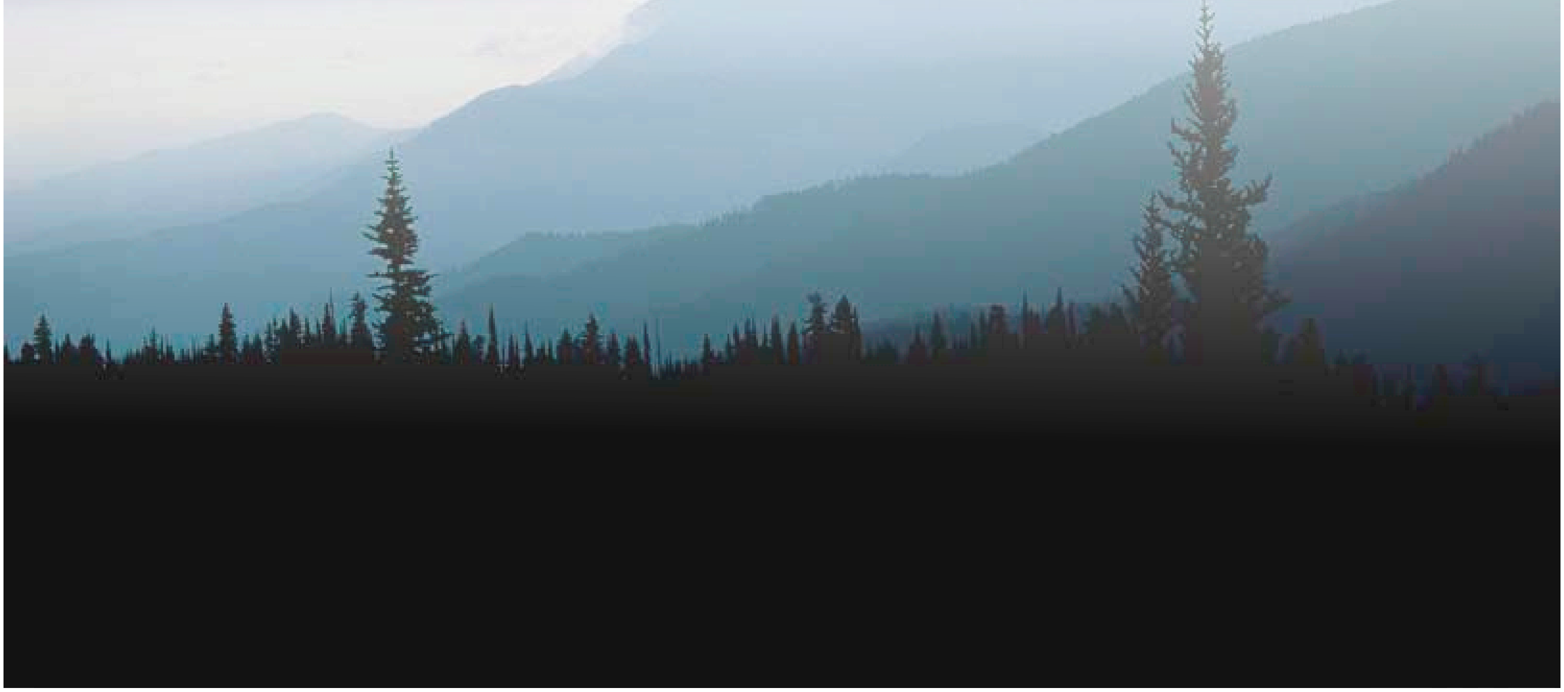
The IRP portfolio analysis evaluates candidate portfolios that City Light should consider to meet customer demands based on how well those portfolios deliver reliability, environmental responsibility, and cost efficiency while limiting risk. First there is an initial evaluation to identify the leading contenders, then City Light conducts a further evaluation to help identify a preferred portfolio.

Initial Evaluation

The nine IRP portfolios are tested for cost and financial risk and calculated under expected conditions as well as conditions that deviate from the expected. The particular deviations from the expected that are tested include levels of demand, natural gas fuel prices, carbon dioxide costs, and water conditions. In total City Light examined ten scenarios, including the expected case. These scenarios help identify impacts and test the resilience of each portfolio.

- Cost is measured over the 20-year study period on a net present value basis. The cost includes generating and delivering power, offsetting emissions and pollutants to ensure City Light continues to remain greenhouse gas neutral. It also subtracts net sales of surplus energy in the market.
- Financial risk is measured based on annual cost volatility. The utility has identified a goal to reduce annual volatility to provide stable customer rates.

City Light seeks a final portfolio with a resource mix that reduces cost and risk. Figure 10 shows the relative performance of the nine portfolio options based on cost and risk. Portfolios with lower results for cost and risk perform better than portfolios with higher results. The results are based on how well the future portfolios performed in the ten scenarios. For example, if a single portfolio option performed the best in all ten scenarios, based on the cost measure, it would have a ranking of 10 for cost risk. Similarly if it performed the worst, it would have a ranking of 90 for cost risk.



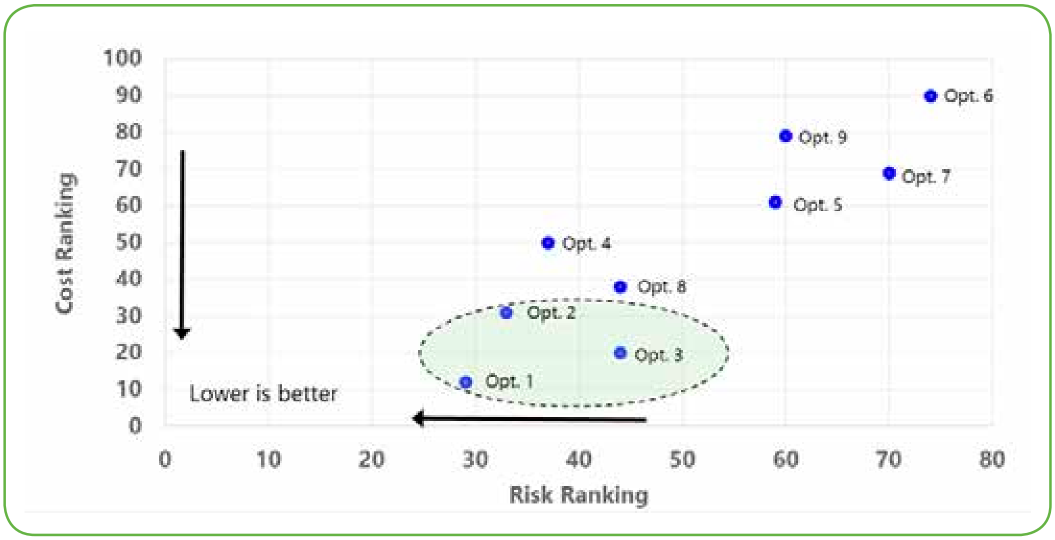


Figure 10. IRP Future Portfolio Options Cost and Risk Ranking

Key Findings

- All three top portfolios include a new BPA Hydro contract with a modest reduction in the energy purchased compared to the existing BPA contract.
- Each has similar amounts of reliable and cost-effective market purchase flexibility.
- RECs are a lower cost way to meet I-937 renewable needs before 2028 because of City Light's energy surpluses.

Further Evaluation and Risk Assessment

The 2016 IRP candidate portfolios were compared based on costs and risks and the top three performing portfolios were selected for further evaluation. The top three portfolios were subjected to probabilistic risk analyses that varied key drivers of cost and risk for City Light: the level of system load, the price of natural gas, and hydro conditions.

Hydro Conditions
City Light's strong reliance on hydropower makes hydro variability a significant concern to the utility. Hydro conditions on different river systems can be very different within the same year and City Light depends on multiple river systems. For the risk analysis, City Light models the levels of City Light's total hydroelectric production, maintaining the inter-relationships between the Skagit, Boundary, and Columbia River systems.

Electricity Demand
City Light is a winter peaking utility and pays particular attention to electricity demand during the coldest winter months. Seattle enjoys a relatively moderate marine climate, yet its location on the 47th parallel means that winter storms from the arctic or the Midwest can bring cold temperatures for periods typically lasting from several days to more than a week. The analysis of variability in demand is critical for resource planning.

Natural Gas Prices
Indirectly, natural gas prices have already had a large impact on City Light finances. With natural gas-fired generation as the price-setter for many hours in western power markets, power market prices and City Light's wholesale revenues tend to move up and down with natural gas prices. In 2008, natural gas prices reached over $12 per million British thermal units (MMBtu). Lower demand for electricity and improved technology for recovery of shale gas have combined to drive prices down to the $2 to $3 per MMBtu range in the near-term. In the 2016 IRP, natural gas prices are not forecast to reach the 2008 highs within the 20-year planning period.

Probabilistic analysis allows City Light to examine over 2,800 outcomes for each of the top three portfolios. The results provide for further examination of the relative expected cost of the portfolios and a measure of financial risk based on the average of the top five percent worst outcomes (highest portfolio costs). This allows portfolios to be evaluated on whether they reduce these bad outcomes.

The results in order of lowest cost and risk are:

1. Portfolio Alternative #1: Base Energy Efficiency, Hydro and Gas with Market Purchase Flexibility
2. Portfolio Alternative #3: High achievement of Energy Efficiency, Hydro and Wind with Market Purchase Flexibility
3. Portfolio Alternative #2: Base Energy Efficiency, Hydro and Wind with Market Purchase Flexibility

The measurements of cost and risk in this analysis are very close since the portfolios are very similar. This is not surprising since the resource mixes are very similar in the early years with small adjustments to the resource mix in the later years relative to the size of the whole portfolio.

SELECTION OF THE 2016 INTEGRATED RESOURCE PLAN STRATEGY

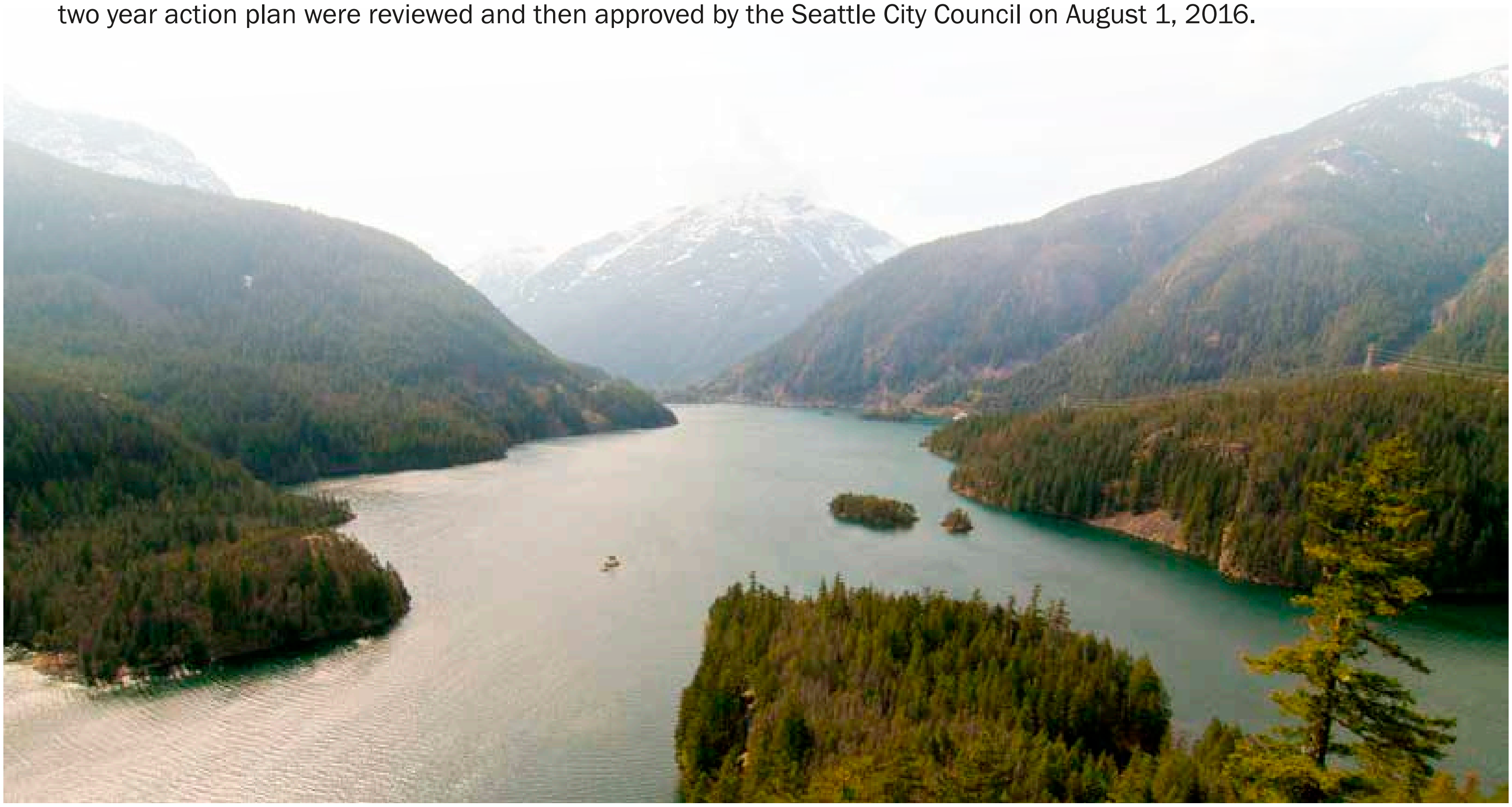
The 2016 IRP analysis finds that City Light is well positioned to meet its needs into the future with continued achievement of programmatic energy efficiency. The “Portfolio Alternative #1: Base Energy Efficiency, Hydro and Gas” portfolio performed marginally better from a cost and risk perspective. However, this portfolio is not preferred because of the inclusion of a long-term natural gas resource contract and does not include additional renewable resources. City Council Resolution 30144 establishes a preference for cost-effective energy efficiency and renewable resources, and the basis for City Light to offset all of its greenhouse gas emissions from fossil fuels. Resolution 31667 includes a provision that opposes the use of fossil fuels.

The “Portfolio Alternative #2: Base Energy Efficiency, Hydro and Wind” portfolio and the “Portfolio Alternative #3: High achievement of Energy Efficiency, Hydro and Wind” portfolio both meet the objectives of the resolutions. “Portfolio Alternative #3: High achievement of Energy Efficiency, Hydro and Wind” performs better from a cost and risk perspective.

Based on the recommendation from stakeholders, its consistency with Seattle City Council policies, and its reasonable cost and risk, City Light identified the “High achievement of Energy Efficiency, Hydro, and Wind” portfolio as the preferred portfolio for planning purposes.

With resource needs being identified far into the future, City Light will continue its IRP process every two years, reevaluating its needs and options as future conditions may change. What will not change is City Light’s commitment to environmental stewardship and the new action plan reflects this commitment.

The following table shows the cumulative portfolio additions from the 2016 IRP preferred portfolio. The portfolio and two year action plan were reviewed and then approved by the Seattle City Council on August 1, 2016.



Recommended Cumulative Portfolio Additions from 2016 IRP
(Average Megawatts)

Cumulative Resource Additions	High achievement of Energy efficiency	New BPA Hydro	Wind	RECs (annual additions)
2016	14	0	0	0
2017	29	0	0	0
2018	46	0	0	0
2019	61	0	0	0
2020	78	0	0	0
2021	94	0	0	0
2022	108	0	0	0
2023	121	0	0	0
2024	133	0	0	2
2025	143	0	0	12
2026	152	0	0	11
2027	160	0	0	56
2028	167	492	56	0
2029	175	500	60	0
2030	182	500	60	8
2031	188	500	60	14
2032	193	500	60	15
2033	197	500	60	15
2034	201	500	66	27
2035	205	500	83	10

How does City Light believe climate change may change its future course?

City Light's 2016 Integrated Resource Plan includes early reviews of climate change impacts on City Light's water resources used for electricity generation and electricity demand. The projected climate change impacts available for study appear to fall within the range of what City Light already has encountered in streamflow fluctuations, dramatic shifts in market conditions, emergency conditions, or other circumstances faced in the past. City Light will continue to evaluate climate change impacts as new research emerges to ensure City Light is ready.

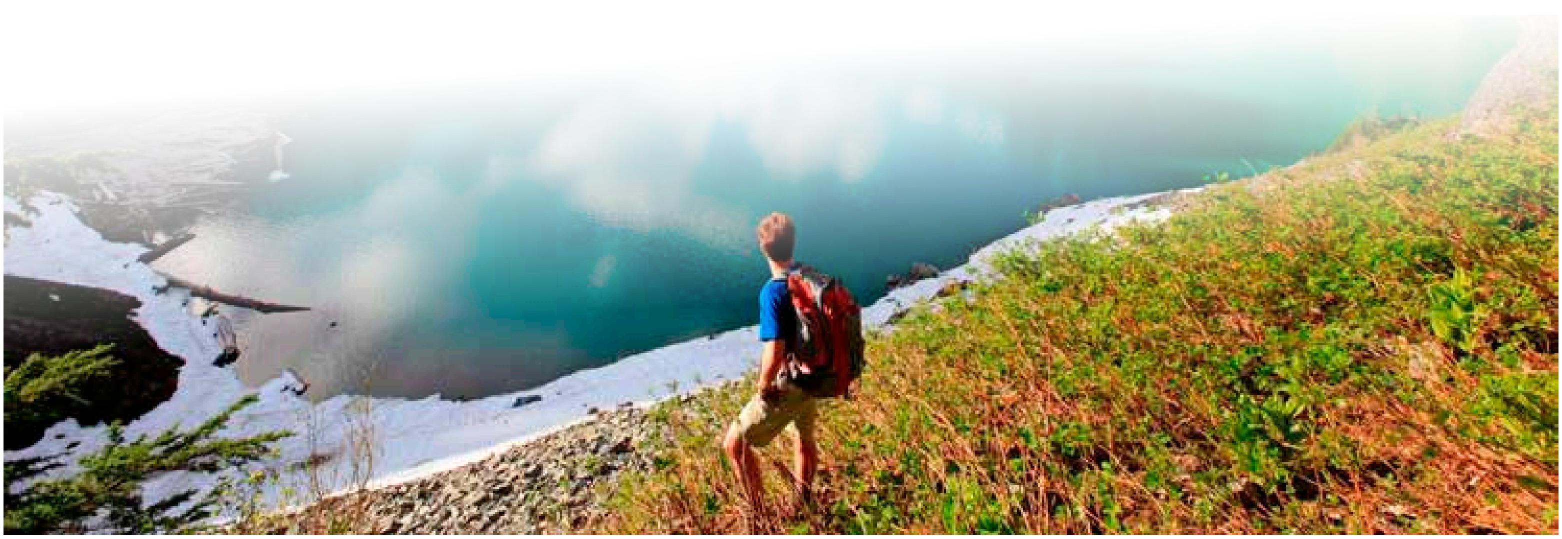
TWO-YEAR ACTION PLAN

To meet power supply needs, the City Light 2016 IRP recommends a long-term energy efficiency and power resource strategy along with a short-term plan. The recommended 2016 IRP Action Plan outlines the following steps:

- Continue high achievement of cost-effective energy efficiency, ever on the look-out for new technologies, energy efficiency programs, and market strategies.
- Continue to assess modeling inputs, assumptions and methodologies related to all work central to the IRP including load forecasts and how customer energy use is changing.
- Continue to engage BPA to limit rising contract costs and work with other regional partners to ensure the upcoming contract remains affordable into the future.
- Serve the retail load with City Light's existing resources portfolio, short-term market purchases, and other transactions to reshape seasonal energy demands as needed.
- Monitor new resource options including their costs and ability to meet City Light's future resource needs.
- Maintain an adept and active power marketing operation.
- Participate in power and transmission regional forums to ensure access to efficient wholesale markets and reliable transmission capacity for serving City Light customers.
- Continue environmental leadership including evaluation of factors that impact hydro generation, electricity demand, and fish populations as new information on the subject is available.

Are there wholesale electricity market changes emerging that City Light will need to consider for marketing its surpluses?

New market developments such as the Western Energy Imbalance Market may be an opportunity for City Light to find additional economic value for its customers. Market changes have been occurring because utilities are facing increasing costs to integrate large amounts of intermittent renewable generation. For the utilities participating, studies have shown reliability and economic benefits when "within the hour" changes in generation and load are added together and managed systematically across multiple participating utilities.



CONCLUSION: KEEPING THE LIGHTS ON

Seattle City Light is here to keep the lights on and more importantly, provide its customers with reliable, safe and affordable clean energy.

This process – the 2016 Integrated Resource Plan – has been a two year process to stay ahead of anticipated changes in supply and demand. The core findings include:

- Seattle City Light expects continued modest load growth despite the building surge visible in the utility's service area.
- Seattle City Light should continue its pursuit of cost-effective new energy efficiency.
- Seattle City Light can expect to meet its power supply needs with cost-effective new energy efficiency programs.
- Seattle City Light should continue to add renewable energy credits and renewable resources as necessary to meet renewable portfolio standard requirements mandated by I-937.
- Seattle City Light should continue to seek existing and new opportunities to maximize economic benefits from its clean and reliable hydro resources.
- Seattle City Light has been a leader in environmental stewardship for more than 30 years, making it ready – even a model – for responding to the increased impacts and changes which may be caused by climate change.

If you are interested in being part of an ongoing conversation with Seattle City Light on the direction, resources and choices to be made, please get in touch and you'll be given options for being involved. City Light will be exploring:

- Renewable resource improvements
- New and existing power supply technology
- Emerging policies and regulations from all levels of governments
- Research underway on climate
- How to get greater public involvement especially from diverse and underrepresented populations unfamiliar with the utility considerations

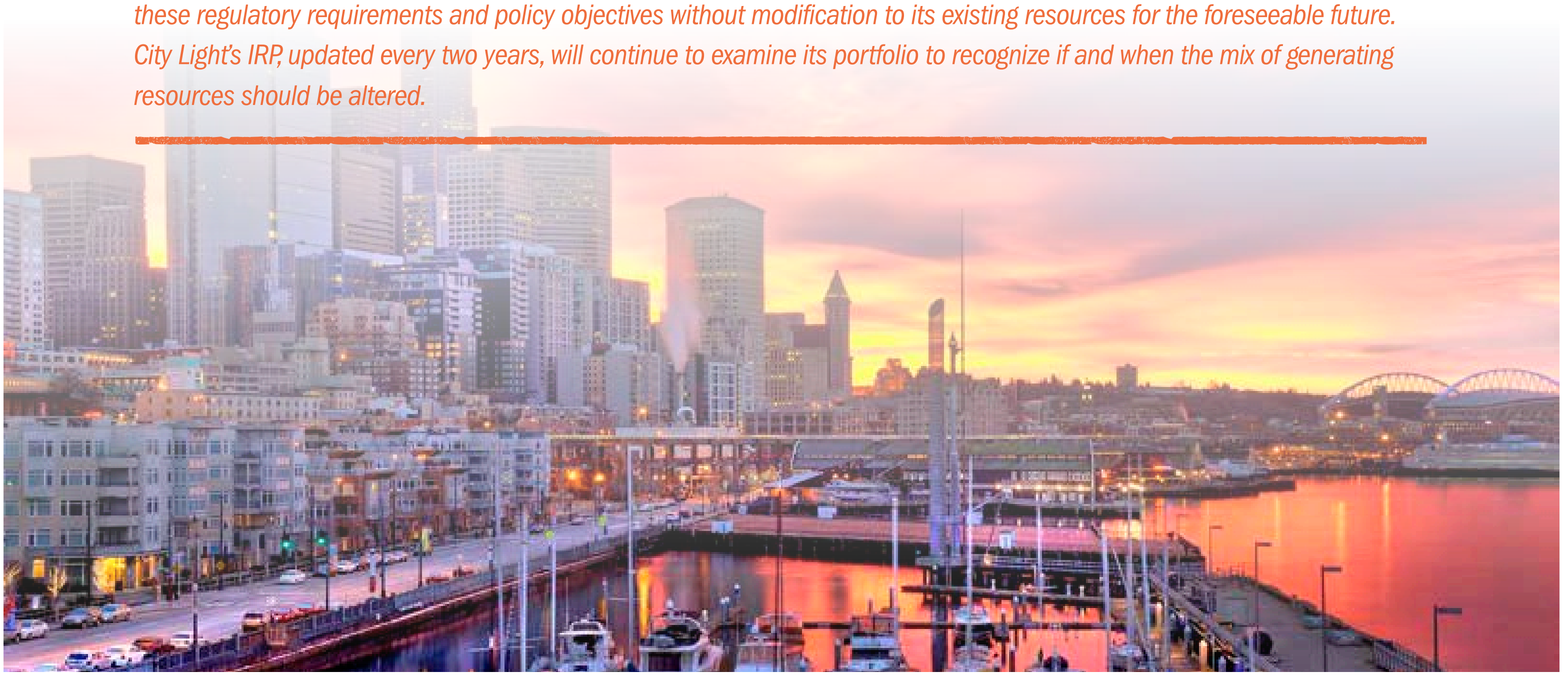
All present an exciting and ever-changing backdrop for the Integrated Resource Plan.
If you have comments, questions, ideas or want to be involved, please go to http://www.seattle.gov/light/irp.

Future IRPs

Many factors could influence the direction City Light takes in meeting power supply demands and determining customer costs. These include impacts to the cost of purchasing and selling power in wholesale energy markets, as well as changes in cost to develop and supply new generation to City Light's customers. These are the costs that need to be recovered through what the utility charges in its rates.

Federal and state financial incentives and market opportunities have offset some of the costs. Additionally, new renewable technology has become more efficient and cost competitive in recent years.

City Light's existing mix of energy efficiency, hydro and renewable generation has positioned City Light to be able to meet these regulatory requirements and policy objectives without modification to its existing resources for the foreseeable future. City Light's IRP, updated every two years, will continue to examine its portfolio to recognize if and when the mix of generating resources should be altered.



LOAD FORECAST FOR INTEGRATED RESOURCE PLAN

As a general matter load forecasts are required to conduct an Integrated Resource Plan (IRP). First, to establish a baseline of regional resources, load, and transmission for the planning period. Second, to establish the resource needs of the utility for portfolio analysis. As a practical matter, long-term load forecasts must be fixed at the beginning of the IRP analysis.

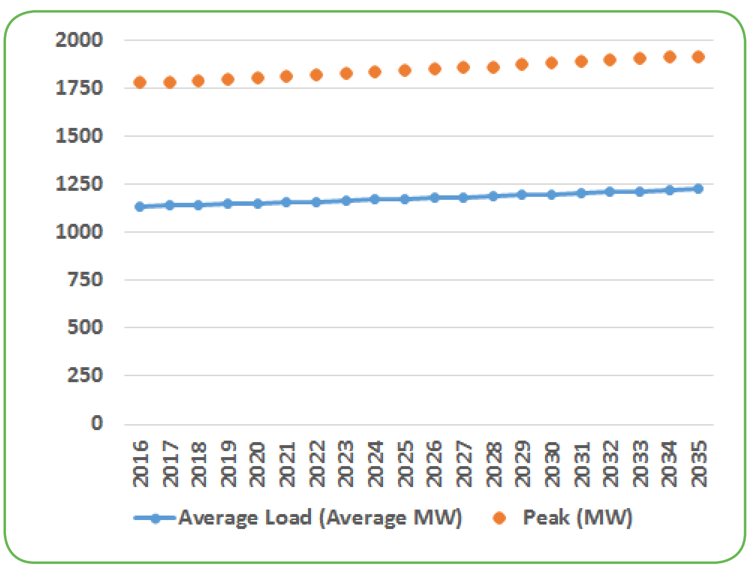
At City Light, a long-range load forecast of system load and system peak is produced annually. Load forecasts are used throughout the utility for a variety of planning purposes, such as the operating plan, the transmission and distribution capacity plan, the revenue forecast, and assessments of energy efficiency potential. It is also distributed to many external entities with planning functions, such as the Bonneville Power Administration, the Western Electricity Coordinating Council, and the Pacific Northwest Utilities Conference Committee. A forecast of load is needed for calculating the amount of renewable resources and cost-effective energy efficiency necessary for compliance with Washington State Initiative 937 (I-937) and for producing the IRP required by Washington law (RCW 19.280).

The forecast of system load is based on normal weather assumptions and forecasts of selected economic and demographic variables for the service area. Primary drivers of load growth include service area employment and the number of households. Employment and number of households are expected to continue growing in the long run, though occasional periods of economic slowdown are likely. Overall, the Seattle area economy is robust, supported by industries such as aerospace, software, and electronic commerce.

The 2016 IRP uses a long-range load forecast accepted by Seattle City Light's Risk Oversight Committee in June 2015. This forecast was based, in part, on national (IHS Global Insight) and regional (Puget Sound Regional Forecaster) forecasts of economic data available at that time, reflecting continued national and regional economic growth. Figure 1 shows Seattle City Light's long-term system load forecast used in the IRP. This load forecast includes historical achieved energy efficiency, but is without new programmatic energy efficiency. This is necessary so that the energy efficiency resource can be evaluated in the same way as generating resources. In essence, this reflects load growth that would occur if there were no more new energy efficiency programs in the utility's future.

The load forecast finalized in June of 2015 reflects growth in the commercial sector, stability in the industrial sector, and an expected continued decline in residential load. With increases in urban density, a higher percentage of the population residing in multi-family housing, continued technological gains in energy-efficient appliances, lighting, and building designs, and ever-stricter codes and standards for new construction, constraints on future load growth are expected.

Figure 1: Seattle City Light Long-Term Load Forecast
(does not include new programmatic energy efficiency)



CURRENT RESOURCE PORTFOLIO

City Light uses a combination of energy efficiency and power resources to meet its customers' energy needs. The utility's current resource portfolio includes energy efficiency, owned generation resources and long-term contract resources, supplemented with power exchange agreements and near-term purchases and sales made in the wholesale power market. City Light owns transmission facilities and depends primarily on the Bonneville Power Administration (BPA) for electric transmission outside its service area.

The following sections discuss existing energy efficiency, generation, and market resources City Light uses to meet its customers' need for energy services.

ENERGY EFFICIENCY

Energy efficiency was introduced into City Light's resource mix over 30 years ago and has remained the utility's first choice resource for meeting load growth. The energy efficiency partnership between the utility and its customers has successfully deferred acquisition of expensive new resources, especially those that negatively affect the environment, while maintaining system reliability.

Energy efficiency programs encourage customers to use power more efficiently and allow the utility to defer the acquisition and expense of new resources. Energy efficiency is low cost and has low environmental impacts, including no greenhouse gas emissions. It is integral to developing City Light's Integrated Resource Plan (IRP), to maintaining its status as a greenhouse gas neutral utility, to supporting the City's climate change policy goals, and to meeting the renewable portfolio standard (RPS) requirements. It has also been good policy in a transforming energy market because it reduces price risk and availability risk.

Energy efficiency programs are designed for all customer classes and address specific energy end uses such as efficient lighting, water heaters, laundry appliances, HVAC (heating, ventilation and air conditioning), and motors and manufacturing equipment. They also encourage weatherization and high-efficiency construction methods. Monetary incentives to utility customers include rebates, loans, or outright purchase of savings for installed energy efficient measures.

Using information from City Light's most recent energy efficiency potential assessment, conducted in 2015, the 2016 IRP assumes there are at least approximately 25.62 aMW of cost-effective energy savings potential available in 2016-2017 and 128.1 aMW over the next 10 years of the planning horizon.

ENERGY SAVED BY ENERGY EFFICIENCY PROGRAMS

City Light has one of the longest-running energy efficiency programs in the country. Since its start in 1977, energy efficiency measures supported by the utility have been installed in residential, commercial and industrial facilities throughout our service territory. As a result of this legacy and current energy efficiency programs, City Light's annual load is reduced by 1,560,594 megawatt-hours. That is enough electricity to power over 195,600 average Seattle homes – over one-third of our residential service.

In 2000, a home in our service territory used 10,300 kilowatt-hours of electricity per year, which was very close to the national average. Today, the average City Light residential customer uses approximately 7,975 kilowatt-hours–almost 3,000 kilowatt-hours less than the national average.[1]

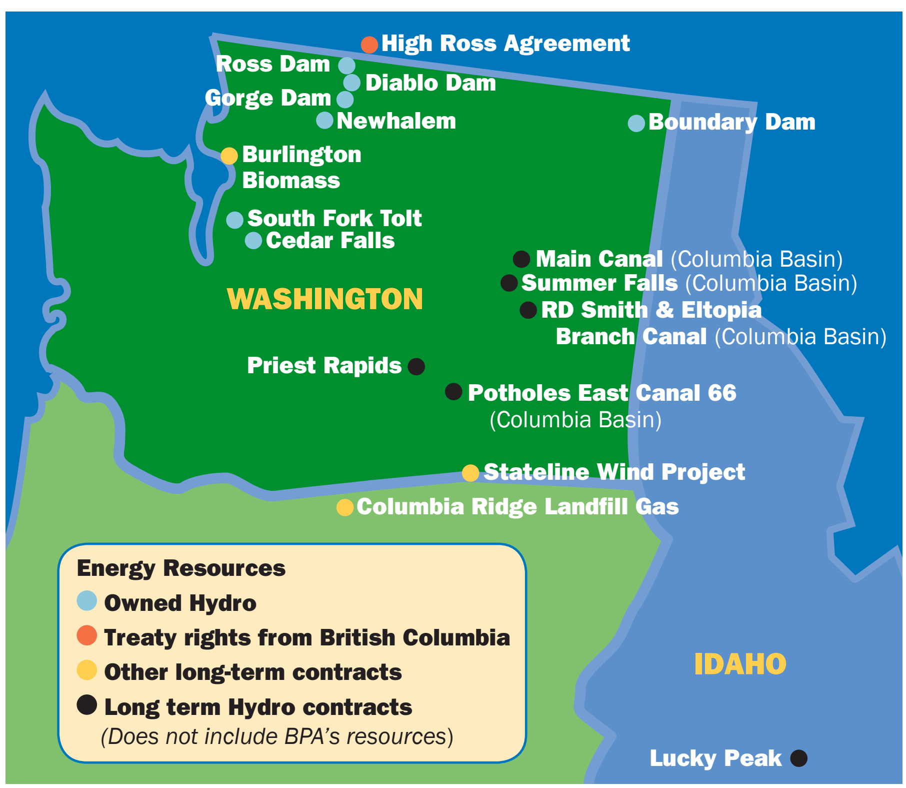
Due to energy efficiency measures currently in place across our service territory, City Light avoided the annual release of more than 998,780 metric tons of carbon dioxide into the atmosphere in 2015. That is equivalent to 219,732 households driving one fewer car for a year.

GENERATION RESOURCES

Over 90 percent of City Light's power is generated by hydropower, including its own low-cost hydroelectric facilities in Washington State. As a municipal utility, City Light enjoys preferential status in contracting for the purchase of additional low-cost power that BPA markets. The utility has contracts with several other owners of hydroelectric projects in the region. In 2002, City Light signed a 20-year contract with the Stateline Wind Project; in 2007, City Light began purchasing power from a biomass plant owned by Sierra Pacific Industries in Burlington. In November 2012, City Light has contracted an additional 6.4 MW with Waste Management Renewable (WMRE), because of the expanded capacity of the Columbia Ridge facility. City Light has contracted with King County for output from a cogeneration plant at the West Point Treatment Plant in Discovery Park.

The West Point Treatment plant is within City Light's service area. Its other resources and their locations are shown on the map in Figure 1. See Figure 3, following the descriptions of City Light resources, for the amounts generated by City Light resources over the period 1999-2014.

Figure 1: City Light's Generation Resources



City Light Resources

Boundary Dam is City Light's largest resource with a peaking capability of 1,055 MW and average generation of about 438 MW annually. Under the Federal Energy Regulatory Commission (FERC) license, part of Boundary output must be sold to Pend Oreille County Public Utility District No. 1 to meet the PUD's load growth. In addition, about five aMW of energy must be delivered to the PUD in compensation for Boundary Project's encroachment on its Box Canyon Dam. Energy from Boundary is delivered to consumers over BPA's transmission grid.

Skagit Project includes the Ross, Diablo, Gorge and Newhalem projects, which have a combined one-hour peak capability of 692 MW at full pool. City Light's transmission lines carry the power generated from the Skagit Project to Seattle.

South Fork Tolt has a one-hour peaking capability of less than 17 MW. Project costs are offset by BPA billing credits. Power from this project is delivered over a line owned by Puget Sound Energy.

Cedar Falls Dam has capacity of 30 MW. Power is transmitted by Puget Sound Energy.

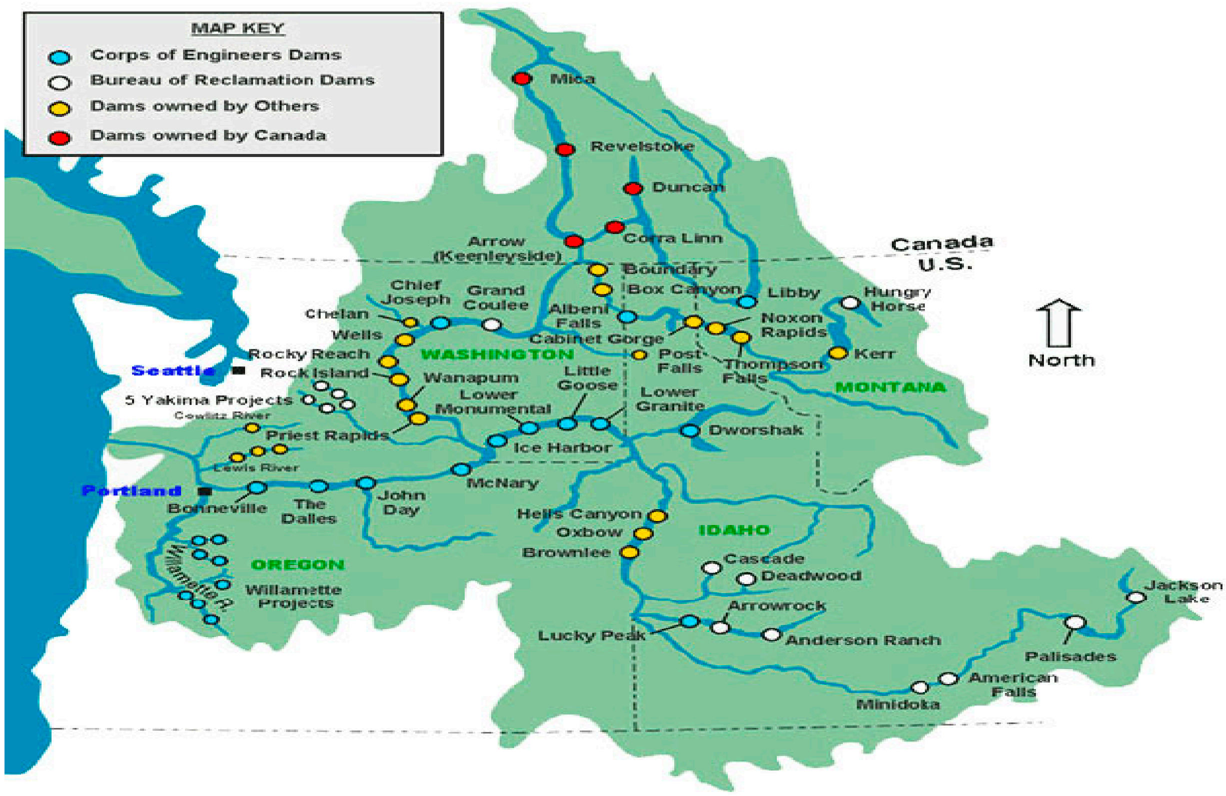
Contracted Resources

Bonneville Power Administration

City Light's largest power purchase contract is with BPA. The contract allows the utility to receive power from 31 hydroelectric projects and several thermal and renewable projects in the Pacific Northwest. Energy is delivered over BPA's transmission grid. In December 2008, City Light signed a contract with BPA to continue City Light's access to the power resources that BPA markets through September 2028. Figure 3 identifies the hydro generation resources in the Pacific Northwest. City Light receives from BPA a share of the hydroelectric generation identified by Corps of Engineers dams and Bureau of Reclamation dams in the map.

Under the BPA contract, power is delivered in two forms: a shaped block and a slice. Through the block product, power is delivered in monthly amounts shaped to City Light's monthly net requirement, defined as the difference between City Light's projected monthly load and the resources available to serve that load under critical water conditions. Under the slice product, City Light receives a fixed percentage of the actual output of the federal system and pays the same percentage of the actual costs of the system. Power available under the slice product varies with water conditions, federal generating capabilities, and requirements for fish and wildlife protection and restoration.

Figure 2: Hydro Generation Resources Pacific Northwest



High Ross Agreement

In an 80-year treaty with the Canadian Province of British Columbia, City Light abandoned plans to raise the height of Ross Dam in exchange for power purchases from British Columbia Hydro (acting through its subsidiary PowerEx). Power delivery and price are similar to the generation and costs City Light would have experienced had construction taken place. Through 2020, the power City Light receives from the contract has a relatively high cost. In 2021, the price reduces to about a dollar per MWh because the cost portion, equivalent to debt service that would have been issued to build the High Ross Dam, will terminate. PowerEx delivers the power to City Light over its and BPA-owned transmission lines.

Lucky Peak

Because of its location near Boise, Idaho, Lucky Peak can sell power to all major western trading hubs (Mid-C, COB, PV, Mead, and Four Corners) without encountering normal transmission constraints. City Light has the option to sell to the highest price market. City Light has contract rights to Lucky Peak output (approximately 34 aMW annually) until 2038.

Priest Rapids Project

The Priest Rapids Project consists of two dams: the Priest Rapids Dam and Wanapum Dam. City Light purchases power from this project under two agreements with Grant PUD, which owns and operates the project. The term of the agreements is to the end of the current federal license for the project, which is April 2052. Seventy percent of Priest Rapids Project's output has been allocated to Grant PUD. Under one agreement, City Light purchases about two to three average megawatts of output at the production cost of the facility. Under the second agreement, City Light has the option to receive a share of proceeds, if any, from an auction of 30 percent of the output, or to purchase the share of the output at the price set in the auction. City Light uses BPA transmission to deliver the power.

Columbia Basin Hydro[2]

City Light has contracts to buy half of the output, or about 27 aMW, from five Columbia River Basin hydroelectric projects. City Light's contracts expire over the period 2022-2027. The projects are part of three irrigation districts, so electric generation is mainly in the summer months. BPA and local agencies transmit the power to Seattle.

Northern California Power Agency

Under its exchange agreement with the Northern California Power Agency (NCPA), City Light delivers 60 MW of capacity and 90,580 MWh of energy to NCPA in the summer. In return, NCPA delivers 46 MW of capacity and 108,696 MWh of energy to City Light in the winter. Deliveries to NCPA started in 1995 and will expire in 2018.

Stateline Wind Project

City Light has an agreement with Constellation Energy to purchase wind-generated electrical energy and associated environmental attributes from the Stateline Wind Project on the Washington and Oregon border outside Walla Walla, Washington. City Light receives wind energy at an aggregate maximum delivery rate of 175 MW per hour through December 2021. Energy delivered under the contract is expected to average about 45 aMW. City Light has also entered into an agreement through 2021 to purchase integration and exchange services from PacifiCorp. BPA and PacifiCorp provide transmission for delivery to City Light's service area.

Burlington Biomass Facility

City Light has an 11-year power contract (2007-2017) with the Sacramento Municipal Utility District (SMUD) to deliver 15 MW of the output of a 23 MW capacity biomass generating plant (Sierra Pacific Industries' sawmill and co-generation plant in Burlington, Washington) to the California-Oregon border. City Light purchases energy and environmental attributes. The amount is expected to average about three aMW over the course of the year. Puget Sound Energy provides transmission from Burlington to Seattle; City Light uses BPA transmission to deliver the energy to California.

Columbia Ridge Landfill Gas Project

City Light has a 20-year power purchase agreement with Waste Management Renewable Energy, LLC to purchase the output, approximately 12 aMW, from the Columbia Ridge Landfill Gas project in Arlington, Oregon. As organic materials decay in a landfill, a by-product is methane, which can be collected and burned to produce electricity. The plant began commercial operations in January 2010. The Columbia Basin Co-Op and BPA provide transmission.

King County Wastewater Treatment

City Light has a 20-year power purchase agreement that began in February 2010 with King County to purchase the output from a cogeneration plant at the West Point Treatment Plant in Discovery Park. The expected output is 2.5 aMW. Methane is a by-product of the treatment process, and the methane will be collected and burned to produce electricity. The plant is inside City Light's service area so no transmission is required.

Power from Existing Generation Resources

Figure 3 shows the recent history of annual power production from each of the generation resources described previously, as well as some no longer part of City Light's portfolio. The table demonstrates how the portfolio has changed in recent years and illustrates power production variability caused by weather. City Light's current generation resource portfolio is more than 90 percent hydro. Its hydro storage capability has the advantage of operational flexibility but the disadvantage of being significantly affected by weather conditions. The amount of water available for power generation is affected by the amount and the timing of precipitation, run-off from snow melt, and regulations governing the recreational use of lakes, irrigation, protection of fish habitat and other environmental concerns. Operational flexibility allows the utility to meet peak load easily most of the time, but the ability to serve year-round load can be greatly diminished when water levels are low.

Prior to 2006, the West experienced six consecutive years of drought conditions, with 2001 as the most severe. Water conditions in 2010 on the federal hydroelectric system are the fifth lowest since 1929. Thus, City Light's resource portfolio must be able to serve load under prolonged drought conditions that do occur in the region.

As shown in Figure 3, the amount of power produced from owned generation in 1999 was nearly twice the amount produced in 2001, illustrating the risks associated with hydropower production. To make up the shortfall in 2001, City Light increased its purchases from BPA, but was still forced to make purchases from the market. By 2002, City Light had signed a new contract with BPA that nearly doubled its purchases, which phased in through 2007. The current contract with BPA went into effect on October 1, 2011; it provides for nearly as much power as the previous contract with a larger share of block and smaller slice under low water conditions. Wind power from Stateline came online in 2002, and power from that source increased over the next two years to its current level.

Figure 3: Power Generated Annually from Existing Resources in Average Megawatts

OWNED GENERATION	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Boundary	508.1	431.7	267.1	452.2	408.1	398.8	395.1	493.1	414.6	435.1	410.3	359.1	513.6	432.9	395.6	485.2
Skagit – Gorge	135.4	109.3	70.4	117.0	106.3	105.2	88.7	99.6	122.9	104.4	95.9	99.5	124.9	123.1	109.0	120.8
Skagit – Diablo	116.7	92.7	54.5	102.8	84.9	88.5	74.8	85.1	95.3	86.1	78.9	82.2	105.1	106.7	94.5	97.9
Skagit – Ross	109.9	84.4	44.9	95.6	83.1	77.6	64.3	73.2	98.1	75.0	71.0	74.0	99.4	107.0	82.9	90.9
Skagit - Newhalem	-	0.4	1.1	1.1	0.9	1.4	0.7	1.0	0.6	0.2	0.3	0.5	0.2	-	-	-
South Fork Tolt	8.0	5.0	4.6	8.9	5.6	6.9	5.1	6.1	6.4	6.5	5.8	6.2	5.7	7.2	6.3	7.3
Cedar Falls	8.1	5.7	7.4	9.1	7.3	7.0	4.2	8.6	7.6	9.8	8.7	7.5	12.6	14.0	8.8	7.5
Centralia (sold 2000)	78.7	31.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Owned Generation	964.9	760.7	450.0	786.7	696.2	685.4	632.9	766.7	745.5	717.1	670.9	629.0	861.5	790.9	697.4	809.5

PURCHASE CONTRACTS	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Bonneville Power Administration	180.6	193.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bonneville Power Administration Block	-	-	200.7	152.3	147.1	137.8	109.4	174.4	242.2	239.0	237.6	237.3	247.6	269.8	270.0	266.5
Bonneville Power Administration Slice	-	-	71.5	322.4	390.9	392.8	385.1	451.1	411.3	412.1	379.4	361.1	361.9	371.6	309.9	322.0
High Ross (B.C. Hydro)	35.2	33.8	35.1	33.9	36.0	34.8	35.4	36.1	35.8	35.3	35.7	35.1	35.8	35.1	35.7	35.1
Boundary Encroachment (BC Hydro)	1.7	2.0	0.9	1.2	1.6	1.5	1.7	2.6	1.9	1.9	1.7	1.8	2.0	1.4	1.2	1.5
Lucky Peak	48.6	38.8	21.5	33.0	33.4	31.3	25.8	46.5	31.2	35.4	36.9	32.6	44.4	45.7	24.6	35.2
Priest Rapids (Grant County PUD)	47.1	41.4	29.9	37.3	35.5	36.0	32.9	2.8	2.9	2.6	3.8	19.2	3.7	4.1	3.8	2.5
Columbia Basin (formerly GCPHA)	28.6	27.2	30.9	28.3	26.9	28.9	28.5	27.6	29.1	29.6	29.7	27.5	27.1	29.1	29.1	31.1
Stateline Wind	-	-	-	12.2	24.7	39.7	37.4	43.9	44.0	49.2	40.2	39.8	47.2	41.6	41.4	40.8
Klamath Falls (expired 2006)	-	-	37.2	81.0	74.7	81.8	66.4	11.4	-	-	-	-	-	-	-	-
Pend Oreille PUD (expired 2005)	8.1	6.6	4.9	5.0	5.4	6.7	3.0	-	-	-	-	-	-	-	-	-
Columbia Storage Power Exchange (expired 2003)	16.1	12.1	11.6	11.3	3.0	-	-	-	-	-	-	-	-	-	-	-
Columbia Ridge	-	-	-	-	-	-	-	-	-	-	0.2	5.8	5.7	5.7	5.9	7.9
Total Purchase Contracts	366.0	355.6	444.2	717.9	779.2	791.3	725.6	796.4	798.4	805.1	765.2	760.2	775.4	804.1	721.6	742.7

FUTURE OUTLOOK FOR CURRENT GENERATION RESOURCES

Over the next 20 years, not all of the generation resources described above will remain as they are in the existing portfolio. Some contracts will expire or be modified over the planning period.

Recently, City Light's license to operate Boundary Dam has been renewed by Federal Regulatory Commission (FERC) until 2055. The Skagit Project license expires in 2024, and under FERC's current rules, City Light will begin the relicense process at least five years before license expiration.

The Stateline wind contract that provides for about 45 aMW expires in December 2021. Part of City Light's share of Priest Rapids generation is fixed; part of the share of output gradually declines over the 20-year planning horizon at the rate of Grant County PUD's load growth. City Light's contracts with the Grand Coulee Project Hydroelectric Authority begin to expire in 2022.

In December 2008, City Light and BPA executed a contract for the period 2011 to 2028. The contract continues City Light's purchase of the block and slice products. BPA will offer a two tier pricing system. The price of Tier 1 power is based on the cost of the existing federal base system resources. City Light has secured approximately 532 aMW, under critical water, of Tier 1 power, subject to an annual true-up. The price of Tier 2 power will be based upon the actual price of new resources. Presently, City Light has no plans to purchase Tier 2 power.

In the future, the resource portfolio will include more renewable resources, consistent with policy direction from the City Council to meet load growth with energy efficiency and renewable resources to the extent possible, and mitigate for any greenhouse gas emissions associated with meeting new load (Resolution 30144) and RPS requirements. The high achievement energy efficiency resource will also have a substantial impact as City Light continues to fund programmatic energy efficiency.

MARKET RESOURCES

The wholesale electric power market in western North America plays an important role in meeting Seattle's power needs by allowing City Light to balance energy surpluses and shortages. Surplus power can be sold and power shortages can be made up with purchases both seasonally and over a period of years. Power can also be obtained from the wholesale market through seasonal capacity contracts, although City Light currently has no such contracts. In order to ensure winter reliability, the Resource Adequacy analysis for the 2016 IRP assumes that a maximum of 200 aMW of energy is available to City Light for purchase in the wholesale power market to meet short-term winter needs. Any needs above 200 aMW in the plan must be met by new energy efficiency and new firm resources.

With colder winter temperatures driving Seattle's power demand to peak in November through February and the spring snow melt driving hydropower production to peak in April to June, a seasonal mismatch exists between demand and supply of power. Keeping sufficient power generation capability to meet winter demand leads to excess generation capability the rest of the year. In addition to seasonal variation in supply and demand, precipitation may vary substantially from year to year, making it difficult to predict the supply of hydropower.

City Light actively manages its portfolio of power supply resources by purchasing and selling power in the wholesale markets and transacting seasonal exchanges of power. These transactions lower the rates charged to the utility's retail customers by generating revenues from sales of surplus energy and allowing purchases of lower cost power.

WESTERN ELECTRIC TRANSMISSION SYSTEM

The western electric transmission system physically defines the wholesale market for electricity in western North America. This market is broadly made up of 11 western states, two Canadian provinces, and northern Baja California, Mexico, as shown in Figure 4.

Constructed primarily in the 1950s and 1960s, the high- voltage transmission system is owned by a number of both private and public utilities. In the Pacific Northwest, BPA operates about 75 percent of the transmission system, with other large transmission owner/operators, including PacifiCorp, Puget Sound Energy, Avista, Idaho Power, British Columbia Transmission Company, and Portland General Electric, operating the rest. The high voltage transmission system is near capacity in some parts of the West, including the Pacific Northwest.

Market transactions and seasonal exchanges are facilitated by City Light's ownership share of transmission capacity rights on the Third AC Intertie. This ownership share was acquired in 1994, when City Light signed an agreement with BPA for rights to 3.33 percent (up to 160 MW) of transmission capability over BPA's share of the Third AC Intertie. The Third AC Intertie is an alternating current (AC) line that connects the Northwest region with California and the Southwest.

Figure 4: Western Electric Transmission System

[1] https://www.eia.gov/tools/faqs/faq.cfm?id=97&t=3
[2] Recently, Columbia Basin Hydro (CBH) changed its name from Grand Coulee Project Hydroelectric Authority.

THE REGULATORY ENVIRONMENT

City Light's resource decisions are made within a policy context that includes state and federal laws, internal policies established by the mayor, city council and the utility, and the policies and guidelines of regional power planning agencies and organizations. Over the years, the utility industry has become increasingly regulated.

With many organizations' laws and policies affecting the planning environment, there is ongoing uncertainty about the rules and environment in which City Light plans to meet the electricity demand of its customers. Those that have had and will have the greatest impact on City Light's resource planning are described in this appendix.

The most recent comprehensive federal energy legislation, the Energy Policy Act of 2005, includes a range of provisions pertaining to energy efficiency, generating resources and fuel supply, energy research and development, transmission, and climate change. To augment this comprehensive legislation, newer federal regulations, standards and rules have been added to ensure that as utilities modify existing generation or add new resources that cleaner generation technologies are added to the resource mix.

Figure 1: Policies and Regulations Affecting Resource Planning

Policy / Regulation	Energy Efficiency	Renewable Resources	Planning Methods	Transmission	Resource Adequacy	Power Supplies	Financial Incentives	CO_2 offsets	Climate Change
Resolution 31352	▷								
Resolution 30144	▷	▷						▷	▷
Resolution 30359								▷	▷
Resolution 30976									▷
Resolution 31312	▷								▷
Resolution 31447	▷								
Resolution 31667						▷			
Ordinance 122610									▷
RCW 19.285	▷	▷	▷						
RCW 19.280			▷						
RCW 80.50				▷					
RCW 80.60		▷							
RCW 82.16		▷					▷		
BPA Regional Dialogue						▷			
NPCC Policies	▷		▷		▷				
EPACT 2005	▷	▷	▷	▷			▷		▷
RCW 80.80						▷			▷

THE CITY OF SEATTLE

City of Seattle and City Light's policies guide the utility's planning and operations as they relate to the environment and to greenhouse gas emissions. City Light has also developed policies to manage the risks of being short or long on resources and strategies to deal with energy surpluses and deficits.

Environmental Policy

City of Seattle and City Light's environmental policies help guide the resource planning and acquisition process in order to protect natural resources and to minimize environmental impacts while serving Seattle's electricity needs. City Light's Environmental Policy Statement calls for City Light to avoid, minimize or mitigate impacts to the ecosystems that it engages with and to consider environmental costs, risks, and impacts when making decisions.

City Light's vision, mission, and values statement reaffirms that minimizing environmental impacts and enhancing, protecting and preserving the environment are key parts of the utility's goals. Minimizing environmental impacts is one of the four criteria used to evaluate the Integrated Resource Plan (IRP) candidate portfolios.

Conservation and Renewable Resources

In 2000, the Seattle City Council passed Resolution 30144, stating that City Light should "use cost-effective energy efficiency and renewable resources to meet as much load growth as possible," as part of a goal to meet Seattle's electrical power needs with net zero greenhouse gas emissions.

City Light has continued its long-term practice of acquiring conservation through its programs at an annual rate of approximately 10-14 aMW, and it has contracted for the purchase of approximately 45 aMW of wind power (175 MW of capacity) from the Stateline Wind project. The Seattle City Council monitors utility compliance with Resolution 30144 as part of the annual reporting of council metrics.

City Light's conservation plans are consistent with the City of Seattle's Climate Action Plan, the Northwest Power and Conservation Council's Power Plans and the Kyoto Protocols. Following through with these plans City Light exceeded I-937 conservation requirements.

Greenhouse Gases and Climate Change

Resolution 30144 also directs City Light to mitigate greenhouse gas emissions from any fossil fuel use and to set a long-term goal of net zero annual greenhouse gas emissions. City Light achieved net zero in 2005 and has continued each year since. The Greenhouse Gas Mitigation Strategy Resolution 30359 was passed in 2001. It sets standards for calculating greenhouse gas emissions and mitigation projects. Climate change policy does not prevent City Light from acquiring electricity from resources that produce greenhouse gases, but it does require that the utility fully offset those emissions.

In February 2005, the mayor proposed that the city achieve reductions in greenhouse gas emissions based on the Kyoto Protocol goal for the United States – a seven percent reduction in greenhouse gas emissions compared to 1990 levels – to be achieved by the year 2012.

In 2007, the Mayor's Climate Action Now was launched to promote reduction in greenhouse gas emissions on a community-wide basis. The program requires City Light to meet load growth with conservation and renewable resources and to offset greenhouse gas emissions. Resolution 30976 and Ordinance 122610 updated Seattle's Comprehensive Plan to accelerate the reduction of greenhouse gas emissions in Seattle by 30 percent from year 1990 levels by 2024 and by 80 percent from 1990 levels by 2050.

In 2011, the City Council passed Resolution 31312 that set a goal for Seattle to strive to reach net zero greenhouse gas emissions by 2050 and for Seattle to prepare for the likely impacts of climate change In 2013 the City passed Resolution 31447 adopting the 2013 Seattle Climate Action Plan. That plan focuses on city actions that reduce greenhouse emissions and also support vibrant neighborhoods, economic prosperity and social equity. These actions include an emphasis on road transportation, building energy and waste. The plan also includes actions that will increase community resilience to the likely impacts of climate change.

Most recently in 2016, City Council confirmed its resolve opposing the use of fossil fuels altogether in Resolution 31667. This resolution guides resource strategies to support clean and safe electricity production, opposing the use of fossil fuels and new nuclear energy in the generation of electricity. City Light's existing power supply resources, operations, and planning processes reflect the City's values to address climate change and be a good steward of the environment.

In the IRP analysis, City Light ensures the amount of greenhouse gas emissions of various resources and alternative portfolios has been calculated. The cost of offsetting those emissions is calculated based on estimated carbon dioxide allowance prices. City Light's 2016 IRP reflects City Light's commitment to greenhouse gas neutrality.

STATE OF WASHINGTON

Washington's Energy Independence Act (I-937)

In 2006, climate change concerns and an interest in developing a new green energy industry took center stage in Washington State with the passage of Initiative 937 (I-937). The initiative requires electric utilities to have 15 percent of their energy provided by new, renewable resources by 2020. The Energy Independence Act (RCW 19.285) requires utilities in Washington with more than 25,000 customers to acquire all cost-effective conservation at a prescribed pace and to acquire "qualifying" renewable resources at a rate of:

- 3 percent of retail load by 2012
- 9 percent of retail load by 2016
- 15 percent of retail load by 2020

Qualifying renewable energy must either be sourced from within the Pacific Northwest, or be purchased outside the Pacific Northwest but delivered into Washington on a firm transmission path, real-time, without integration services.

Hydroelectric power is not qualifying renewable energy, unless it is the direct result of qualifying hydro-efficiency improvements made after March 31, 1999. The requirement for qualifying renewables can be met with renewable energy credits (RECs), which represent the environmental attributes of qualifying renewable resources at the rate of one REC per megawatt-hour. Generation from distributed generation resources with a generating capacity of not more than 5 megawatts qualifies at a rate of two times the output for meeting I-937.

About ninety percent of City Light resources come from existing hydropower, which does not count toward I-937's renewable resource requirements. This meant City Light had to acquire renewable resources or RECs for regulatory compliance.

Since I-937 requirements are largely independent of how much energy a utility actually needs, the regulatory requirement can drive resource acquisitions that would not otherwise be made.

The requirements and timing of targets set by I-937 put many utilities into the renewable energy resource market at the same time, driving demand for renewable resources in Washington and the Pacific Northwest. Similarly, renewable portfolio standards in other states (Oregon, California) have impacted the prices for renewable energy credits and renewable resources in markets in which City Light participates.

In meeting the conservation-related intent of I-937, the 2014- 2015 target of 207,437 megawatt-hours (equivalent to 23.68 aMW) was established and surpassed by over 60 percent. Resolution 31631 was passed on December 11, 2015, establishing the 2016-2017 energy conservation target of 25.62 aMW and a ten-year potential of 128.1 aMW. This target and potential were established using the utility analysis option to document its biennial target and ten-year potential.

Integrated Resource Planning

RCW 19.280, HB 1010 (Chapter 195, Laws of 2006) passed by the Washington legislature in 2006, requires certain Washington utilities, including City Light, to regularly prepare IRPs. Under statute, IRPs must describe the mix of energy supply resources and conservation needed to meet current and future needs at the lowest reasonable cost to the utility and its ratepayers, using available technologies. Utilities must also consider and include in their planning cost-effective conservation and a wide range of commercially-available generation technologies, including renewable technologies.

Facilities Siting

RCW 80.50 HB 1020 (Chapter 196, Laws of 2006) designates the Energy Facility Site Evaluation Council (EFSEC) as the State's authority for siting transmission facilities under the Federal Energy Policy Act of 2005. The law extends EFSEC jurisdiction to electrical transmission facilities that operate in excess of 115 kilovolts within national interest transmission corridors and also to electrical transmission lines in excess of 115 kilovolts that connect a power plant to the grid.

Net Metering

Net metering measures the difference between the electricity supplied by a utility and electricity generated by a customer. If the customer generates more than needed, the excess power is sold to the utility's system and credited to the customer. Under RCW 80.60, Washington State requires utilities to provide net metering service to encourage development of renewable and distributed resources. The maximum allowable generating capacity for net metering systems is 100 kilowatts. The list of qualified generating sources for net metering includes solar, wind, water, fuel cells, and biogas from animal waste. On January 1, 2014 the cumulative generating capacity available to net metering systems for City Light increased to 20 megawatts (one percent of the Department's peak demand during 1996).

Incentives for Renewables

Certain provisions of RCW 82.16 create an investment cost recovery incentive to support certain renewable energy projects. Customers who generate electricity from a renewable energy system may seek annual incentive payment from their participating electric utility up to $5,000 annually. Utility participation is voluntary. Participating utilities, such as City Light, are allowed a credit against their public utility tax equal to the incentives paid to customers.

Governor's Executive Order on Climate Change

In February 2007, Governor Christine Gregoire issued Executive Order 07-02, the Washington Climate Change Challenge. The greenhouse gas reduction goals in order include:

- By 2020, reduce overall emissions of greenhouse gases in the state to 1990 levels
- By 2035, reduce overall emissions of greenhouse gases in the state to twenty-five percent below 1990 levels
- By 2050, the state will reduce overall emissions to fifty percent below 1990 levels

Governor Jay Inslee in 2014 issued an Executive Order outlining next steps to reduce pollution.
Some of these steps include:

- Creation of a Carbon Emissions Reduction Taskforce
- Reductions in coal-fired electricity generation
- Acceleration of clean cars and clean fuels
- Updates to the state's greenhouse gas emission limits
- Focus on reducing emissions from buildings by improving their efficiency

More recently, Governor Inslee announced an initiative to accelerate the adoption of zero emission electric vehicles in public and private fleets. http://www.governor.wa.gov/issues/issues/energy-environment

Power Plant Greenhouse Gas Performance Standard

In 2007, the Washington State legislature passed ESSB 6001 (RCW 80.80). This bill entered the Governor's Executive Order 07-02 into law. It also established a greenhouse gas emissions limit, called the performance standard, for new power plants. The original limit was set at 1,100 pounds of greenhouse gases per megawatt-hour of power produced, roughly equivalent to an existing natural gas plant emission rate. However, the State Department of Commerce in 2013 adopted a new limit at 970 pounds per megawatt-hour.

Greenhouse gases that are captured and sequestered are not counted toward the emissions limit. The technologies for achieving capture and sequestration, however, are in early development stages. The law also prohibits electric utilities in Washington State from renewing or entering into new contracts longer than five years for power plants that emit above the limit, unless they contract with a provider of "coal transition power."

REGIONAL

Regional policies and guidelines relevant to utility resource planning are summarized below, including those of the Bonneville Power Administration, Northwest Power and Conservation Council, and the Western Governors' Association.

Bonneville Power Administration

The Bonneville Power Administration (BPA) is the power- marketing agency for electricity generated from projects owned and operated by the Army Corps of Engineers and the Bureau of Reclamation. City Light purchases approximately 40 percent of its power supply from BPA, and decisions affecting the marketing of this power at the federal level can significantly impact City Light's resource portfolio cost, risk, and reliability. City Light also relies heavily on purchases of significant amounts of transmission from BPA to transfer power from City Light's remote generating resources to its service area.

BPA customers, including City Light, have joined to promote long-term, cost-based contracts to restore and protect low-cost regional power in the face of periodic attempts to divert the benefits of BPA from the Pacific Northwest.

In December 2008, City Light signed a contract with BPA to continue City Light's access to the power resources the BPA markets through September 2028. BPA is involved in structuring contracts that will fairly apportion its least expensive base system generation among its customers. All other BPA power will be available as variously designed products. Investor owned utilities should get a financial settlement of their residential exchange rights.

Northwest Power and Conservation Council

The Northwest Power and Conservation Council (NPCC) is a public agency created by the Pacific Northwest Electric Power Planning and Conservation Act of 1980. The agency's three major functions are to:

- Develop 20-year electric power planning for the Northwest that guarantees adequate and reliable energy at the lowest economic and environmental cost
- Develop programming to protect and rebuild fish and wildlife populations affected by hydropower development in the Columbia River Basin
- Educate and involve the public in the Council's decision-making processes

Power Planning

The NPCC's seventh power plan (February 2016) was developed over the last few years with the Pacific Northwest power system facing significant uncertainties including how federal carbon dioxide emissions regulations will be implemented, and what will happen with future fuel prices, resource retirements, salmon recovery actions, economic growth, and cost to integrate increasing amounts of renewable generation. The NPCC finds that after adding renewable generation as required by state renewable portfolio standards that to meet the region's future electricity needs energy efficiency is the most cost-effective resource to meet the majority of the needs. Secondary to energy efficiency the plan calls for the region to develop the capability to deploy demand response. After these two resources, the plan explains that new natural gas resources are the most cost-effective resource option and increasing the use of natural gas over higher emitting fossil fuel sources reduces regional carbon emissions. The plan encourages investments in research, development, and demonstration projects in advanced technologies to help them reach their full potential.

Regional Resource Adequacy Standard

In 2008, the NPCC adopted a new regional standard intended to ensure an adequate supply of electricity for the Pacific Northwest. The regional standard is also expected to be included for the Northwest region within the broader west- wide efforts on resource adequacy by the Western Electricity Coordinating Council (WECC).

The NPCC's regional adequacy standard is intended to address the unique characteristics of the Pacific Northwest, including the region's winter-peaking loads (compared to summer-peaking loads across most of the west) and its heavy dependence on hydroelectric generation.

In 2011 the latest adequacy standard was adopted. The Pacific Northwest energy aim is to limit the likelihood of supply shortages to a maximum of 5 percent, also referred to as a 5 percent loss of load probability (LOLP).

Western Governors Association

In June 2004, the Western Governors adopted a resolution to:

- Examine the feasibility of developing 30,000 MW of clean and diverse energy by 2015
- Increase energy efficiency to 20 percent by 2020
- Provide adequate transmission to meet the region's needs through 2030

In 2005, they created the Clean and Diversified Energy Advisory Committee (CDEAC) to oversee the work of seven task forces that examined the feasibility of reaching those goals. The task forces prepared reports with recommendations in the following areas: energy efficiency, advanced coal, geothermal, wind, biomass, solar, and transmission.

In 2006, the Western Governors adopted Resolution 06-10, agreeing to:

- Provide production tax credits for all renewable energy technologies and energy efficiency investments
- Raise the cap on the residential investment tax credit to $10,000 for renewable energy or distributed generation systems
- Support improvements in national appliance efficiency standards

In June 2007, the Western Governors adopted Resolution 07-17, making recommendations for renewable portfolio standards that were largely satisfied in Washington State by I-937. Resolution 07-17 supports:

- Hydropower research and emerging hydrokinetic/ocean technologies
- Long-term reauthorization of renewable production tax credits
- Achieving energy efficiency savings from new and existing residential and commercial/public buildings
- Transmission to accommodate the integration of large amounts of renewable generation in the Western power system
- Effective utilization of existing hydropower facilities and more effectively using small hydro potential

In 2008, the Western Governors launched the Western Renewable Energy Zone (WREZ) initiative, which provided tools, information and analysis to encourage utilities to work cooperatively to develop renewable generation in the west.

In 2009, the Regional Transmission Expansion Project was begun. Funded by a grant from the U.S. Department of Energy, the project will analyze transmission requirements under a variety of possible futures and develop long-term, interconnection-wide transmission expansion plans.

Most recently, Western Governors' adopted policy resolutions to support the enhancement of species conservation and the endangered species act and published a 10-year Energy Vision to secure a clean, affordable, and reliable energy future.

The Climate Registry

Building on the work done by the California Climate Action Registry, a multi-state greenhouse gas emissions registry called The Climate Registry (TCR) was formed in 2007. Its development has moved quickly, and today, membership includes more than 300 diverse organizations including corporate, non-profit, and government entities. The Registry has been discussed as the platform for federal legislation for reporting and reducing greenhouse gas emissions. The City of Seattle is a founding member of TCR.

FEDERAL

Electric utilities are regulated by numerous federal regulations including the Clear Air Act, Clean Water Act and rules regulating electricity transmission and wholesale electricity sales. The federal government also licenses hydropower plants and ensures compliance.

Environmental Regulations

At the federal level, EPA regulations (the Clean Air Interstate Rule and the Clean Air Mercury Rule) have set tighter limits for emissions of common air pollutants from power plants: oxides of sulfur and nitrogen, and mercury. Other regulations will further limit emissions of particulate matter. These regulations may become more restrictive during the planning period of the IRP, and states may set their own more restrictive standards. Meeting these limits can be a significant technical challenge, as well as a significant additional cost, for power plants that burn fossil fuel.

Federal Clean Water Act regulations have also become more stringent. Power plants that use water for cooling could be affected by these changing regulations, as restrictions increase on removing water from, and discharging cooling water into, surface and groundwater sources. These restrictions are often related to protecting habitat for fish and wildlife, as well as protection of human health.

The Endangered Species Act (ESA) can affect the potential to site new power plants and transmission facilities. Currently, hydropower operations are significantly regulated because of their potential impacts on ESA-listed fish species. As new species are listed, and as new information about the effects of hydropower operation on those species becomes available, the operational rules may change. Consequently, this could possibly change both the amount and the timing of hydropower output. This issue is extremely important to City Light, given its reliance on both its own hydropower facilities and on the Bonneville Power Administration's supply.

With climate change, federal regulation under the Clean Air Act is now targeting carbon dioxide pollution regulation. For many years utilities have speculated about when federal regulation of carbon dioxide emissions would occur. In 2013 President Obama announced his Climate Action Plan. Under this Plan, the president set new goals to establish carbon pollution standards for power plants. In 2014, the U.S. Environmental Protection Agency (EPA) released its Clean Power Plan proposed rule. The Clean Power Plan rule set targets to reduce carbon pollution from the power sector 32 percent below 2005 levels by 2030. On February 9, 2016 the Supreme Court stayed implementation of the Clean Power Plan after 15 states filed a complaint arguing the EPA overstepped its authority. Many states including Washington State are still continuing discussions to develop a plan for implementation.

Energy Policy Act of 2005

The last comprehensive federal legislation related to energy was passed in 2005. It addressed a wide range of issues including energy efficiency, generating resources and fuel supply, transmission, and climate change.

Energy Efficiency

Several provisions related to energy efficiency may have influenced the acquisition of conservation resources within City Light's service area.

The Energy Policy Act of 2005 authorized $50 million in funding annually between 2006 and 2010 for state-administered energy efficient rebate programs for residential Energy Star products. These include appliances, heating and cooling systems, home electronics, lighting, and windows, doors and skylights. The legislation establishes financial grants for state-run programs to achieve at least 30 percent efficiency improvements in new and renovated public buildings. The formula used in the Energy Policy Act of 2005 was again used in the American Recovery and Reinvestment Act of 2009. Another $300 million was funded by the US Department of Energy for consumer purchases of new Energy Star qualified home appliances.

Generation Resources and Fuel Supply

Hydroelectricity

The 2005 Act authorized $100 million for hydroelectric efficiency improvements at existing dams and modernized the hydropower laws to allow increased production. It created a 10-year tax credit that applied to “qualified hydropower production” placed in service prior to January 1, 2008. Relicensing provisions were amended to allow applicants or other parties to propose alternatives to conditions set by the agencies.

Natural Gas

The 2005 Act confirmed that the Federal Energy Regulatory Commission (FERC) has exclusive authority over siting, construction, expansion and operation of liquefied natural gas (LNG) import terminals located onshore or in state waters. In addition, it confirms FERC's role as the lead agency for National Environmental Policy Act compliance and for purposes of coordinating all applicable federal authorizations. The Act also confirms existing rights of states to review LNG terminals under the Coastal Zone Management Act, Clean Water Act and Clean Air Act.

Coal

The Act authorized $200 million per year from 2006 to 2014 for a federal government cost-share program to conduct demonstrations of commercial-scale advanced clean coal technologies. It also authorized $3 billion in the form of loans, cost-sharing, or cooperative agreements to encourage new sources of advanced coal-based power generation and to upgrade existing sources of coal-based generation to improve air quality to meet current and future obligations of coal-fired generation units regulated under the Clean Air Act.

The Act authorized a total of $1.095 billion over three years in funding for the Department of Energy (DOE) clean coal research and development program, and $75 million over three years for a DOE program to develop carbon capture technologies that can be applied to the existing fleet of coal units

Innovative Technologies

The Act established a loan guarantee program to provide incentives for “innovative energy technologies” that avoid, reduce, or sequester air pollutants or greenhouse gases and use technologies improved in comparison to those in commercial use. Eligible projects include renewable systems, advanced fossil energy technologies (including coal gasification), hydrogen fuel cell technology, advanced nuclear energy facilities and others. There is no cap on the amount of funds used for this program.

Nuclear Energy

The Price-Anderson Act was re-authorized for commercial nuclear power plants and DOE contractors for 20 years; it increased the indemnification for DOE contractors to $500 million. In addition, it authorized construction of a nuclear reactor at the DOE Idaho National Laboratory that will generate both electricity and hydrogen, and it created a federal loan guarantee program to encourage the design and deployment of innovative technologies including advanced nuclear power plants.

Transmission

To promote investment in electric transmission infrastructure, FERC was directed to undertake an incentive rate rulemaking and to provide for participant funding. In addition, it provided for expedited siting processes on both federal and private lands and for the use of advanced transmission technologies.

The Act established an Electric Reliability Organization to develop and enforce reliability standards for the bulk transmission system. The Act also requires FERC to identify the steps needed to make available real-time information on the functional status of all transmission lines within each of the transmission interconnections and to implement such a transmission information system.

The DOE was directed to study electric transmission congestion and possible designation of “national interest electric transmission corridors.” The designation of such corridors would have a significant impact on the development of new electric transmission facilities. Congress gave FERC backstop authority to grant permits for the construction or modification of electric transmission facilities within these corridors in certain situations, including the withholding of approval by a state siting authority. (In Washington State, HB 1020 designates the State EFSEC to prevent a FERC backstop.)

Climate Change

Climate change actions directed by the 2005 Act included forming a Climate Change Technology Advisory Committee charged with integrating existing federal climate change reports and activities. The Committee is to submit a national strategy to promote the deployment and commercialization of greenhouse gas intensity reductions and to identify barriers to these technologies and ways to remove those barriers. Best management practices are also to be developed for calculating, monitoring, and analyzing greenhouse gas intensity.

Amendments to the Public Utility Regulatory Policy Act (PURPA)

The Act amended PURPA to repeal the requirement for mandatory purchase from qualifying facilities by electric utilities if a competitive market exists, and established new criteria for qualifying cogeneration facilities.

The Act amended PURPA to require state regulators and certain non-regulated electric utilities to consider five new standards based on the purposes of PURPA:

1. Net metering,
2. Fuel sources,
3. Fossil fuel generation efficiency,
4. Smart metering, and
5. Interconnection.

Washington State's IRP law and City Light's IRP process meet the consideration and determination requirements required under PURPA. City Light does not anticipate the need for substantial discussion on the fuel sources and fossil fuel generation efficiency standards, since they are covered by existing state law.

Other Federal Regulations and Programs

The federal government has also enacted other regulations and renewed and created new financial incentives that impact resource planning in recent years. Current programs include federal appliance standards, clean renewable energy bonds, weatherization assistance programs, and interconnection standards for small generators, qualified energy conservation bonds, and renewable electric production tax credits. These programs have contributed to the greater use of energy efficiency, the increased adoption of renewable generation, and reduction in costs to adopt these newer technologies.

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.

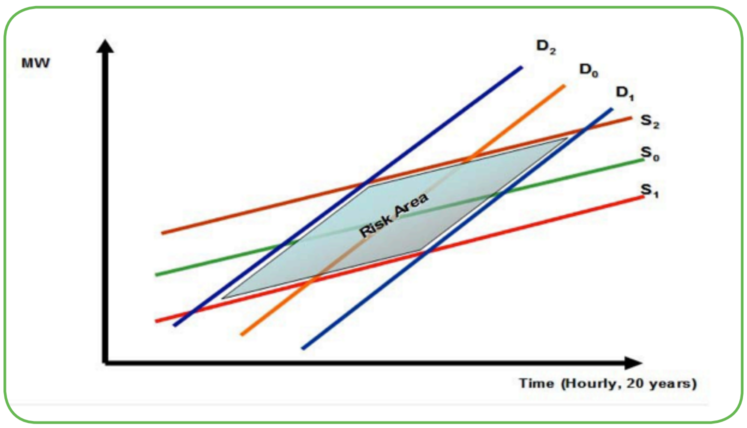
Since supply and demand factors vary from region to region or system to system, it is difficult to standardize resource adequacy criteria and methodologies. Different regions and utilities have adopted different standards and methodologies in order to optimally measure their resource adequacy as well 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)

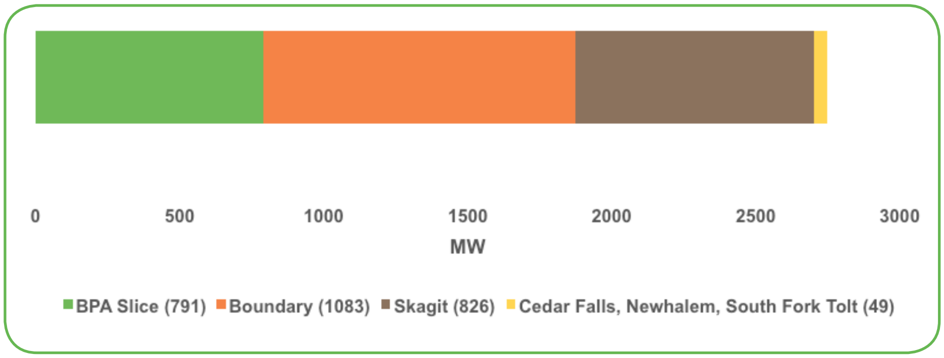
Volatilities in Dispatchable Capacity Resources

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] .

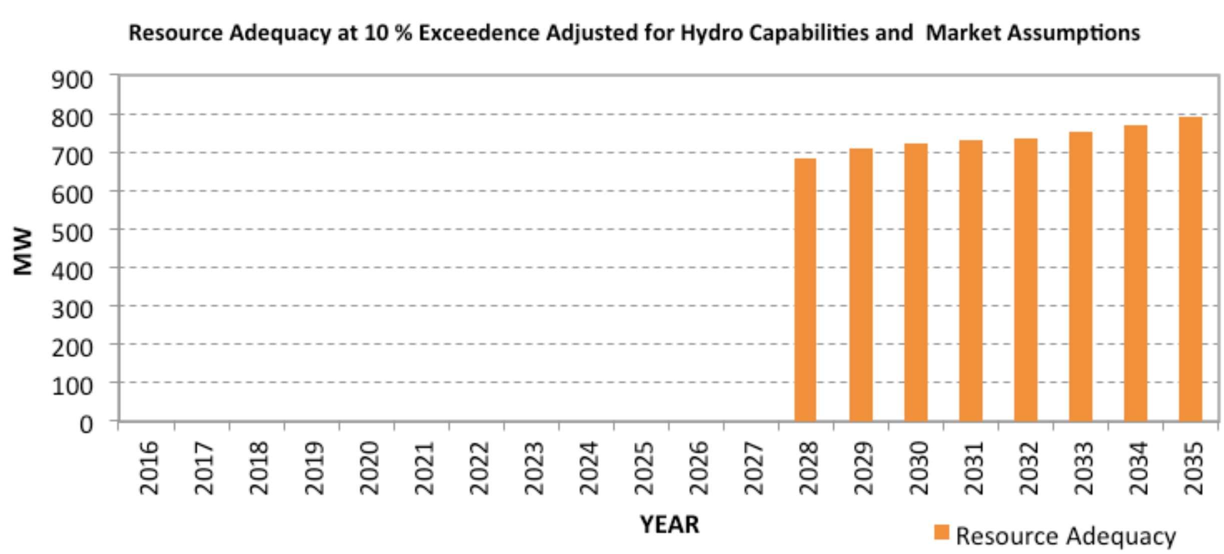
City Light has made further assumptions about the supply variables as follows:

- 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 τ_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.

RESOURCE OPTIONS

An essential step for integrated resource planning is to identify and evaluate a broad range of resources, as required by Washington state law (RCW 19.280), including energy efficiency. This appendix contains information about resources currently available to electric utilities that are considered for the 2016 Integrated Resource Plan (IRP). The resources evaluated include energy efficiency programs, nonrenewable generation resources (natural gas), renewable generation resources (such as wind and solar) and short-term power purchases from the western wholesale energy market.

ENERGY EFFICIENCY RESOURCE

As a low-cost, low-carbon alternative to other types of energy generation, energy efficiency is City Light's first choice resource for meeting growing demand for power. Through the longest running energy efficiency programs in the nation, City Light partners with its customers to use energy-efficient equipment and practices in homes and businesses. These programs offer direct customer value, but also deliver broad benefits to the utility by avoided high-cost generation, deferred transmission and distribution investments, and reduced air pollution and greenhouse gas emissions. Acquiring energy efficiency is also a good policy in a changing energy market because it avoids price risk and availability risk.

Characteristics

Utilities must be able to match resources to load. Dispatchability refers to a utility's ability to control the output of a generation resource in real time. More readily controlled resources, such as gas turbines, have a greater degree of dispatchability. Energy efficiency measures are not dispatchable and their impact is defined by seasonal, daily and hourly usage patterns. The ability to save energy is based on when the energy consuming equipment is in use. Some equipment, like refrigerators, are on constantly. Other equipment, such as washing machines, make an impact during the times they are in use.

Energy efficiency measures can be considered either discretionary resources or lost opportunity resources. Lost opportunity energy efficiency can occur when there is a single decision point where the energy efficiency choice can be made. Lost opportunity energy efficiency must be captured when a new building is built or when a new appliance is installed; if not, the energy efficiency opportunity can be lost. In contrast, discretionary measures can be implemented at any time within practical limits. Discretionary measures are energy efficiency improvements that can occur from equipment replacements and equipment upgrades. Discretionary energy efficiency can be shifted during the study period based on the timing of incentives and programs, while lost opportunity energy efficiency must follow building construction trends.

Conservation Potential Assessment

The 2016 Conservation Potential Assessment (CPA), conducted by Cadmus, Inc., examined energy savings available in the residential, commercial and industrial sectors in City Light's service area. The assessment considered hundreds of potential energy efficiency measures, distinguishing between discretionary resources and lost opportunity resources. The study also incorporated non-energy benefits.

The CPA identified the total 20 year opportunity for energy efficiency and then adjusted the potential based on market conditions. Technical potential refers to the maximum savings that could be achieved if every cost-effective efficiency measure were implemented in every customer facility. Achievable potential is the portion of technical potential that will likely be viable over the planning horizon, given market barriers and an economic screen. The result was an achievable cost-effective energy efficiency potential that totals 205.4 aMW over the 20-year planning horizon.

Modeling Energy Efficiency in the 2016 IRP

In the 2016 analysis, staff modeled different energy efficiency scenarios. The base and high achievement of energy efficiency scenarios were selected as part of the candidate resource portfolios (Figure 1: Cumulative Energy Efficiency by Year). The main difference between base and high achievement of energy efficiency was that although the overall potential was the same, high achievement of energy efficiency shifted forward some of the discretionary measures.

In general, the reported energy efficiency cost structure suggests that the cost of energy efficiency is not a limitation for achievable energy efficiency. The most meaningful constraints to energy efficiency have been physical. In the 2010 IRP, City Light found that it should acquire energy efficiency as quickly as possible, as long as the cost was significantly below the levelized avoided cost threshold.

In estimating the pace of the high achievement of energy efficiency, the model logic does not address practical considerations of energy efficiency program implementation. For the high achievement of energy efficiency, the relevant question was implementation: "How quickly can City Light actually 'mine' discretionary energy efficiency from existing buildings?" The answer to this depends on issues such as City Light's and customers' budgets, policy-makers' priorities, customer incentives, staffing, office space, consultants, energy efficiency contractors, and coordination of schedules.

Figure 1: Cumulative Energy Efficiency by Year

YEAR	BASE	HIGH ACHIEVEMENT
2016	12.53	14.35
2017	25.06	28.91
2018	37.60	45.69
2019	50.14	61.09
2020	62.64	78.22
2021	75.18	93.54
2022	87.70	108.28
2023	100.23	121.05
2024	112.80	132.69
2025	125.24	142.80
2026	137.67	152.03
2027	148.48	160.21
2028	157.66	167.38
2029	166.72	175.02
2030	174.42	181.71
2031	181.02	187.56
2032	187.07	192.49
2033	192.41	196.95
2034	197.37	201.15
2035	202.01	205.22

GENERATION RESOURCES

Generation resources produce electrical energy from other forms of energy, such as heat or solar; or potential energy, from wind or falling water. The types of generation resources analyzed for an IRP are proven and commercially available. Generation resources added to City Light's existing portfolio will have characteristics important to City Light's future needs. The most important characteristics to consider when comparing generation resources are costs, dispatchability, transmission requirements, and environmental attributes.

Evaluating the Resources

This section describes the types of generating resources that were candidates for inclusion in the candidate resource portfolios for the 2016 IRP and how those resources were selected from the available technologies.

- Wind
- Biomass
- Geothermal
- Solar
- Natural Gas-Fired Combined-Cycle Combustion Turbine (CCCT)
- Natural Gas-Fired Single-Cycle Combustion Turbine (SCCT)
- Hydro

As research and development continue for new or enhanced types of generating resources, it is difficult to predict future technological advancements and how they will affect resource costs and availability. For this reason, most IRPs identify and monitor promising generating resource technologies that may become technically viable and commercially available, but do not include them in the quantitative analysis. Washington state law governing IRPs states that they should contain commercially available technologies and select resources with the lowest reasonable cost. In keeping with state law and IRP best practices, this IRP does not contain forecasts of new technologies or their costs.

Selecting a Range of Resources

The IRP staff followed a structured process to compare and choose from an array of available resource types. City Light evaluated more types of generating resources than were included in the recommended resource portfolio. Including a broad range of resource types has advantages, including the assurance that the IRP process is objective and does not prematurely narrow the field of resource alternatives. Each type of generating resource has a unique combination of advantages and disadvantages, including costs, benefits, opportunities, and risks. Evaluating a particular resource does not imply a predetermined preference for or against its inclusion in City Light's portfolio.

Analyzing various types of generating resources helps identify which combinations of new resources can best complement the existing resources in City Light's portfolio. A single type of generating resource might not meet all of the utility's long-term needs, while a diversified mix of resources may be more likely to meet the utility's objectives of maximizing reliability and minimizing cost, risk and environmental impacts.

Various types of generating resources have proponents and opponents. The net impacts of a particular type of generating resource on the utility's overall resource portfolio are often not obvious and can remain obscured if the resource is only evaluated on a stand-alone basis. Quantitative analysis of candidate resource portfolios that combine a variety of resource types provides the means to incorporate input from many perspectives such as capacity, efficiency, potential availability, dispatchability, environmental emissions, and cost. These inputs can be used for comparisons between portfolios. Quantitative analysis of the candidate resource portfolios with different mixes of resources can produce useful information for selecting a long-term resource strategy.

Based on results from quantitative analysis, City Light's candidate resource portfolios contain resources that are known to be commercially viable at the point the IRP is produced. Some resources were not included in the quantitative analysis because their costs are significantly higher or due to governmental regulations or environmental constraints, they are not viable options for consideration in the resource portfolios - ultimately they are not commercially available to City Light.

Costs of New Generation Resources

City Light conducts in-depth research using many reliable technical sources to determine the outlook of the costs for generation resources during the IRP study period. Due to federal, state, and local environmental policies and regulations[1] as well as governmental incentive programs,[2] renewable generation resource costs, such as wind and solar photovoltaic (PV) have declined. The combination of existing and new environmental regulations and policies, lower electricity demand, and increased natural gas production have led to the reduction of demand for natural gas and lower natural gas costs. As a result of lower natural gas prices, the generation cost for natural gas-fired turbines has been driven down.

Information about the costs of new resources came from many sources, including new existing renewable contracts in WECC, the U.S. Department of Energy, Northwest Power and Conservation Council, California Energy Commission, and Integrated Resource Plans from other utilities in the Pacific Northwest.

Transmission costs for new resources are assumed to be consistent with the BPA's policy for new transmission. The policy is that the BPA will build new transmission as needed by its customers, not to exceed an amount that would increase rates by 5 percent.

Figure 2 provides costs and other assumptions for new generation resource options that were evaluated in the 2016 IRP.

Figure 2: New Generation Resource Options Evaluated in the 2016 IRP

RESOURCE	2014 $/ MWH
CCCT	$ 76.31
SCCT	$ 143.58
Biomass: Landfill Gas	$ 96.40
Biomass: Wood Waste Cogen	$ 101.34
Biomass: CHP Gasification	$ 141.44
BPA Hydro	$ 51.49
Non-BPA Hydro	$ 55.09
Geothermal	$ 144.59
Solar PV	$ 127.14
Solar Thermal	$ 244.59
Wind	$ 76.97

Resources Evaluated in the IRP

As mentioned earlier, the most important characteristics of generation resources added to City Light's current portfolio are costs, dispatchability, potential availability, transmission requirements and environmental attributes. For each new generation resource evaluated, the following basic information was gathered:

- Resource technology and fuel
- Current status and outlook
- Resource characteristics

WIND POWER

The use of wind power has increased rapidly, making it the predominant renewable resource technology in the Pacific Northwest, where the installed capacity of wind power projects has increased from zero to more than 3,000 megawatts in the last decade.

WIND POWER	
TECHNOLOGY & FUEL	Wind power is the process of mechanically harnessing energy from the wind and converting it into electricity. The amount of wind power that can be produced at a given place is dependent on the strength and frequency of wind. Wind velocity and frequency is particularly important because the quantity of power increases as wind speed and frequency of wind increases, up to the maximum capacity of the wind turbine. In general, wind turbine generators are grouped together in order to minimize costs while maximizing output. Wind power has no fuel cost. However, lease payments to landowners are a cost of accessing the wind "fuel".
CURRENT STATUS & OUTLOOK	The Northwest Power and Conservation Council (NPCC) estimates the potential for wind power in the Pacific Northwest exceeds 6,000 megawatts. In the region, wind projects range anywhere from less than 1 MW to 343 MW.
CHARACTERISTICS	Transmission requirements. The cost of transmission for wind power is higher per megawatt-hour than for other generating resources because it has a low capacity factor. Dispatchability. Wind power is not a dispatchable resource. One approach for firming up the intermittent generation from wind power projects is to coordinate their operation with dispatchable resources (e.g. combustion turbine generation) or with resources that have the ability to shape or store energy (e.g. hydroelectric generation). Environmental attributes. Wind power is renewable and does not consume fossil fuels or produce air emissions. Primary environmental concerns are bird and bat mortality and visual impacts.

SOLAR POWER

Solar PV and solar thermal power prices have dropped significantly from $210.7 per MWh (levelized cost of energy) in 2011[3] to $114.3 per MWh in 2015[4] and $311.8 per MWh in 2011 to $220.6 per MWh respectively. Solar PV growth has dramatically increased in the US. Despite having a low solar efficiency rate in many parts of the Pacific Northwest, as a result of the existing and new regulations and policies such as RPS and Federal and State incentive programs, solar power projects have become more commercially available.

SOLAR POWER	
TECHNOLOGY & FUEL	Solar power is generated by transforming solar radiation by converting it into heat and electricity. There are two ways that solar energy can be converted into electricity: Photovoltaics change sunlight directly into electricity and solar thermal generate electricity by concentrating solar energy to heat a fluid to produce steam that is used by a power generator.
CURRENT STATUS & OUTLOOK	The Northwest Power and Conservation Council (NPCC) estimates solar costs will drop to $1 per watt for utility-scale solar PV projects coming online by 2020, representing a 75% cost reduction since 2010. Solar PV projects are still highly dependent on federal incentives. The Federal Investment Tax Credit (ITC) which provides a 30% credit for solar projects has been extended until 2019, then the credit steps down annually to be reduced to 10% by 2022. In the region, solar project capacities range anywhere from less than 1 MW to 14.3 MW.
CHARACTERISTICS	Transmission requirements. The cost of transmission for solar power is much higher per megawatt-hour than for other generating resources because it has a low capacity factor. Dispatchability. Solar power is not a dispatchable resource. Solar power is dependent on daylight and is also impacted by location and cloud cover to produce high amounts of energy. One approach for compensating for the intermittent generation from solar power projects is to coordinate their operation with dispatchable resources (e.g. combustion turbine generation) or with resources that have the ability to shape or store energy (e.g. hydroelectric generation). Environmental attributes. Solar power does not consume fossil fuels or produce air emissions. Primary environmental concerns for solar technologies are the hazardous materials used in the manufacturing process.

BIOMASS

Biomass generation is the production of electricity using biomass fuel which is made from organic material that can be burned or converted into a combustible material. Examples of biomass fuels that can be used to generate electricity include waste wood (e.g. residues from forest thinning, logging and mill processes), methane produced at wastewater treatment plants, methane produced from the decomposition of animal manure, agricultural residues, natural degrading and decomposition of municipal solid waste in sanitary landfills, and energy crops.

For the 2016 IRP, wood waste cogeneration, gasification CHP, and landfill gas were used as potential biomass resources.

BIOMASS	
TECHNOLOGY & FUEL	Biomass is converted into fuel using thermochemical or biochemical processes. Biomass plants generate electricity by processing the raw biomass into a combustible fuel and burning it. Conventional steam-electric turbines with or without cogeneration are the chief technology for electricity generation using wood-derived fuels. Generating electricity from biomass requires large quantities of organic material because the raw forms of biomass fuel sources have low energy content.
CURRENT STATUS & OUTLOOK	Biomass type resources are situation-specific. Details vary based on the fuel source and the technological process used to generate electricity from that source. In the region, biomass projects range anywhere from less than 1 MW to 113 MW in capacity. City Light has a contract with King County's West Point Water Treatment Facility and a small contract with Columbia Ridge landfill gas plant.
CHARACTERISTICS	Transmission requirements. Biomass generation is usually sited near transmission or distribution lines. Dispatchability. Biomass generating resources usually operate as base load generation. Environmental attributes. Most biomass fuel is a renewable resource, with low environmental impacts. Biomass generation does not add large amounts of additional carbon dioxide to the atmosphere, but it does emit nitrogen oxides and particulate matter. When using conventional steam-electric turbine technology consumes significant amounts of water – up to 55,000 gallons per megawatt-hour, depending on fuel source and production technology.

GEOTHERMAL

Geothermal is the only large renewable resource that combines base load generation with long-term firm fuel supply and scalability. While other renewable energy resources like wind and solar generate power intermittently, and hydro availability varies from year to year, geothermal can be operated over 95 percent of the time and may operate for 100 years or more.

GEOTHERMAL	
Technology & Fuel	Geothermal energy is derived from heat that originates deep in the earth's crust. There are three basic types of geothermal generating technologies: dry steam, flash, and binary.
Current Status & Outlook	A Western Governors' Association Geothermal Task Force Report estimates nearly 1,300 megawatts of developable geothermal generation in Washington. However, the outlook for development of geothermal generating resources in Washington and parts of the Pacific Northwest is unclear because extensive exploratory drilling has not been done. In the region, geothermal project capacities range anywhere from 12 MW to 28.5 MW.
Characteristics	**Transmission requirements.** Sites with geothermal potential are located near City Light owned or controlled transmission. If geothermal plants are built in those areas in the future, upgrades to the existing transmission system may be necessary. Geothermal is easy to integrate into a hydroelectric system because it has a high capacity factor. **Dispatchability.** Geothermal energy is usually operated as a base load supporting resource but it has some limited dispatchability on-peak and off-peak. **Environmental attributes.** Geothermal energy is a renewable resource. No fossil fuels are consumed, but the potential for release of pollutants, potential impacts to ground and surface water, and land use issues make it difficult to site in wilderness areas.

NATURAL GAS: COMBINED-CYCLE COMBUSTION TURBINES & SIMPLE-CYCLE COMBUSTION TURBINES

Combustion turbine technology has been used to generate electricity for several decades. Natural gas generation technologies considered for the 2016 IRP are CCCTs and SCCTs.

NATURAL GAS	
Technology & Fuel	There are two types of combustion turbines. The CCCT uses the combustion turbine to generate power and then recovers exhaust heat from the combustion turbine to make steam for a turbine generator that in turn produces additional power. The simpler and less fuel-efficient SCCT generates power directly, without recovery of exhaust heat. CCCTs are more complex than SCCTs, and have higher capital costs. However, CCCTs are more fuel-efficient, with total running costs lower than for SCCTs. Both CCCT and SCCT projects are primarily fueled with natural gas.
Current Status & Outlook	In the Pacific Northwest, there are approximately 5000 megawatts of CCCT generating capacity. The region also has slightly more than 1,500 megawatts of SCCT generating capacity. Natural gas project capacities range anywhere from less than 1 MW to 689.4 MW. Historically, volatile natural gas prices and surplus generating capacity in the Pacific Northwest slowed the development of new combustion turbine generating projects until recently. New shale gas supplies and much lower natural gas prices created an increase in natural gas-fired generation development.
Characteristics	**Transmission requirements.** Siting requires access to a natural gas pipeline in addition to electric transmission. **Dispatchability.** Combustion turbines are highly dispatchable. SCCT generating units can go from a cold start to full operation in less than 10 minutes. CCCT generating projects can be started up and shut down in a matter of hours. Combustion turbines operate at highest efficiency under full load. Because SCCT generating projects have higher operating (fuel) costs than CCCT generating projects, SCCTs are usually used to meet peak load requirements and provide standby resources for system reliability purposes. CCCT generating projects are normally used more for base load and mid-range purposes. **Environmental attributes.** Combustion turbines emit carbon dioxide, small amounts of sulfur dioxide (SO2), nitrogen oxides (NOX), and other air pollutants. Control technologies are used to eliminate most emissions of SO2 and NOX. CO2 production remains a major consideration. Some projects require large amounts of water, and there are other impacts from fuel extraction and transportation.

HYDRO

In previous IRPs it has been assumed that the current BPA contract would be renewed at the end of 2028. City Light's BPA hydro contract averages anywhere from 39% to 41% of the resource portfolio. In this IRP, the BPA contract expires at the end of September 2028, allowing City Light to identify potential options or cost-effective modifications that could impact the resource portfolio.

MARKET RESOURCES

A transmission grid system that serves the 11 states of the Western Region enables City Light to participate in many types of wholesale power market transactions. Seasonal exchanges and short-term energy and capacity purchases can be used to "reshape" power from spring to winter, allowing City Light to sell generation when loads are low or generation is high and to buy generation in the wintertime from other producers when loads are high or generation is low.

Seasonal Exchanges

A seasonal exchange is a power transaction that takes advantage of the seasonal diversity between Northwest (winter peaking) and Southwest (summer peaking) loads. City Light can transfer firm power from north to south during the Southwest's summer load season and from south to north during the Northwest's winter load season. Exchanges are helpful in meeting the utility's seasonal resource needs since it enables the utilities in different locations to maintain less generating capacity than would otherwise be necessary. City Light's current portfolio includes a seasonal exchange with Northern California Power Agency (NCPA).

Exchanges are often done on a megawatt-hour for megawatt- hour basis, though the actual delivery schedules of firm energy in the exchange may vary. For example, one utility could deliver 25 aMW for four months of the year while the other utility delivers 50 aMW for two months of the year. In modeling exchanges, energy transfers were not megawatt-hour for megawatt-hour on a calendar year basis, since winter transfers to Seattle occur from November through February, bridging calendar years, while transfers during the summer months occur within the same calendar year.

When assessing seasonal exchanges or short-term energy "reshaping" transactions, City Light first determined whether or not the utility will have sufficient rights to firm transmission capacity available along the transmission path between the winter peaking utility (such as City Light) and the summer peaking utility (such as those in California or the Desert Southwest).

Another important consideration in assessing exchanges is ensuring that the total amount of energy City Light delivers during the summer months does not deprive City Light of the energy needed to meet growing summer loads.

RESOURCE ADDITIONS AND PORTFOLIO DESIGN CONSIDERATIONS

In planning the 2016 IRP and considering new resources, City Light examined the particular characteristics of each resource. The requirements of the Renewable Portfolio Standard (RPS, which was previously known as I-937), the use of Renewable Energy Credits (RECs), and the future need for new transmission for new resources. These considerations are described below.

Renewable Portfolio Standard

I-937, the Energy Independence Act, was passed by Washington voters in November 2006 and became the Renewable Portfolio Standard. Without purchasing any additional resources, City Light meets the renewable resource requirement through 2024 because of wind energy purchased from the Stateline Wind Project and forward purchases of renewable energy credits (RECs). Until then, resource adequacy is the main consideration in renewable resource acquisition choices.

Renewable Energy Credits

Renewable Energy Credits (RECs) are tradable certificates that represent the environmental attributes of one megawatt-hour of electricity generated by a power plant that is a qualifying renewable resource under state law. Evaluation of REC strategies is an important issue in the IRP process. Targets for RPS compliance were established based upon the formula and information stated within the 2006 legislation (RCW 19.285), rulemaking, and City Light's long-range load forecast. RCW 19.285 requires electric utilities to have 15 percent of their energy provided by new, qualifying renewable resources by 2020. Since the 2010 IRP, the utility has acquired renewable resources and sufficient RECs to meet RPS requirements through the year 2024.

REC prices in the Pacific Northwest have fallen precipitously as the result of legislation, regulatory decisions in California, and transmission congestion. In a 2012 decision by the California Public Utilities Commission, the amount of RECs that can be purchased from outside California was capped. California's SBX1-2 increases the requirements for renewable energy under the renewable portfolio standard, but at the same time it limits the use of tradable renewable energy credits (TRECs) to 25 percent of a utility's requirement. Additionally, by 2017 and thereafter, California's cap on TRECs will tighten to 10 percent. In October 2015 California's legislature passed SB 350 which increases RPS requirements to 50 percent by 2030. In 2016, the Oregon legislature passed SB 1547 which increases RPS requirements to 50 percent by 2040 and a total phase-out of coal fired electricity by 2035. Pacific Northwest wind generators are also constrained from selling wind energy (including the associated RECs) in California and Oregon by transmission congestion. The combined effects of regulatory decisions and transmission constraints greatly diminished the Pacific Northwest market for RECs.

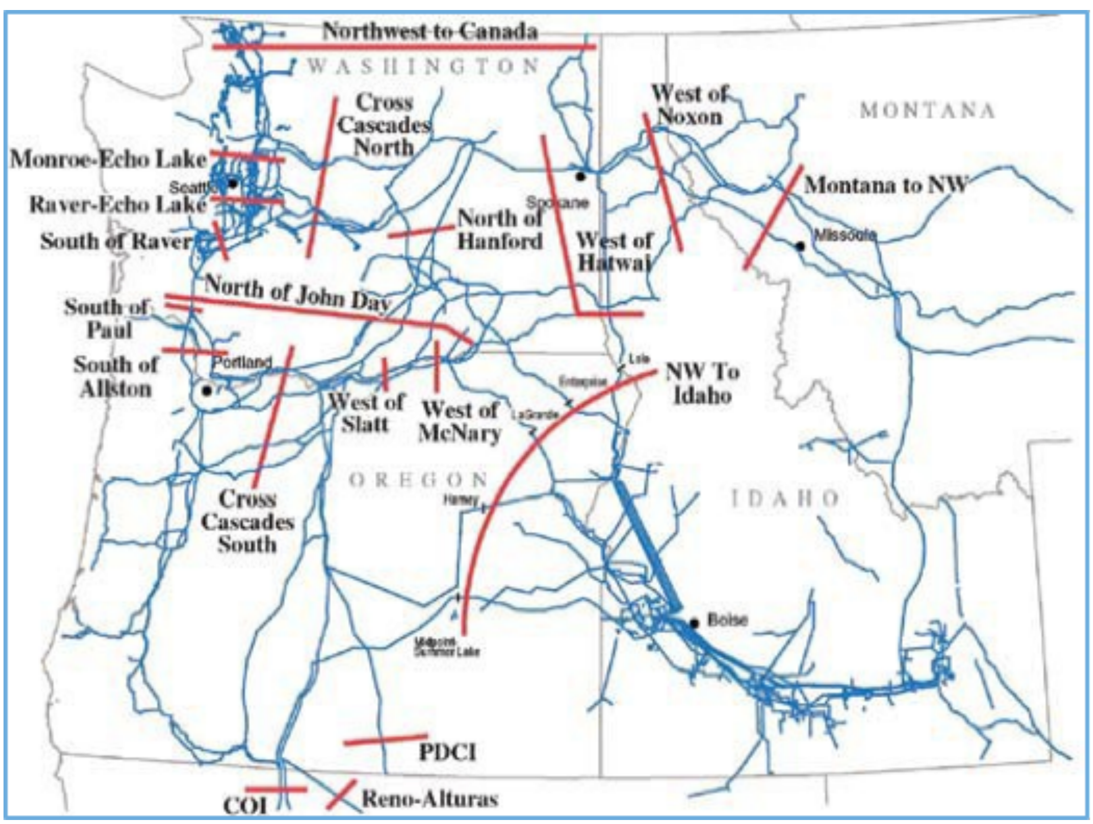
City Light's estimated long-term cost of RECs is expected to be lower for this IRP as a result of regulatory action in the WECC sub-regions, transmission constraints between geographical areas, and an overall regional declining trend in demand largely caused by energy efficiency. REC costs are small in comparison to costs of other resources and have no impact on relative portfolio rankings.

Transmission for New Resources

City Light owns only 657 miles of transmission facilities – primarily from the Skagit Hydroelectric Project to its service area – and a share of the Third AC Intertie. The utility is dependent upon access to transmission systems owned by others to reach the Western power market for balancing its seasonal power supply surpluses and deficits, as well as gaining access to new power supplies in the future. The capacity of the existing regional transmission system – of which approximately 70 percent is owned and operated by BPA – is almost fully subscribed, and available capacity on key transmission paths is extremely limited. The congested transmission paths, or flow gates, in the Northwest are shown in Figure 3.

As congestion in the Western grid continues to increase, existing firm transmission rights become more valuable and acquisition of new transmission capacity from existing transmission providers becomes more difficult. As the transmission system ages, maintenance outages that are more frequent and of longer duration will be needed to maintain system capacities and prevent path deratings. Scheduled outages often cause inefficient management of generation resources. Energy efficiency seems to be the most cost-effective option to avoid the high costs of new transmission lines in addition to the more obvious environmental benefits. The likely upgrade on BPA's transmission system could potentially be the integration of renewable resources by utilities from the area, however given the high costs of integration and new transmission, it is unlikely to occur in the near term. City Light will monitor whether or not new transmission facilities can be permitted and built to see if new generating resources can be delivered to Seattle.

Figure 3: Northwest Constrained Transmission Paths



TRANSMISSION CONTRACTS

City Light has long-term firm transmission contracts that provide point-to-point (PTP) contract demand rights of approximately 2,000 MW. These rights are predominantly purchased from BPA under its FERC-compliant open-access transmission tariff and provide distinct quantities of transmission capacity on a point-of-receipt to a point-of-delivery basis. These rights provide City Light with some flexibility to secure firm transmission for resources located to the east and south of Seattle. City Light also has transmission agreements for lesser quantities of transmission service with PacifiCorp, Idaho Power, Avista and Puget Sound Energy.

City Light has reserved most of this transmission capacity for current operations by designating the plant capacity at the point-of-receipt, thus leaving limited transmission transfer capability available for use in acquiring future distant resources.

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[1] Renewable Portfolio Standard (RPS)

[2] Production Tax Credit (PTC) and Investment Tax Credit(ITC)

[3] EIA Annual Energy Outlook 2011: Table 1. Estimated Levelized Cost of New Generation, 2016. U.S. Average Levelized Costs (2009 $/MWh) for plants entering service in 2016

[4] EIA Annual Energy Outlook 2015: Table 1. Estimated levelized cost of electricity (LCOE) for new generation resources, 2020. U.S. Average Levelized Costs (2013 $/MWh) for plants entering service in 2020

CONSERVATION POTENTIAL ASSESSMENT

1.1. Overview

In 2015, City Light completed a Conservation Potential Assessment (CPA), which is a rigorous estimate of conservation resources available within its service territory. This study identified the magnitude, timing, and costs of energy efficiency potential in each of City Light's major customer sectors, including residential, commercial, industrial, and street lighting. The CPA is used to meet legal requirements associated with Washington Initiative 937 (I-937), as well as to support City Light's 2016 Integrated Resource Plan (IRP). Primary objectives were to:

- Develop comprehensive energy conservation measure (ECM) data sets;
- Categorize the energy savings potential from these ECMs by market sector, segment, and building type;
- Using an avoided cost forecast, calculate the total resource cost (TRC), and measure levelized cost of the ECMs;
- Determine the conservation potential for 2016–2035, divided into 2-,10-, and 20-year increments; and
- Provide supply curves of achievable potential as inputs to the IRP.

This study relied on City Light-specific data, compiled from the Residential Building Stock Assessment (RBSA), Commercial Building Stock Assessment (CBSA) conducted in the City Light service territory, and other regional data sources. This study used a methodology consistent with the Northwest Power and Conservation Council's (the Council) 7th Power Plan and incorporates savings and costs for all energy ECMs in the Council's draft 7th Plan workbook and active Regional Technical Forum (RTF) unit energy savings (UES) workbooks. City Light partnered with CADMUS to complete the analysis, and the full CPA report can be found at: http://www.seattle.gov/light/conserve/cv5_pub.htm.

1.2. Analysis Approach

City Light's methodology can be best described as a combined "top-down/bottom-up" approach. The top-down component started with the most current load forecast and adjusts for building codes, equipment efficiency standards, and market trends. Then, the adjusted load forecast was disaggregated into sector (residential, commercial, industrial) and end-use components (lighting, HVAC, etc). The bottom-up component considered potential technical impacts of various ECMs on each end-use. Impacts were then estimated based on engineering calculations, current market saturations, technical feasibility, and costs.

This approach offered two advantages:

- First, savings estimates would be driven by a baseline calibrated to City Light's forecasted sales (2016 through 2035). Other approaches may simply generate the total potential by summing estimated impacts of individual measures, which can result in total savings estimates representing unrealistically high or low baseline sales percentages.
- Second, the approach maintained consistency among all assumptions underlying the baseline and alternative forecasts (technical, economic, and achievable potential). The alternative forecasts changed relevant inputs at the end-use level to reflect ECM impacts. As estimated savings represented the difference between baseline and alternative forecasts, these savings could be directly attributed to specific changes made to analysis inputs.

1.3. Energy Conservation measure (ECM) Data

City Light developed a comprehensive database of technical and market data for ECMs; these applied to all end-uses in various market segments. This database included the following measures:

- All measures included in the Council's Draft 7th Northwest Power
- Regional Technical Forum Measures (RTF)
- Particular technologies that required a Seattle-specific forecast, notably enterprise data center, indoor agriculture, and street lighting measures

City Light only included Council and RTF measures applicable to sectors and market segments within City Light's service territory. For example, the study did not characterize measures for the agriculture sector or for the residential manufactured home segment as these represented a small fraction of City Light's customer mix. Total measure count is shown in Table 1 below and the permutations by building type.

TABLE 1–MEASURE COUNTS AND PERMUTATIONS

Sector	Unique Count	Permutations
Residential	234	887
Commercial	1,311	3,130
Industrial	39	379
Street Lighting	6	24
Total	1,590	4,420

1.4. Definitions of Potential

This study includes analysis of four sectors. Within most of these sectors, City Light considered multiple market segments, construction vintages (new and existing), and end-uses. Specifically, the analysis addressed the following sectors:

- Residential: Single-family and three types of multifamily homes (low-rise, mid-rise, and high-rise)
- Commercial: Eighteen major commercial segments, including enterprise data centers
- Industrial: Primarily process-driven and manufacturing customers
- Street Lighting: City-owned street lighting

For each sector, City Light developed a baseline end-use load forecast that assumes no new future programmatic energy efficiency. The baseline forecast includes savings from building energy codes, equipment standards, and other naturally occurring market forces. Energy efficiency potential estimates were calculated by assessing the impact of each ECM on this baseline forecast. Therefore, conservation potential estimates presented in this report represent savings beyond naturally occurring savings. This study considers three types of energy efficiency potential:

- Technical potential includes all energy efficiency measures that could technically be installed and reduce energy, regardless of costs and market barriers. This is the theoretical upper bound of available conservation potential, estimated after accounting for technical constraints.
- Economic potential represents a subset of technical potential, consisting only of measures meeting cost-effectiveness criteria based on City Light's avoided supply costs for delivering electricity. Adherent to WAC 194-37-070, City Light uses the Total Resource Cost (TRC) to identify cost-effective measures using a method consistent with the Council.
- Achievable economic potential represents the portion of economic potential that is achievable now, or predicted to become achievable in the course of the 20-year study horizon based on an understanding of the market. Ramp rates, defined as the acquisition rates for specific technologies, determine the amount of economic potential considered achievable on an annual basis, beginning in 2016.

1.5. Results

Table 2 shows baseline sales and cumulative savings potential by sector over the entire study period (2016-2035) and include line losses. Results indicate 362 aMW of technically feasible conservation potential (27% of baseline sales) by 2035, with an estimated 257 aMW (19% of baseline sales) that is both cost-effective and technically feasible (economic potential). Cumulative achievable economic potential equals 205 aMW in 2035 (15% of baseline sales). Note that achievable economic potential is used to set the savings targets for I-937 target setting and the IRP.

TABLE 2 TECHNICAL, ECONOMIC, AND ACHIEVABLE POTENTIAL BY SECTOR – 2035

Sector	Baseline Sales	Technical Potential		Economic Potential		Achievable Economic Potential	
		aMW	Percent of Baseline	aMW	Percent of Baseline	aMW	Percent of Baseline
Residential	370	121	33%	59	16%	49	13%
Commercial	740	226	31%	186	25%	146	20%
Industrial	208	12	6%	10	5%	9	4%
Street Lighting	10	2	22%	2	22%	2	22%
Total	1,328	362	27%	257	19%	205	15%

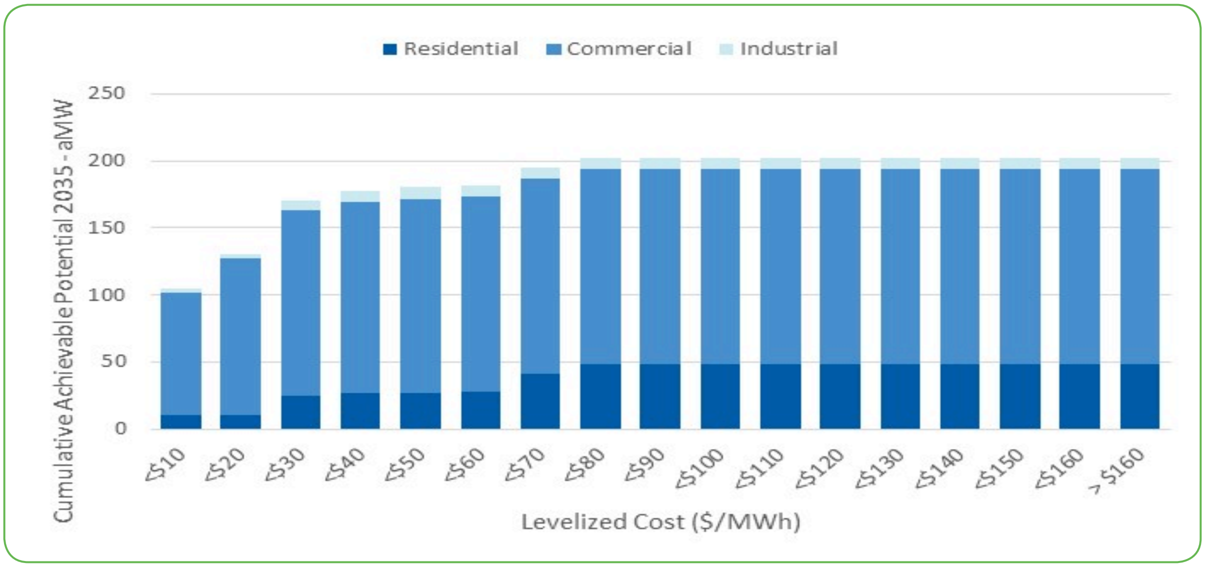
Table 3 shows the achievable economic potential, broken down by time period. Note that the potential reflects a front loaded savings acquisition: approximately 63% of the 20-year conservation potential is achieved within the first 10 years. City Light determined the acquisition rate of incremental achievable potential by each measure's ramp rate, applying ramp rates developed by the Council for the 7th Power Plan, and modified the application of these ramp rates based on Seattle's historic energy efficiency achievements. Consistent with its largest proportion of baseline energy use, the commercial sector accounts for the largest portion of the savings, followed by the residential and then the industrial sectors. Note that 20% of 10-Year Potential is the calculation used for I-937 target setting.

TABLE 3–CUMULATIVE ACHIEVABLE POTENTIAL BY SECTOR

Sector	Achievable Economic Potential - aMW			
	Two-Year (2016-2017)	10-Year (2016-2025)	20-Year (2016-2035)	20% of 10-Year Potential
Residential	5.9	36.5	48.6	7.3
Commercial	10.3	82.2	145.9	16.4
Industrial	1.7	7.1	8.8	1.4
Street Lighting	2.2	2.2	2.2	0.4
Total	20.1	128.1	205.4	25.6

The energy efficiency supply curve in Figure 1 shows cumulative achievable potential in $10/MWh levelized cost bins. This figure reflects to amount of energy efficiency over the study period that can be captured at increasing cost thresholds. City Light identified cost-effective energy efficiency potential up to $80/MWh. Efficiency measures with relatively high levelized costs tend to deliver savings over a very long time period or have significant deferred transmission and distribution benefits. Study results indicate that energy efficiency is a low cost resource, with roughly 177 aMW of achievable economic potential at a cost of less than $40/MWh levelized–this represents nearly 88% of total cumulative 20-year achievable potential.

Figure 1– Supply Curve, Achievable Economic Potential (All Sectors)



Lighting measures in both the residential and commercial sectors account for a large portion of savings, and many of these measures have relatively aggressive ramp rates. The figures below compare the available savings by end-use over the entire study period. Note that new LED lighting measures have largely driven this increase in relative potential.

Figure 2 – Achievable Residential Potential by End-use

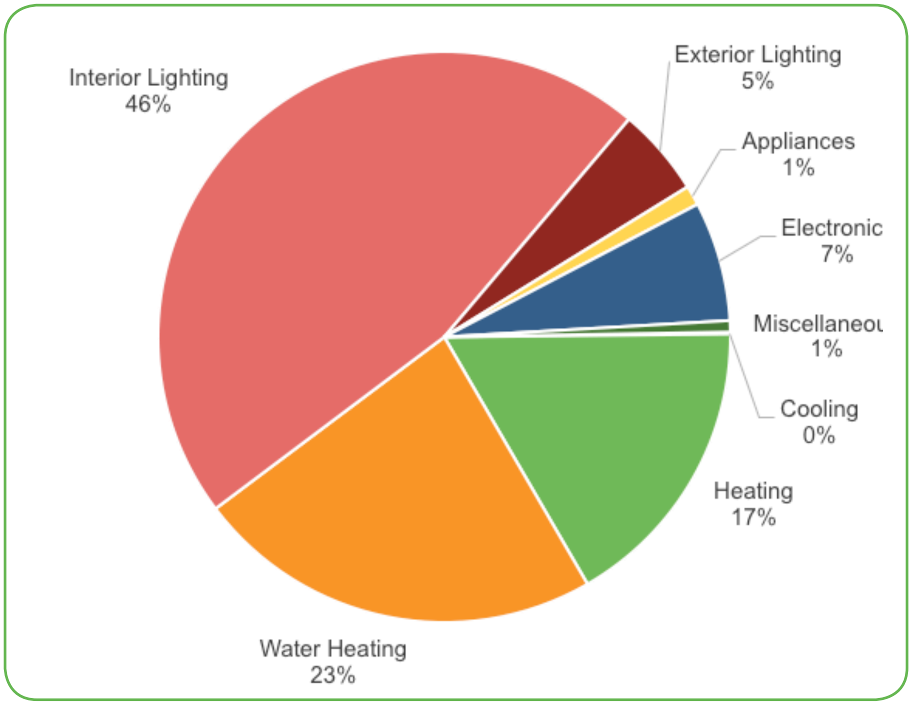
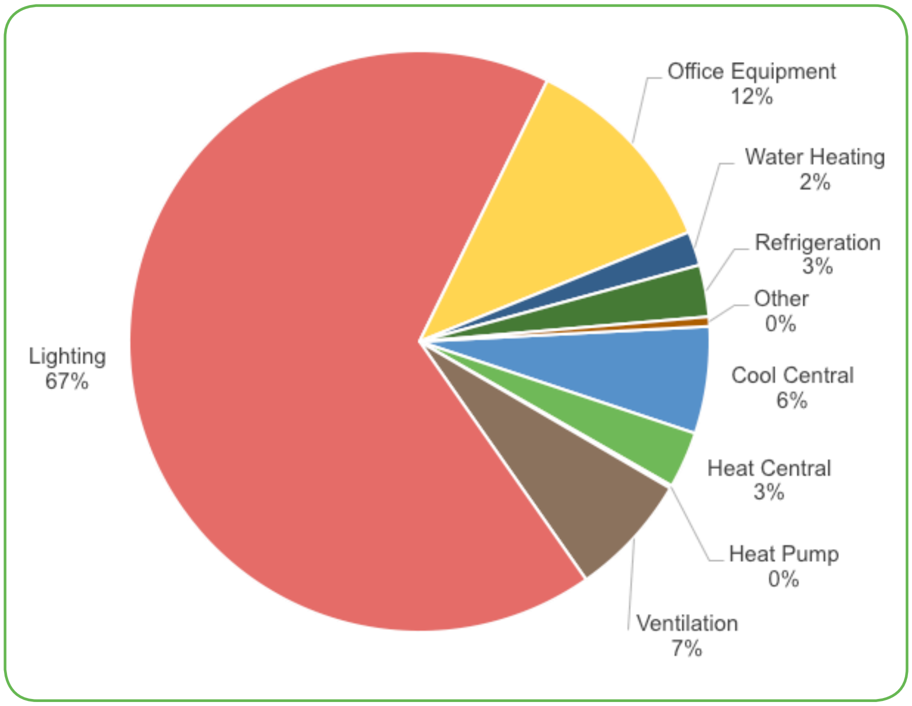


Figure 3 – Achievable Commercial Potential by End-use



1.6. Comparison to Previous CPA

The 2016 CPA differs from the 2014 CPA in several key ways:

- Residential: The 2016 CPA indicates lower residential technical, economic, and achievable potential as a fraction of baseline load than those indicated in the 2014 CPA. This largely results from reduced savings potential for home electronics measures. While efficient home electronics accounted for 22% of economic potential in the 2014 CPA, the end-use group only accounts for 7% of economic potential in the 2016 CPA. Compared to the 2014 CPA, the 2016 CPA found that a higher proportion of home electronics are already efficient, which contributed to lower savings potential.
- Commercial: The 2016 CPA indicates similar commercial potential as a fraction of load comparable to the 2014 CPA, but the potential savings derive from a different mixture of measures than those used in the 2014 CPA. For example, water-heating measures accounted for 11% of the 20-year economic potential in the 2014 CPA; in the 2016 CPA, they account for roughly 2% of economic potential. This decrease is due to lower assumed savings for tank type water heaters and reduced water heater baseline consumption.
- Industrial: The 2016 CPA indicates significantly lower industrial achievable economic potential as a fraction of baseline sales in the 2016 CPA (4%) than does the 2014 CPA (8%). This primarily results from program accomplishments. City Light achieved approximately 30,000 MWh savings in the industrial sector from 2014 through 2016. Additionally, projects expected to complete in 2016 will contribute an additional 10,000 MWh savings. This 40,000 MWh is equivalent to approximately 40% of the estimated 20-year industrial potential identified in the 2014 CPA.
- Street Lighting: The 2016 CPA indicates street lighting potential is roughly 50% lower than estimated potential in the 2014 CPA. This decrease in potential results from the City of Seattle's recent LED conversions.

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[1]https://www.nwcouncil.org/energy/powerplan/7/technical

[2]http://rtf.nwcouncil.org/measures/Default.asp

CANDIDATE RESOURCE PORTFOLIO DEVELOPMENT

This appendix provides an overview of the process for developing resource portfolios to meet power supply needs for the utility during the next 20 years. When constructing the resource portfolios the following items are taken into account to develop potential resource combinations (“candidate portfolios”): the load forecast, regulations, resource adequacy, air emissions rates and costs, energy efficiency potential assessment, resource options, and public involvement.

Before selecting a single resource plan to meet the power supply needs as an Integrated Resource Plan (IRP) does, it is necessary to evaluate available resource options to meet these needs and develop candidate portfolios. The Resource Options appendix describes in more depth the resource options considered in this IRP that are used in the development of candidate portfolios.

To develop candidate portfolios City Light uses an optimization tool. The optimization tool constructs the lowest cost possible combinations of alternative resource combinations to meet resource needs that consider regulatory requirements and commercially available technologies. Constraints are set up to take into account City of Seattle, stakeholder, and customer preferences for resource mixes. This approach provides the ability to look at a broad range of options before recommending an IRP preferred plan for meeting resource needs.

Constructing Portfolios

The candidate resource portfolios each contain all of City Light’s current resources (owned generation and contracts). Contracts are assumed to end at their current expiration date. One key change from previous IRPs, is how City Light is treating the Bonneville Power Administration (BPA) contract. In the past, it was assumed that the BPA contract would be renewed, being that it is anywhere from 39 to 41 percent of the current resources portfolio on average. In the 2016 IRP, the contract is dropped in September of 2028 for seven of the nine portfolios evaluated to evaluate its competiveness. During portfolio development, different resource options were evaluated as potential replacements for the BPA contract. As determined by the resource needs shown in the resource adequacy study, each portfolio also contains different mixes of new power contracts and energy efficiency. The new resources in each portfolio were designed using an optimization program with criteria.

All candidate resource portfolios were designed to meet requirements for resource adequacy and compliance with the Washington State renewable portfolio standard (RPS) . Targets for RPS compliance were established based upon the formula and information stated within the 2006 legislation (RCW 19.285), rulemaking, and City Light’s system long-range load forecast. RCW 19.285 requires electric utilities to have 15 percent of their energy provided by new, renewable resources by 2020. Given the renewable portion of City Light’s current resource portfolio mix, the utility has acquired renewable resources and sufficient RECs to meet RPS requirements through the year 2024. After developing candidate resource portfolios their performance is tested, which is discussed in the Portfolio Analysis appendix. The nine candidate resource portfolios are presented as tables at the end of this appendix.

Based on the screening of resource options, the following resources were available to the optimization program to construct the candidate resource portfolios:

- Base Energy Efficiency
- High Achievement of Energy Efficiency
- Biomass Cogeneration
- Biomass CHP Gasification
- Biomass Landfill Gas
- Geothermal
- Wind
- Combined - Cycle Combustion Turbine (CCCT)
- Simple - Cycle Combustion Turbine (SCCT)
- BPA Hydro (for the portfolios where the existing BPA contract was not extended)
- Small Hydro
- Solar - Thermal
- Solar - Photovoltaic (PV)
- Renewable Energy Credits (RECs)
- Market purchase flexibility (up to 200 MW)

The portfolios were designed with the following objectives:

- Ensure that the resource adequacy and Energy Independence Act requirements are always met each year, and use RECs as needed to fill in short-term deficits.
- Use at a minimum all cost-effective energy efficiency identified in the most recent Conservation Potential Assessment as the first available resource;
- Maximize the use of cost-effective renewable resources in accordance with the Energy Independence Act requirement;
- Resources options are assumed to be Power Purchase Agreement (PPA) contracts with firm energy, such as a shaped BPA block. Since resource options are generic at the time of acquisition of resources the utility would need to decide whether contracts or owning resources make the most sense during the acquisition process.

PORTFOLIO OPTIONS

Using a multi-objective optimization process and considering stakeholder, customer, and City of Seattle preferences the following resource portfolio options were identified:

- BPA contract extension or consideration of a new smaller BPA hydro contract
- Presence or absence of 200 MW of market purchase flexibility
- Level of diversity in portfolios
- Base or high achievement of energy efficiency
- With and without natural gas fired generation (CCCT or SCCT)

Based on the preceding sections, Figure 1 compares the nine City Light's candidate resource portfolios for the 2016 IRP. All candidate portfolios show cumulative energy at the year ending 2035, with the exception of the RECs which are consumed each calendar year. The candidate resource portfolios were named to reflect the resource strategy, or a dominant new resource. Tables 1 to 9 identify resource additions by calendar year and technology type in cumulative average megawatts, with the exception of the RECs as explained.

Figure 1: Summary of Candidate Portfolio Options at year ending 2035 (cumulative aMW)

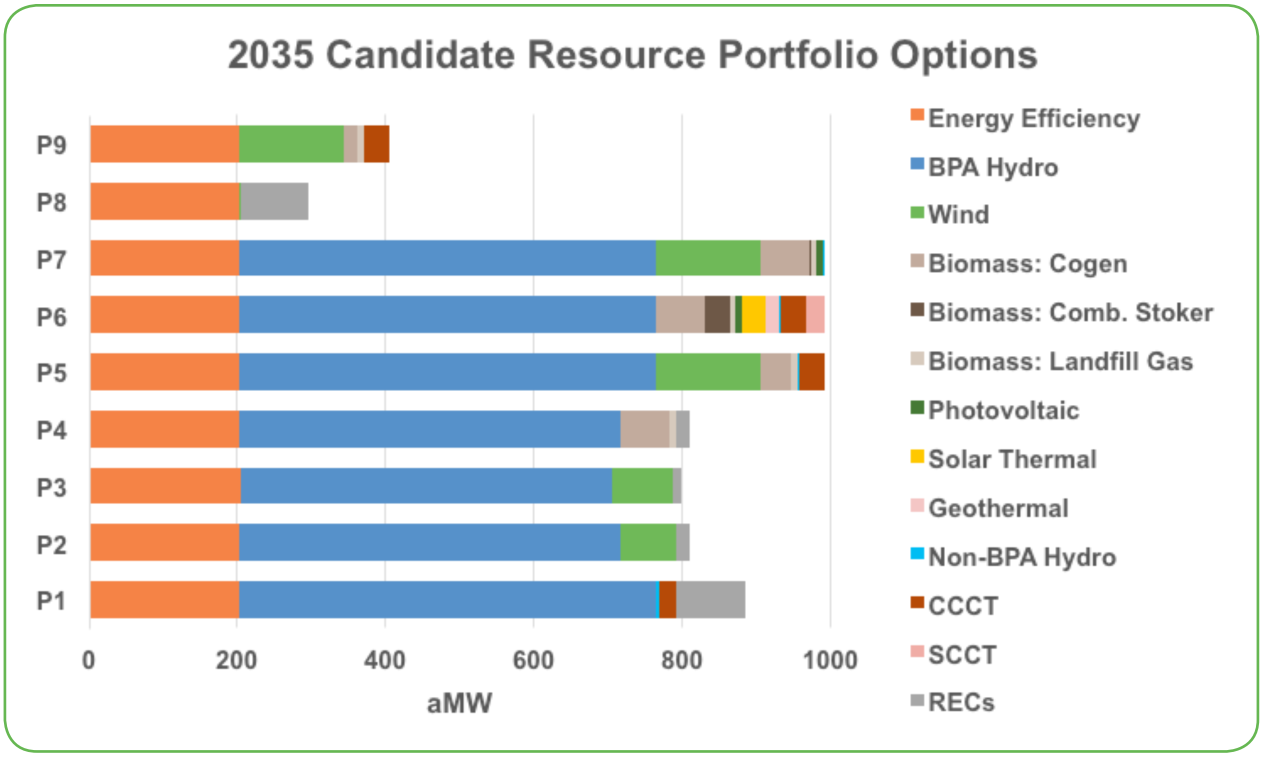


Table 1: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 1: Natural Gas with 200 Market Purchase Flexibility
(Average Megawatts)

	Energy Efficiency	Small Hydro	CCCT	BPA Hydro	RECs	Total RECs & Resources
2016	13					13
2017	25					25
2018	38					38
2019	50					50
2020	63					63
2021	75					75
2022	88					88
2023	100					100
2024	113				11	124
2025	125				13	138
2026	138				12	150
2027	149				57	206
2028	158	3	2	563	56	782
2029	167	3	10	563	61	804
2030	174	3	10	563	68	818
2031	181	3	10	563	75	832
2032	187	3	10	563	75	838
2033	192	3	10	563	76	844
2034	197	3	10	563	93	866
2035	202	3	24	563	93	885

Table 2: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 2: Wind with 200 Market Purchase Flexibility
(Average Megawatts)

	Energy Efficiency	Wind	BPA Hydro	RECs	Total RECs & Resources
2016	13				13
2017	25				25
2018	38				38
2019	50				50
2020	63				63
2021	75				75
2022	88				88
2023	100				100
2024	113			11	124
2025	125			13	138
2026	138			12	150
2027	149			57	206
2028	158	56	512		726
2029	167	61	515		743
2030	174	61	515	7	757
2031	181	61	515	14	771
2032	187	61	515	14	777
2033	192	61	515	15	783
2034	197	61	515	32	805
2035	202	75	515	19	811

Table 3: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 3: High Achievement of Energy Efficiency with 200 Market Purchase Flexibility (Average Megawatts)

	Energy Efficiency	Wind	BPA Hydro	RECs	Total RECs & Resources
2016	14				14
2017	29				29
2018	46				46
2019	61				61
2020	78				78
2021	94				94
2022	108				108
2023	121				121
2024	133			2	135
2025	143			12	155
2026	152			11	163
2027	160			56	216
2028	167	56	492		715
2029	175	60	500		735
2030	182	60	500	8	750
2031	188	60	500	14	762
2032	193	60	500	15	768
2033	197	60	500	15	772
2034	201	66	500	27	794
2035	205	83	500	10	798

Table 4: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 4: Renewables: No Wind with 200 Market Purchase Flexibility
(Average Megawatts)

	Energy Efficiency	Biomass: Cogen	Biomass: Landfill Gas	Photo-voltaic	BPA Hydro	RECs	Total RECs & Resources
2016	13						13
2017	25						25
2018	38						38
2019	50						50
2020	63						63
2021	75						75
2022	88						88
2023	100						100
2024	113					11	124
2025	125					13	138
2026	138					12	150
2027	149					57	206
2028	158	48	8		512		726
2029	167	53	8		515		743
2030	174	53	8		515		757
2031	181	53	8		515	14	771
2032	187	53	8		515	14	777
2033	192	53	8		515	15	783
2034	197	53	8		515	32	805
2035	202	66	8	1	515	19	811

Table 5: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 5: Renewables & Natural Gas
(Average Megawatts)

	Energy Efficiency	CCCT	Wind	Biomass: Cogen	Biomass: Landfill Gas	BPA Hydro	Total RECs & Resources
2016	13	3					16
2017	25	3					28
2018	38	34	52				124
2019	50	34	52				136
2020	63	34	52				149
2021	75	34	52				161
2022	88	34	52				174
2023	100	34	52				186
2024	113	34	52				199
2025	125	34	52				211
2026	138	34	52				224
2027	149	34	52				235
2028	158	34	141	19	8	563	926
2029	167	34	141	27	8	563	943
2030	174	34	141	27	8	563	950
2031	181	34	141	27	8	563	957
2032	187	34	141	27	8	563	963
2033	192	34	141	27	8	563	968
2034	197	34	141	27	8	563	973
2035	202	34	141	41	8	563	992

Table 6: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 6: Diversity
(Average Megawatts)

	Energy Efficiency	Geo-thermal	Bio-mass: Cogen	Bio-mass: Comb. Stoker	Small Hydro	CCCT	Photo-voltaic	Bio-mass: Landfill Gas	BPA Hydro	SCCT	Solar Thermal	Total RECs & Re-sources
2016	13					3						16
2017	25					3						28
2018	38					34		8				124
2019	50		44			34		8				136
2020	63		44			34		8				149
2021	75		44			34		8				161
2022	88		44			34		8				174
2023	100		44			34		8				186
2024	113		44			34		8				199
2025	125		44			34		8				211
2026	138		44			34		8				224
2027	149		44			34		8				235
2028	158	18	66	33	3	34	8	8	563	25	10	926
2029	167	18	66	33	3	34	8	8	563	25	18	943
2030	174	18	66	33	3	34	8	8	563	25	18	950
2031	181	18	66	33	3	34	8	8	563	25	18	957
2032	187	18	66	33	3	34	8	8	563	25	18	963
2033	192	18	66	33	3	34	8	8	563	25	18	968
2034	197	18	66	33	3	34	8	8	563	25	18	973
2035	202	18	66	33	3	34	8	8	563	25	32	992

Table 7: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 7: Diversity: No Gas
(Average Megawatts)

	Energy Efficiency	Biomass: Cogen	Biomass: Comb. Stoker	Wind	Photo-voltaic	Biomass: Landfill Gas	BPA Hydro	Small Hydro	Total RECs & Resources
2016	13			3					16
2017	25			3					28
2018	38			86					124
2019	50			86					136
2020	63			86					149
2021	75			86					161
2022	88			86					174
2023	100			86					186
2024	113			86					199
2025	125			86					211
2026	138			86					224
2027	149			86					235
2028	158	53		141		8	563	3	926
2029	167	61		141		8	563	3	943
2030	174	61		141		8	563	3	950
2031	181	61		141		8	563	3	957
2032	187	61		141		8	563	3	963
2033	192	61		141		8	563	3	968
2034	197	61		141		8	563	3	973
2035	202	66	1	141	8	8	563	3	992

Table 8: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 8: BPA Extension with 200 Market Purchase Flexibility
(Average Megawatts)

	Energy Efficiency	Wind	RECs	Total RECs & Resources
2016	13			13
2017	25			25
2018	38			38
2019	50			50
2020	63			63
2021	75			75
2022	88			88
2023	100			100
2024	113		11	124
2025	125		13	138
2026	138		12	150
2027	149		57	206
2028	158		56	214
2029	167		61	228
2030	174		68	242
2031	181		75	256
2032	187		75	262
2033	192		76	268
2034	197		93	290
2035	202	2	92	296

Table 9: Resource Portfolios Evaluated in the 2016 IRP
Portfolio 9: BPA Extension & Resource Mix
(Average Megawatts)

	Energy Efficiency	Bio-mass: Cogen	Wind	CCCT	Biomass: Landfill Gas	Total RECs & Resources
2016	13			3		16
2017	25			3		28
2018	38		90	34		162
2019	50		90	34		174
2020	63		90	34		187
2021	75		90	34		199
2022	88		113	34		235
2023	100		113	34		247
2024	113		120	34		267
2025	125		120	34		279
2026	138		120	34		292
2027	149		120	34		303
2028	158		120	34		312
2029	167		123	34		324
2030	174		129	34		337
2031	181		134	34		349
2032	187		134	34		355
2033	192		139	34		365
2034	197	1	141	34	8	381
2035	202	19	141	34	8	404

CANDIDATE PORTFOLIO ANALYSIS

ANALYSIS OF CANDIDATE RESOURCE PORTFOLIOS

This appendix presents the IRP analysis leading to the selection of a preferred IRP portfolio. Nine optimized candidate portfolios were constructed to meet resource adequacy requirements, RPS requirements, and Seattle City Council policies. Candidate portfolios were tested under different scenarios (stress testing) to identify the top performing portfolios measured by cost and financial risk. Similar to previous IRPs, the higher cost and risk portfolios were eliminated from further consideration and the three top performing portfolios identified as lowest cost and risk underwent additional testing. The top three portfolios were subjected to probabilistic risk analysis that varied key assumptions. After review of the top performing portfolios and consideration of how each meets the objectives for reliability, cost, and environmental responsibility, a preferred portfolio was selected.

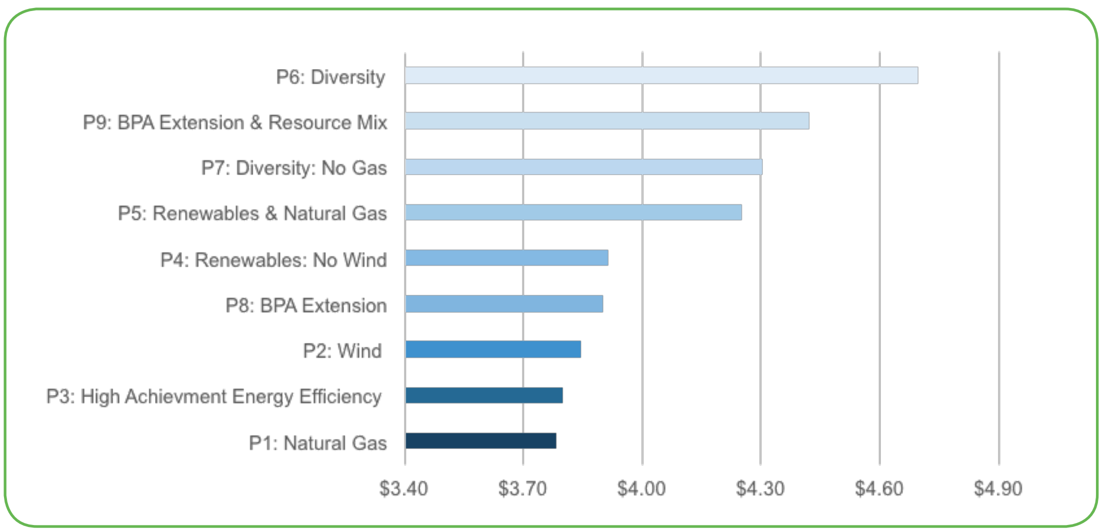
PERFORMANCE MEASURES OF PORTFOLIOS

The quantitative performance of each of the portfolios was evaluated based upon two metrics: cost and financial risk. Cost is measured as the net present value (NPV) of the net power costs (NPC) of the portfolios over the 20-year study period. The net power costs are the total costs of the portfolio, minus the revenues received from any surplus power sales. The net power costs of the portfolio include costs for emissions (if applicable) of carbon dioxide, sulfur dioxide, mercury, and particulates. Financial risk is measured based on the coefficient of variation (CV). CV measures the degree of deviation from the mean and is used to measure the annual volatility cost.

DETERMININSTIC ANALYSIS OF CANDIDATE PORTFOLIOS

First deterministic analyses were conducted on candidate resource portfolios for the years 2016 through 2035 under the expected demand, hydro conditions, fuel prices, and operating constraints. The net present values of the net power costs for each candidate portfolio are illustrated in Figure 1. Details about the resources included in each portfolio are in the Candidate Resource Portfolio Development Appendix. The descriptions in Figure 1 identify unique attributes about the candidate portfolio identified.

Figure 1: Net Present Value of the Net Power Cost by Candidate Resource Portfolios' Expected Conditions

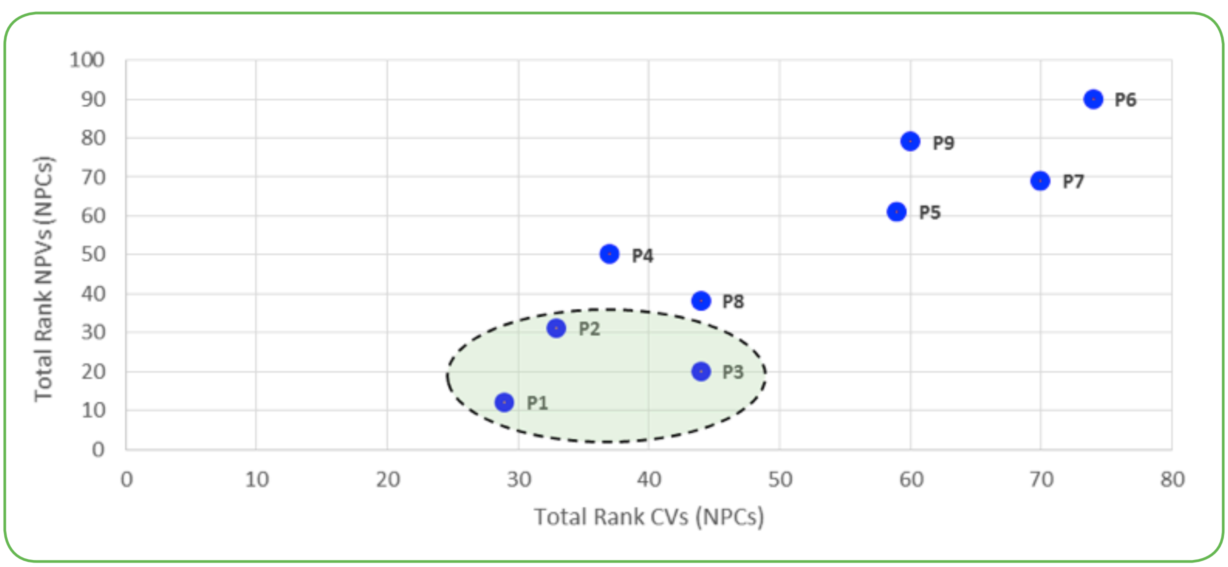


The candidate resource portfolios were further examined under different scenarios to evaluate their performance based on costs and risk measures. This process has resulted in the identification of the top performing portfolios. By performing scenario analysis, further stress testing was performed, analyzing the following nine individual changes from expected conditions:

- Low Demand Growth
- High Demand Growth
- Low Natural Gas Prices
- High Natural Gas Prices
- Low CO2 Prices
- Base CO2 Prices
- High CO2 Prices
- Low Water Conditions
- High Water Conditions

Since City Light's portfolio is 90% hydro, one of the most impactful scenario is low (dry) water conditions. Under such a scenario, Natural Gas (P1), Wind (P2), and High Achievement (P3) portfolios performed the best in comparison with other portfolios in terms of costs and risks. To identify the top performing portfolios, the results of the deterministic runs were ranked based on cost performance and separately ranked based on financial risk performance. The rank order is representative of how well the portfolio performed from a cost perspective (or financial risk perspective) in the 10 deterministic scenarios. If a portfolio was the lowest cost in all ten scenarios, its rank order would equal 10. If a portfolio was highest cost in all ten scenarios, its rank order would be 100. Figure 2 shows the cost vs financial risk performance using the total rank order of the candidate resource portfolios. Taking into consideration the expected results and the scenario analysis, the portfolios that performed the best were Natural Gas (P1), Wind (P2), and High Achievement of Energy Efficiency (P3). P1 having both the least cost and risk, P3 having the second least cost, and P2 having the second least risk.

Figure 2: Total Rank Order of Candidate Resource Portfolios (Cost and Risk)



Based on the preceding analyses, the top three portfolios were identified for further evaluation:

1. P1: Natural Gas
2. P2: Wind
3. P3: High Achievement of Energy Efficiency

All three top portfolios include a new BPA Hydro contract with a modest reduction in the energy purchased compared to the existing BPA contract. Each has similar amounts of reliable and cost-effective market purchase flexibility. At this point, the other portfolios were eliminated.

RISK MEASURE

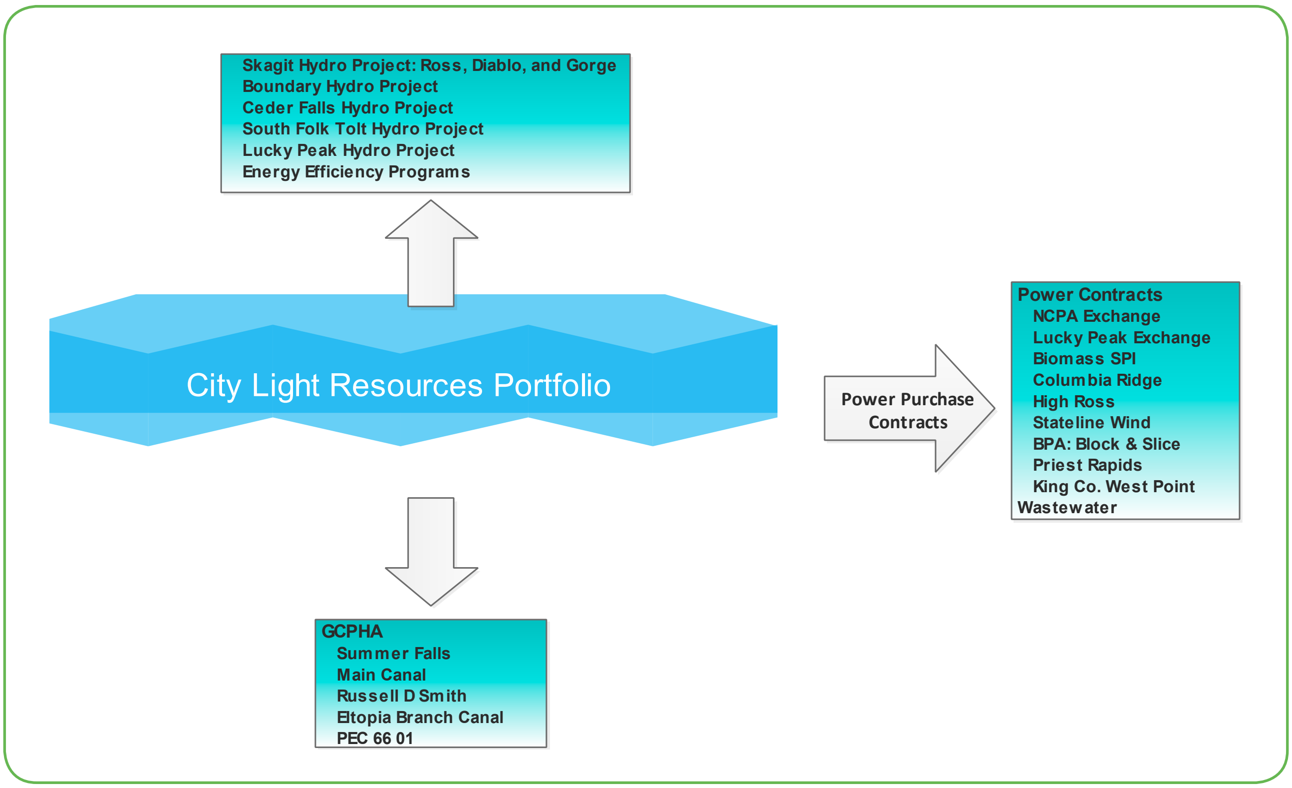
Volumetric risk analysis

Risk refers to the existence of volatilities that can result in adverse events. For Seattle City Light, risk refers to volatilities in supply resources and system load (demand). Volatility can affect City Light's ability to meet customer demand with cost-effective and environmentally-friendly generating resources at all times.

In general, risk analysis uses techniques to identify and assess the factors that cause these volatilities in supply and demand and help to design preventive measures to hedge against possible adverse events, increasing the reliability of City Light's power system.

A resource portfolio is a collection of power generating resources which is owned totally or partially by an entity or an organization. Figure 3 illustrates the elements of City Light's resource portfolio (existing resources).

FIGURE 3: SEATTLE CITY LIGHT RESOURCE PORTFOLIO (EXISTING RESOURCES)



City Light faces two main sources of risk that affect the reliability of its power system:

1. Demand risk is the volatility in customer demand (system load) which challenges City Light's ability to meet these changes in real-time, all the time, and
2. Supply risk is the volatility in the generation capabilities of City Light's power generating resources, which can affect its ability to meet customer demand.

Both of these sources of risk can change the reliability of City Light's power system. If adverse events for supply and demand are encountered singly or simultaneously, countermeasures need to be identified to successfully deal with these events.

City Light has elected to use a 90 percent reliability level of supply resources as the risk measure for meeting customer demand for the 2016 IRP. The volatility of supply and demand is incorporated into the probabilistic analysis for calculating this measure. For each portfolio, the expected net present value of annual net power costs corresponding to the 90 percent level of reliability has been calculated for purposes of evaluating the candidate portfolios.[1]

RISK ANALYSIS FOR SEATTLE CITY LIGHT

Developing Risk Metrics for City Light Resource Portfolios

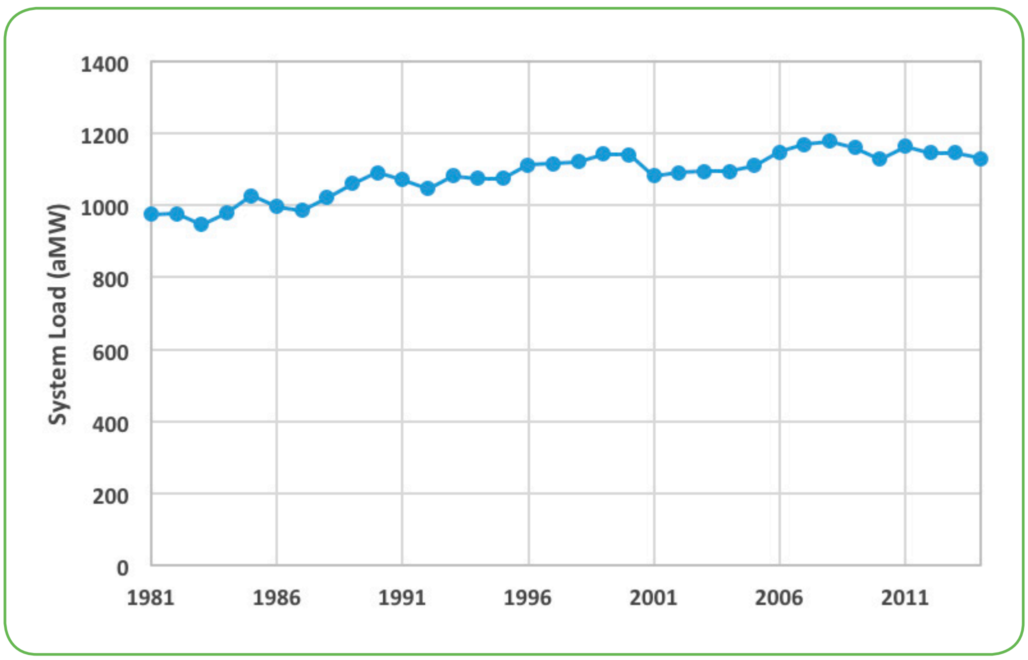
1. Demand, Supply and the Aggregate

a. Demand Risk

Demand volatility is one of the main sources of uncertainty for City Light's power system. On a yearly level, the most significant factor that causes this uncertainty is economic upturns and downturns.[2]

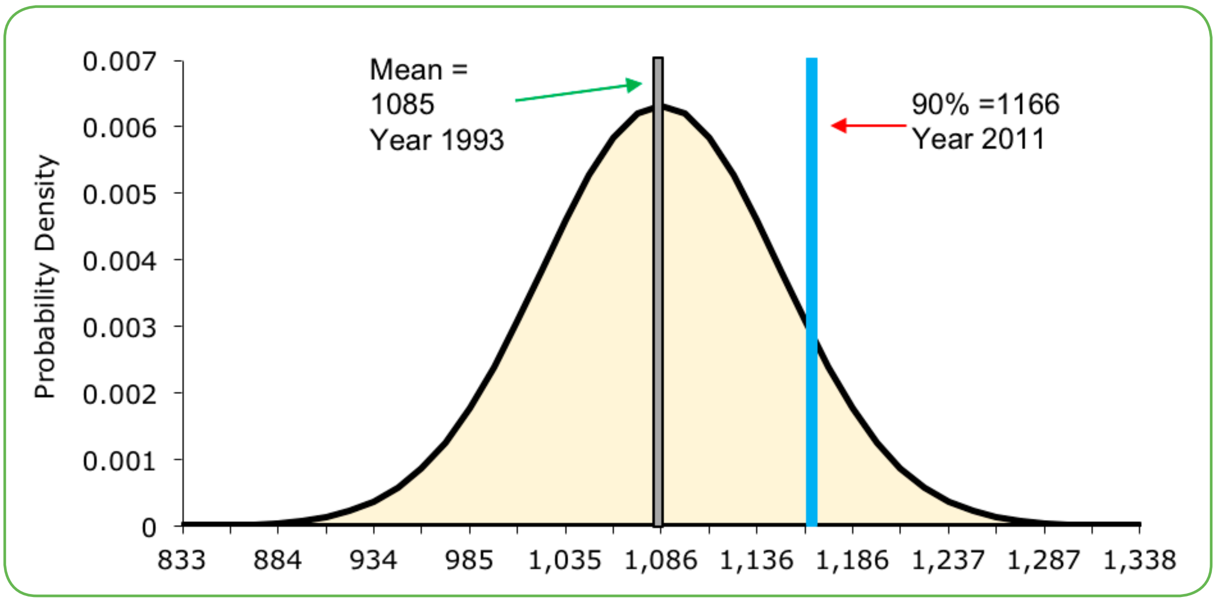
Figure 4 illustrates historical yearly demand data. As demand data moves progressively into more discrete time periods (e.g. annual to monthly to hourly), demand volatility becomes progressively higher.

FIGURE 4: Average yearly system load: 1981-2014



Our analysis concludes that City Light's yearly historical demand approximately follows a normal distribution pattern. A normal distribution, mean, and standard deviation are used for the purpose of simulation. Figure 5 illustrates the normal distribution fitted to the historical yearly demand.

FIGURE 5: Normal (Gaussian) distribution of average yearly historical Seattle City Light demand: 1981-2014

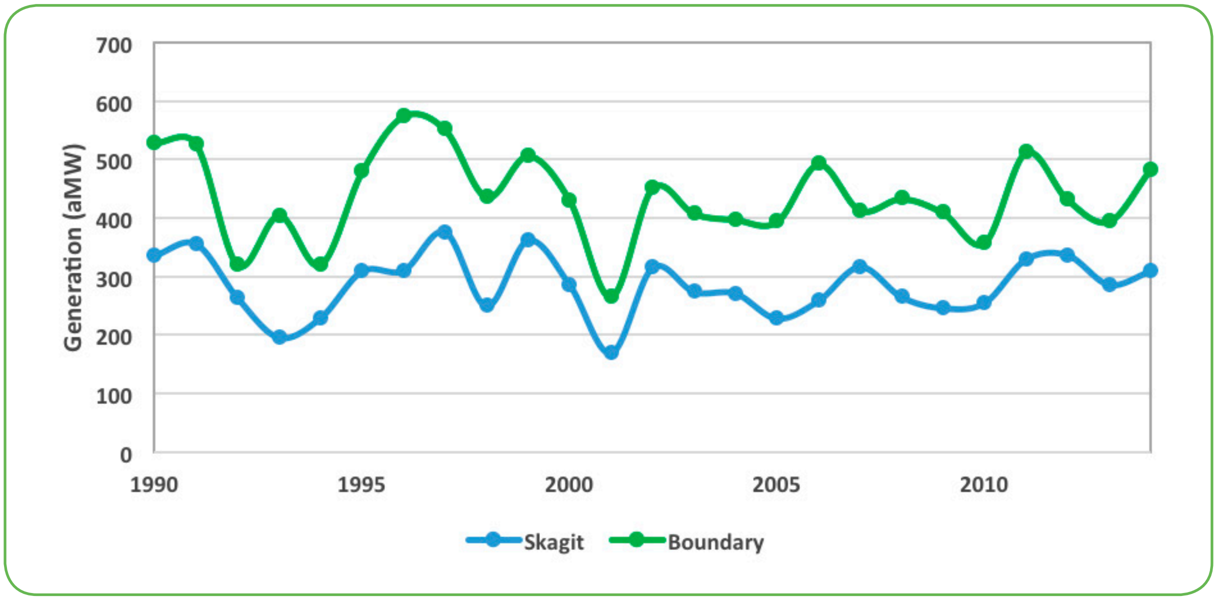


Economic expansions and contractions significantly affect the pattern of electric consumption in all three sectors of City Light customers (industrial, commercial and residential), which causes demand to deviate from expected consumption patterns. City Light completed statistical analyses on historical yearly demand data, 1981 to 2014, and demand volatility (historical variations) has been incorporated into the probability distribution analysis for simulation.

b. Supply Risk

About 90 percent of City Light's electric supply comes from hydro generation in a typical year. Yearly hydro generation capability is highly correlated to water conditions. Water conditions are very uncertain, thus hydro generation capability is very uncertain. This uncertainty in the supply of City Light's power system significantly affects its ability to respond to demand volatility and can affect resource reliability. Figure 6 illustrates historical yearly generation and the associated volatility of City Light's two main hydro projects, Skagit and Boundary, from 1990 to 2014.

FIGURE 6: Average yearly historical generation of Skagit and Boundary: 1990-2014



City Light has completed statistical analyses on yearly historical hydro generation, hydro volatility, and their cross-sectional correlations for Skagit, Boundary, and BPA's hydro resources (Appendix 4 - Resource Adequacy). As with demand, it is assumed that yearly historical hydro generation approximately follows a normal distribution. This assumption is supported by our statistical analysis. The historical mean of hydro generation and the associated standard deviation of each hydro project are taken into account in the probability distribution analysis. Yearly cross-sectional correlations between hydro projects are also taken into account for the total probability distribution analysis. These are incorporated into the probability distribution analysis for the purpose of simulation.

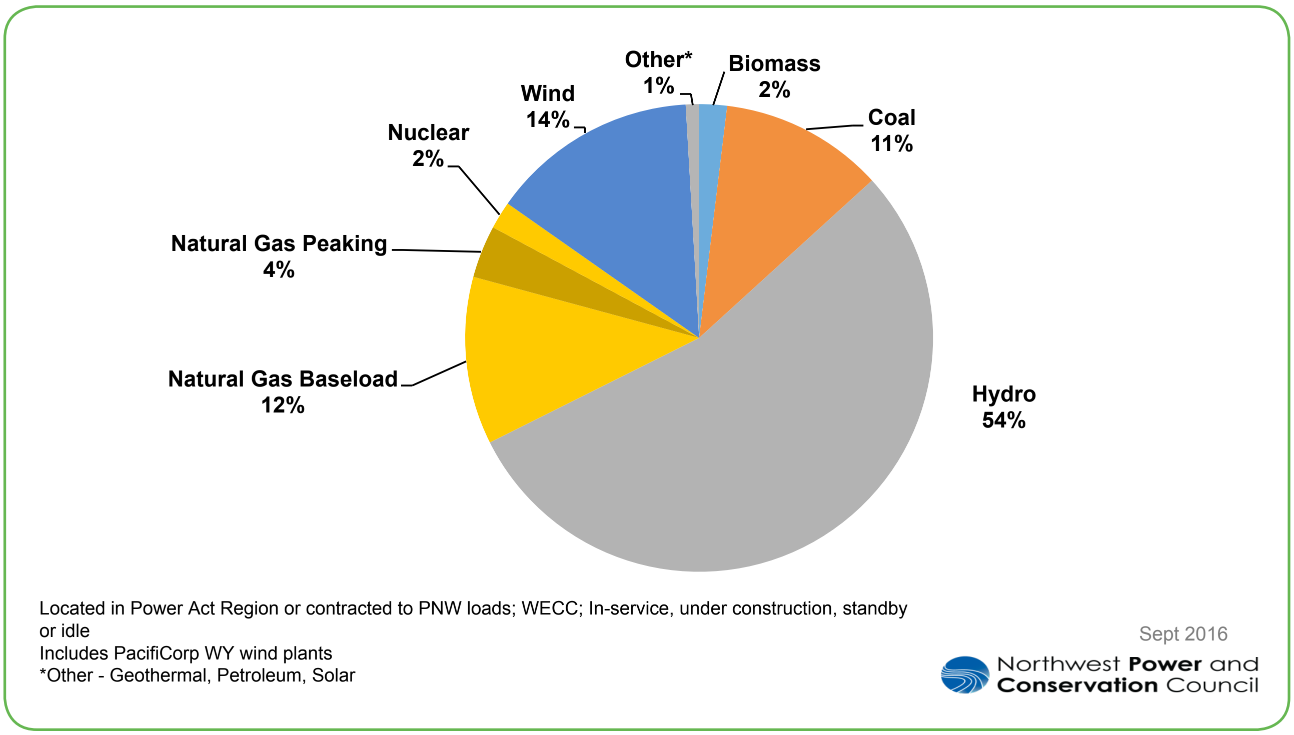
c. The Aggregate of Supply and Demand Uncertainties

If the uncertainties of demand and supply were highly correlated, it would be much easier to manage a balance between demand and supply for City Light's power system (load-resource balance). However, there is almost no correlation between these uncertainties. The simultaneous compositions of these uncertainties cause significant variation in the load-resource balance such that City Light's portfolio changes from surplus to deficit. ($S_T < D_T$) in some hours. The net deficits are associated with financial costs for City Light that accrues when power needs to be acquired from the wholesale market.

2. Fuel

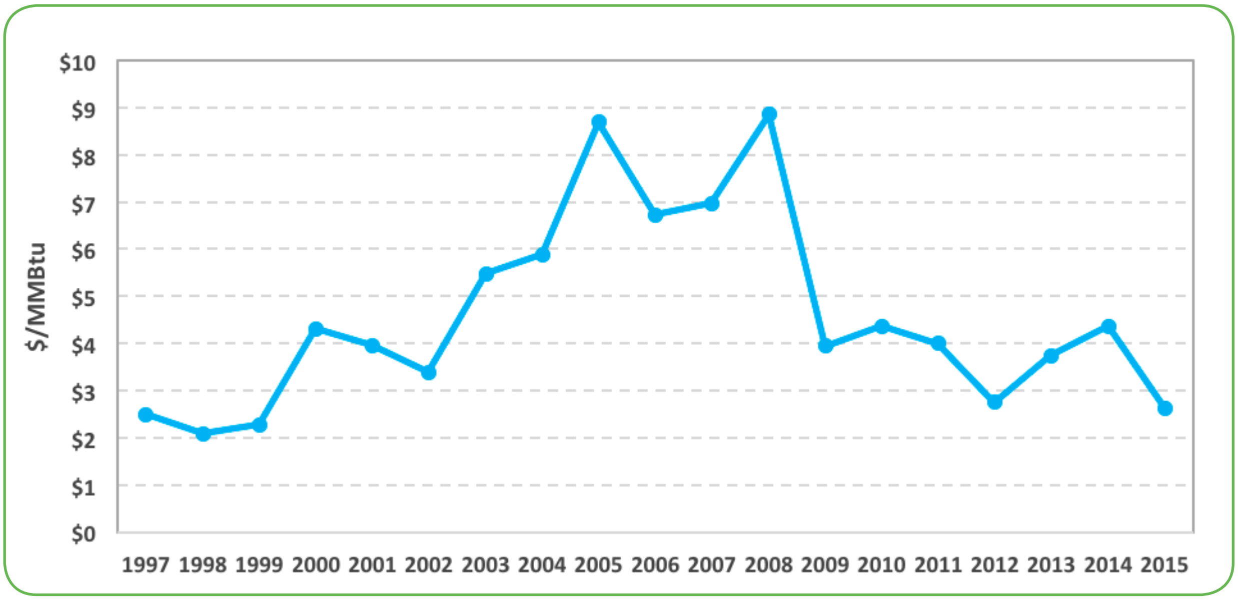
Approximately 50 percent of electric generation capacity in the Pacific Northwest is hydropower (Figure 7). Under current power market conditions, it is assumed that the market price of power is equal to the marginal cost. When market supply is less than market demand, the power prices equal the marginal costs of the incremental generating units that meet demand at any given time. The generic marginal units that are called on to meet demand are most often gas-fired generators such as combustion turbines. Given an average heat rate in the Pacific Northwest, fuel prices determine the average power prices when market supply is less than market demand. Therefore, natural gas prices are a determining factor for the financial costs associated with the net deficits for City Light's portfolio.

FIGURE 7: NORTHWEST INSTALLED NAMEPLATE CAPACITY - 83,103 MW[3]



City Light has completed statistical analyses on yearly historical natural gas prices to determine fuel price volatility. Figure 8 illustrates the yearly historical natural gas prices of Henry Hub from 1997 to 2015.

FIGURE 8: Henry Hub historical yearly gas prices: 1997-2015



It is assumed that yearly historical natural gas prices approximately follow a lognormal distribution pattern. Our statistical analysis supports this assumption. A lognormal distribution with the historical mean and associated standard deviation are taken into account in the probability distribution analysis for the purpose of simulation.

The risk function, in abstract form, can be formulated as follows:

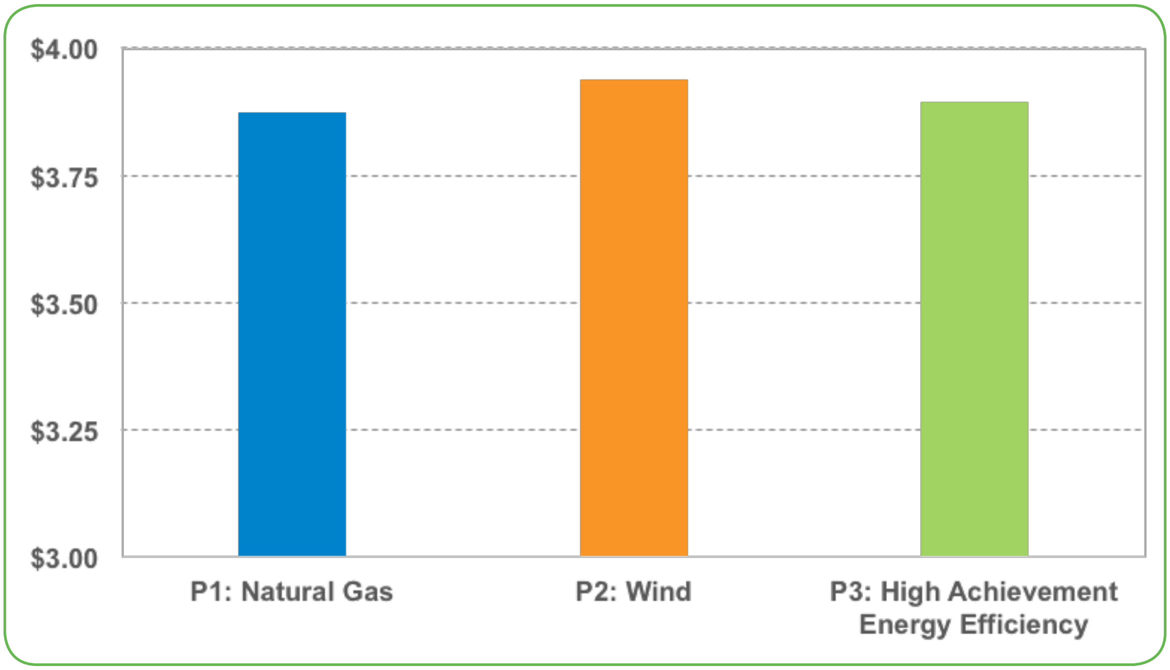
$$Risk_{T_{yr}} = \varphi(D_{T_{yr}}, H_{T_{yr}}, F_{T_{yr}})$$

This function is used to perform risk analysis on the best performing candidate portfolios.

RESULTS

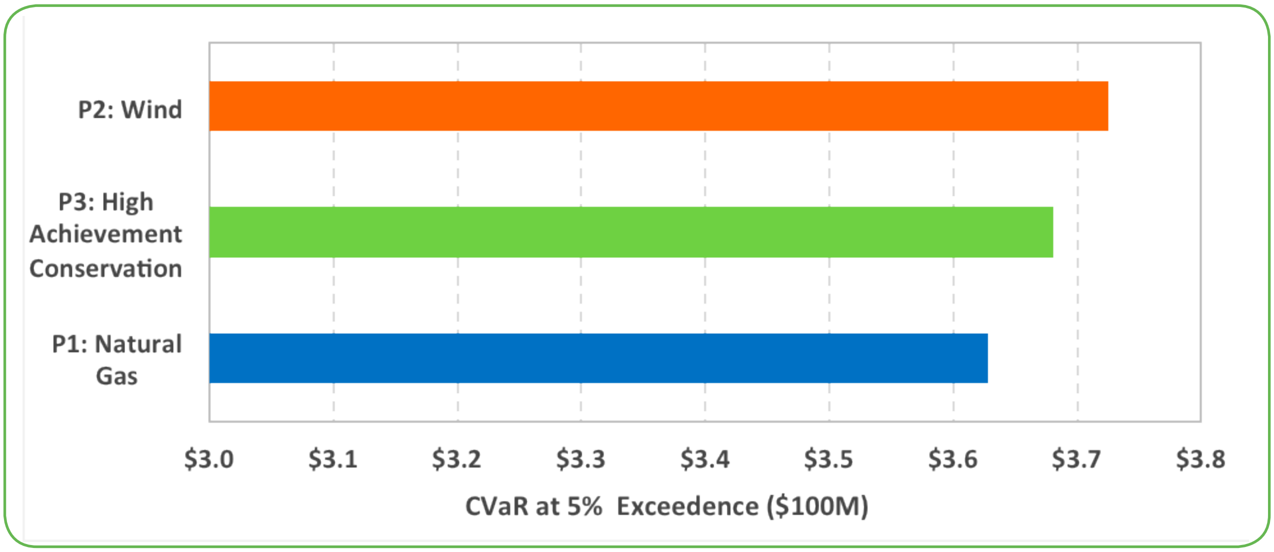
The expected cost of each portfolio is shown in Figure 9. This illustrates that portfolio 2 (Wind) has the highest expected cost.

Figure 9: Net Present Value of Net Power Cost (2016-2035)



City Light has chosen five percent (5%) conditional value at risk to measure the riskiness of the top three portfolios. The conditional value at risk measures the expected net power cost of the portfolios in the worst five percent (5%) of scenarios. It can be seen from Figure 10 that portfolio 2 (Wind) has the highest risk amongst the top three portfolios.

Figure 10: Conditional value at risk (CVaR) of net power costs at 5% exceedance



The final results of stochastic analysis show that the top three portfolios perform similarly. The portfolio that performed the best (marginally) from the cost and risk perspectives (the least cost, lowest risk) is portfolio 1 which includes natural gas fired generation. However, this portfolio is not preferred because of the inclusion of a long-term natural gas resource contract and the exclusion of additional renewable resources. City Council has been clear about its preferences for energy efficiency and renewable resources over fossil fuels and these preferences are identified in City Council Resolutions. For example, City Council Resolution 30144 establishes a preference for cost-effective energy efficiency and renewable resources, and the basis for City Light to offset all of its greenhouse gas emissions from fossil fuels. In 2016, the City Council passed Resolution 31667 includes a provision that opposes the use of fossil fuels.

The second best performing portfolio in terms of cost and risk includes High Achievement of Energy Efficiency portfolio which is also consistent with City policy and the Council resolutions stated above. By the support and approval of City Light's 2016 Integrated Resource Planning Stakeholders and Energy Committee of the City Council, City Light has selected the High Achievement of Energy Efficiency portfolio as the preferred portfolio.

[1] *Net Power Cost (NPC) is the sum of the costs of owned power generating resources, power contracts and the difference between market sales and market purchases.*

[2] *Extreme weather conditions resulting in very high or low temperatures significantly affect the expected pattern of electricity usage by City Light's customers when monthly studies are done, but it is not as significant as economic conditions when a yearly study is performed.*

[3] *Power Plants in the Pacific Northwest Installed Capacity. Northwest Power & Conservation Council, September 2016. https://www.nwcouncil.org/energy/powersupply/home/*

AIR EMISSIONS RATES AND COSTS

The purpose of this appendix is to provide information about the assumptions and methodology used to estimate environmental costs of air emissions for the candidate portfolios evaluated in the 2016 Integrated Resource Plan (IRP).

The goal of evaluating air emissions and estimating their costs is to help understand the overall impact of choices that can be made to meet the demand for electricity from City Light customers. In general, avoiding increased energy production through energy efficiency and efficiency measures not only reduces the costs associated with potentially purchasing a new power plant, but also eliminates the environmental impacts from the electricity that was not generated.

Renewables have fewer impacts than traditional thermal resources (fossil fuels, nuclear), but depending upon the technology, renewables can still have some air emissions or other environmental impacts. The treatment of air emissions from various types of power choices is described below.

In the 2016 IRP analysis, the costs of environmental emissions were estimated using air emissions and proxies for environmental externality costs. The calculation of environmental costs that are not captured in costs associated with operation of power plants, delivery, and sale of electricity are called environmental externality costs.

There are a number of approaches to calculating environmental externality costs. City Light uses best estimates of the costs to reduce the air emissions with pollution controls or other measures to meet potential regulatory requirements. This approach does not try to assess the value of the damages, but rather, the cost of mitigating the emissions before damages. These prices are then applied to all uncontrolled (residual) emissions.

The air pollutants that City Light evaluated were carbon dioxide, nitrogen oxides, sulfur oxides, mercury and particulates. The first step in determining an estimate of environmental externality costs is determining the amount of each of the air pollutants that would be emitted in each portfolio. For each resource in the portfolios, emission rates per unit of electricity were assigned. Figure 1 shows the emission rates for the different potential resource technologies that could be included in the portfolios. Figure 2 shows emissions costs for the various pollutants.

Figure 1: Resource Emission Rates (Lbs./MWh)

	Carbon Dioxide	Nitrogen	Sulfur Oxide	Mercury	Particulates
Energy Efficiency	0	0	0	0	0
Hydro	0	0	0	0	0
Landfill Gas	0	.972	0	0	.157
Waste Wood Biomass: Cogeneration	0	.534	0	0	.173
Hydro Efficiency	0	0	0	0	0
Wind	0	0	0	0	0
Geothermal	0	0	0	0	0
Photovoltaic (PV)	0	0	0	0	0
Solar Thermal	0	0	0	0	0
Combined-Cycle Turbine (CCCT)	1042.72	.105	.005	0	.005

Figure 2: Resource Emission Rates ($/lb)

Levelized Emissions Price	(2015 $/lb)
Carbon Dioxide	$0.03
Nitrogen Oxides	$0.95
Sulfur Oxides	$1.06
Mercury	$3.50
Particulates	$1.88

Waste wood biomass cogeneration is a special case. For many years, biomass has been commonly treated as carbon dioxide neutral. However, the U.S. Environmental Protection Agency (EPA) has determined that each feedstock and its production and consumption cycles must be considered in order to assess associated CO2 emissions. In 2014, the EPA released the Framework for Assessing Biogenic CO2 Emissions form Stationary Sources report that includes calculations for varied feedstock types, sources and production methods. EPA has not yet determined how this framework might be applied in regulatory or policy context, therefore, City Light has not yet included this method in the 2016 IRP. The 2012 IRP EIS evaluated several scenarios to understand the potential impacts of an EPA determination that waste wood biomass is not carbon dioxide neutral. Page 34 of appendix C of the 2012 IRP final EIS provides additional information.

Short-term market purchases can have associated net emissions. Market emissions rates are modeled within the IRP analysis and represent the power sources that are used to meet loads in the western power market where City Light buys and sells power. Through economic dispatch, subject to operating and transmission constraints, the AURORAxmp® market model (AURORA®) will select generating plants for short-term market purchases needed for balancing, load following, and other purposes. The most likely generating plants to be dispatched within the model to serve the load are those nearby in the area or region that have surplus generating capability. To the extent that these short- term resources have emissions, the costs are recorded within the model runs and the costs are attributed to the appropriate City Light portfolio.

For long-term Power Purchase Agreements (PPAs) in resource portfolios, the emissions costs of the power resource are included within the contract price. This is done by adding levelized emissions costs to the cost of the resource on a per-MWh basis. In this way, both short-term and long-term emissions costs are captured within the net power cost of a portfolio, so when cost comparisons between portfolios are made, the amounts and types of emissions directly impact a portfolio's performance and chances of being selected as the preferred portfolio.

Finally, Renewable Energy Credits (RECs) are also part of the portfolio resource options. RECs can be used to meet City Light's regulatory obligation for RCW 19.285, or when when short-term deficits exist to meet the RPS requirement. The RECs category is unique, since they represent only the environmental attributes associated with renewable electricity generation. City Light will not receive the power associated with RECs. Each REC represents one megawatt-hour of renewable energy generation. Within IRP portfolio modeling, RECs have no emissions impacts, positive or negative. For more information about RECs, see Resource Options Appendix.

A common goal of City Light as shown in the previous four IRPs is to have a preferred portfolio that reduces overall air emissions as compared to the "no action" alternative. The 2016 IRP has candidate portfolios that would serve the reduction of regional emissions, creating a net positive impact on air quality.

PUBLIC INVOLVEMENT PROCESS

City Light seeks to produce a long-term power supply strategy that is in the best interest of the public and reflects the values of the region it serves. In the IRP process, City Light actively seeks to engage its customers and other stakeholders that may be affected by City Light's future resource plans. In addition to explaining how City Light plans to generate electricity to meet projected needs, its team endeavors to listen to customer comments, encourage questions and ideas, knowing that many of them have never considered these issues previously. In addition to engaging them in discussions about resource futures, part of the job is to listen for barriers that make customers less able to be involved in their own power supply future.

These public engagement activities are designed to:

- Inform the public about the IRP process
- Ask for feedback and encourage general questions about City Light
- Raise awareness of the importance of long-term resource planning and how City Light meets customer's power supply needs
- Involve customers, regional experts and other stakeholders during the IRP process and generally encourage them to be more engaged in the utility's future plans
- Assist City Light in developing its long-term resource plan recommendations to City Council and the Mayor

City Light created a communications plan to organize its overall public outreach strategy related to the IRP. When developing this plan, City Light actively sought ways to address race and social justice concerns and to provide more opportunities for participation by underserved communities.

The communications plan focused on engaging customers in the process, gathering interested individuals to public events, and informing customers about ways to learn more about the IRP. The main events for the 2016 IRP were an online presentation for the general public, presentations at Seattle's Neighborhood District Council meetings, and IRP stakeholders panel meetings.

Public Meetings

For the 2016 IRP, City Light approached the City's pre-existing neighborhood district councils and asked to present at their meetings. City Light made presentations at two neighborhood district councils: Southeast District on April 27th 2016 and Central District on June 9th 2016. These short presentations gave an overview of the IRP and the IRP process, and encouraged the audience to view the online presentation. City Light also produced and distributed flyers for these events. The flyers gave a very brief overview of the IRP and encouraged readers to visit the IRP website.

On May 19th 2016, City Light hosted a live video presentation over the internet, advertised as the “IRP Online Open House”. City Light opted to deliver an online presentation as a means to provide digital equity, reducing the burden on interested parties to attend a meeting, allowing participants to join and learn from their homes, offices, cellphones, or to watch a recording at a later time.

The online presentation covered the definition and purpose of an IRP, the process, and the major considerations that affect City Light’s future resource choices. Participants were able to ask questions that were answered live by City Light employees. The presentation had almost 70 online attendees, making it City Light’s most widely attended online event.

IRP Stakeholders Panel

One of the primary vehicles to incorporate public feedback in City Light’s 2016 IRP was working with an IRP stakeholders panel. The IRP stakeholders panel is an advisory group of volunteers that provides feedback on a technical level. City Light invites stakeholders of diverse backgrounds to participate. While the IRP stakeholders panel is a valuable source of ideas and suggestions, it does not have formal policy-making responsibilities.

The stakeholders panel includes representatives of City Light’s retail electric customers and other local stakeholders, along with experts drawn from groups that are actively involved in regional energy issues.

2016 Stakeholders Panel Members

- Cameron Cossette, Nucor
- Christian Taylor, Boeing
- Jeremy Park, University of Washington
- Henry Louie, Seattle University
- Wes Lauer, Seattle University
- Mike Ruby, Envirometrics, Inc.
- Steve Gelb, Emerald Cities Collaborative
- Rebecca Wolfe, Sierra Club
- Tom Eckman, Northwest Power & Conservation Council (NWPCC)
- Paul Munz, Bonneville Power Administration

City Light held four in-person stakeholders panel meetings and one webinar in the 2015-2016 time period to inform the stakeholders panel on progress and findings, and allow stakeholders to provide input and suggestions. City Light also engaged informally with stakeholders to answer questions, provide additional information and receive feedback.

Summary of public and stakeholders meetings

TYPE	DATE	MAJOR AGENDA ITEMS
Stakeholders	June 17, 2015	▪ IRP process ▪ IRP input assumptions ▪ Climate change preliminary modeling
Stakeholders	November 4, 2015	▪ Demand forecast ▪ Resource adequacy study ▪ Resource portfolios ▪ Conservation Potential Assessment
Public (Southeast District)	April 27, 2016	▪ What is an IRP ▪ How is a long-term plan selected ▪ How to join the discussion
Stakeholders Webinar	May 12, 2016	▪ Portfolio analysis results ▪ Preferred portfolio recommendation ▪ Action plan
Public (Online Open House)	May 19, 2016 and available on internet	▪ What is the IRP ▪ IRP Resource choices ▪ IRP considerations ▪ How to provide feedback
Stakeholders	June 2, 2016	▪ Portfolio analysis results ▪ Preferred portfolio recommendation ▪ Action plan recommendation ▪ Climate change preliminary modeling review
Public (Central District)	June 9, 2016	▪ What is an IRP ▪ How is a long-term plan selected ▪ How to join the discussion
Stakeholders	August 4, 2016	▪ Race and Social Justice and Environmental Equity ▪ Review of 2016 IRP process and results ▪ Recommendations for 2018 IRP process

All materials presented are available on the IRP website, http://www.seattle.gov/light/irp

Feedback received

In summarizing the views of the public participants and stakeholders, their commitment to the environment is clear:

1. There is broad support for a continued aggressive environmental stewardship program.
2. Their focus continues to be the investment by the utility in the aggressive pursuit of energy efficiency with an interest in how newer technologies such as solar, electric vehicles and other distributed resources may impact the utility and how it interacts with customers in the adoption of these resources.

Taking into consideration this feedback, City Light presented the 2016 IRP preferred portfolio and the two-year action plan to City Council for review. On August 1, 2016 the Seattle City Council approved the 2016 IRP and two-year action plan.

AURORAxmp® ELECTRIC MARKET MODEL

This section describes the AURORAxmp® (AURORA®) software that City Light used to analyze the candidate resource portfolios. AURORA®, offered by EPIS,LLC, was initially released in 1997. It continues to be used by many utilities, resource planners, and regulatory agencies for long-term planning.

The AURORA® model contains a database that includes the characteristics of load centers, generating resources and transmission networks throughout the West. The model simulates the operation of the market for electric power on the western grid. It provides aggregated data for the load centers (referred to as zones) in the system. The zones City Light used to model the system are shown in Figure 1.

The model forecasts electricity prices for each zone within the Western Electricity Coordinating Council (WECC) region, taking into account transmission costs and constraints that are a source of differences in wholesale electricity prices from one part of the region to another.

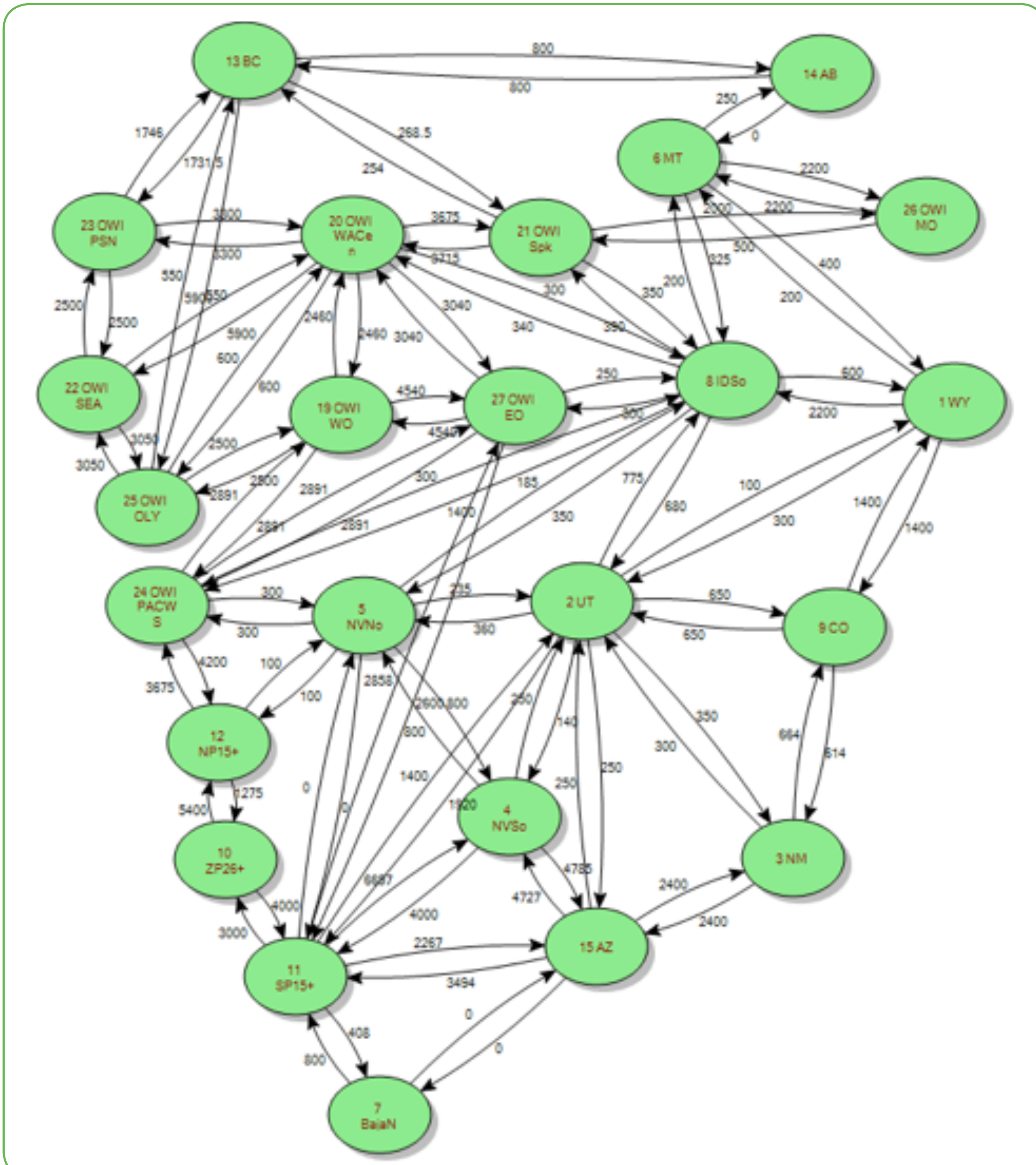
AURORA®'s extensive database of the North American power market is updated regularly by the developer. The type of information in the database includes generating resources with their retirement dates and constraints on generation capability, transmission capacities, pollutant emission rates, and reserve requirements. The database also contains forecasts of certain parameters, such as natural gas prices and other fuel types.

In addition to these data provided by EPIS, City Light reviews and enhances the database based off of additional data sources and internal analysis.

AURORA® forecasts new generating capacity additions using a proprietary optimization algorithm that identifies when and where capacity is needed. It then selects new resources based on which resource is the lowest cost. This cost includes environmental costs.

The model draws on its database to simulate the electric power market using economic dispatch logic. The model stipulates that the resources with the lowest marginal cost will be dispatched first. AURORA® forecasts future hourly demand at each load center, then applies its algorithms in order to economically dispatch resources to meet demand in every hour at every load center, subject to transmission availability. The result is an hourly local market clearing price equal to the marginal cost of the last resource dispatched.

Figure 1: AURORA® Model System Diagram



CLIMATE CHANGE EFFECTS ON SUPPLY AND DEMAND

Summary

- City Light used projected increases in temperature and changes in streamflow from three climate change scenarios to model the effect on demand and hydropower generation.
- Results of the climate change scenarios were compared to the expected base case and "do nothing" portfolio of the Integrated Resource Plan (IRP), not the candidate portfolios in the portfolio analysis, in order to isolate the effects of climate change.
- The inclusion of warmer temperatures in the 20-year demand forecasted lowered the 0.41 projected annual load growth by 0.01 to 0.04 percentage points because of the importance of winter temperatures on City Light's demand forecast.
- Total annual hydropower generation decreases for climate change scenarios that project decreases in annual streamflow and increases for scenarios that project increases in streamflow with a range from a 2.6 percent decrease to a 2.3 percent increase in generation for the three scenarios.
- City Light will continue to evaluate potential effects of climate change on supply and demand as additional information becomes available from the forthcoming climate change study of the Columbia River System.

Introduction

This Appendix summarizes City Light's analysis of the potential effects of climate change on the utility's load-resource balance for the 20-year period of the IRP, 2016 to 2035. City Light used projected increases in temperature and changes in streamflow provided by regional academic institutions to model load and hydropower generation under climate change scenarios and compared results to the expected base case for the IRP. The expected base case and "do nothing" portfolio was used for this climate change assessment because the objective was to isolate the effect of climate change on the load-resource balance and not confound this effect with the differences among multiple portfolios. However, the climate change scenarios used for this analysis are not the base assumptions used to compare resource portfolios in the IRP; the expected base case used to evaluate portfolios in the IRP remains based on historical climate data. Climate data used in this analysis are projections of potential trends due to climate change over time, and not forecasts of the weather, generation, or load in any one year. This appendix describes the climate change scenarios selected for the analysis, methods used to project changes in generation and load, and results of both analyses.

Climate Change Scenarios and Global Climate Model Selection

University of Idaho (UI) provided City Light with downscaled climate data from 20 global climate models of the Coupled Model Intercomparison Project phase 5 (CMIP5)[1]. These climate models use input scenarios of global emissions of greenhouse gases to simulate changes in temperature and precipitation. Global emissions scenarios are essentially storylines of the potential rate and amount of greenhouse gases emitted to the atmosphere over the next century for the entire world. The amount of emissions (and associated warming) diverges among these scenarios later in the 21st century, but for the 20-year time period of the IRP they are very similar, so City Light used the higher emissions scenario (RCP 8.5). Climate models project future climate at a spatial scale that is too coarse for analyzing hydropower generation or demand in a particular location, so the data must be "down-scaled" to a scale appropriate for local analysis. UI used a statistical downscaling method called Multivariate Adaptive Constructed Analogs to downscale data to weather stations of interest to City Light. This method captures the scale necessary for evaluating local impacts of climate trends but preserves the spatial patterns of meteorological data as simulated by the more coarse-scale climate models.

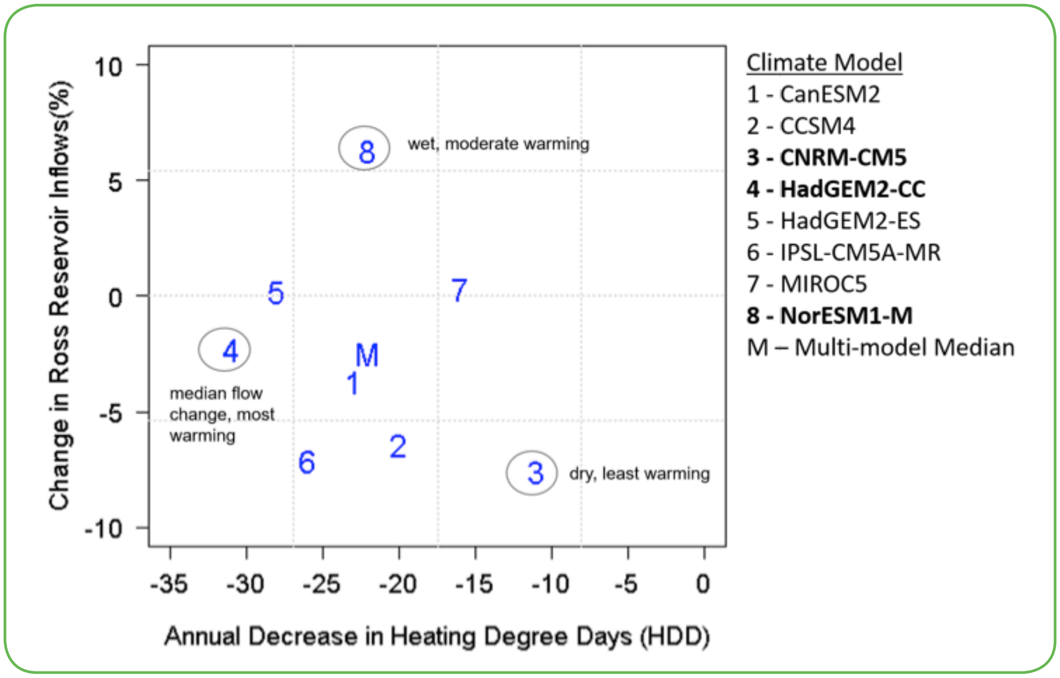
The down-scaled climate data must be used in a hydrologic model to project changes in streamflow at particular locations in order to simulate the effects of climate change on available streamflow for hydropower generation. Researchers at the University of Washington used the Distributed Hydrology Soil Vegetation Model (DHSVM) to simulate changes to inflows at City Light's Skagit hydropower project based on projected future climate from eight of the 20 climate models[2] . The hydrologic modeling includes the effects of changes in precipitation, snowpack, and runoff from glaciers, which all contribute to inflows available for hydropower generation.

City Light selected temperature and streamflow projections from three of the eight climate models (HadGEM2-CC, NorESM1-M, and CNRM-CM5) to cover the range of potential future warming and changes in streamflow (Figure 1) for use in the analysis of effects on the load-resource balance. The criteria for model selection were to capture a high, median, and low change in both temperature for the service area and annual streamflow at the hydropower projects. An additional constraint on model selection was that the same three models be used for the analyses of demand and supply. Each of the three models is considered to be an equally likely scenario of the future climate.

To select the models for load forecasting, temperature projections for each of the eight models were ranked by their respective rates of decrease in heating degree days (HDD) per year. It is because City Light is a "winter peaking" utility (energy use is higher in winter than summer) that HDD projections were used to select the climate models for this analysis. The three models cover the range of decreases in HDD projected for the eight models with annual decreases of 31 HDD (HadGEM2-CC), 22 HDD (NorESM1-M), and 11 HDD (CNRM-CM5).

Streamflow projections for Ross Reservoir show a similar pattern for changes in seasonal inflows for all eight climate models used in the hydrologic modeling but vary in changes in total annual inflows as shown in Figure 1. For the 2011 to 2040 period, the median change in annual inflow at Ross Reservoir is a decrease of 2.5 percent with a range from an increase of 6.3 percent to a decrease of 7.6 percent. The three models selected for assessing effects on hydropower generation cover this range of changes in annual inflows: a 7.6 percent decrease (CNRM-CM5), a 2.3 percent decrease (HadGEM2-CC), and 6.3 percent increase (NorESM1-M). These models were the same as the three selected for the demand analysis.

Figure 1. Annual Change: Current vs 2011 - 2040



Climate Change Effects on Energy Demand

Demand Methods

To provide a demand forecast under conditions of "normal" weather, City Light's Load Forecast Model uses weather data from the SeaTac airport weather station to account for the effect of temperature on energy demand. When determining the IRP's load-resource balance, forecasted load in the IRP base case uses 30-year climate normals at SeaTac as defined by the National Oceanic and Atmospheric Administration (NOAA) for the period of 1981 to 2010. More specifically, and consistent with common practice in the industry, degree days are used to account for the nonlinear relationship between energy and temperature.

City Light's Load Forecast Model was executed to create three new and separate load scenarios with each iteration using the projected change in quarterly temperature data for each of the three climate scenarios, rather than the current normal used in determining the IRP base case. Table 1 shows the change from current (1981-2010) to projected future (2011-2040) HDD climate normals for each of the three climate models.

TABLE 1. Heating degree days at SeaTac weather station for current conditions (1981- 2010) and three climate change models for the period 2011-2040.

Quarter	Current normal	HadGEM2-CC	NorESM1-M	CNRM-CM5
	1899	1798	1848	1868
	869	770	806	832
	217	164	168	197
	1721	1600	1620	1674

Demand Results

The expected load forecast used in the 2016 IRP Base Load Model to assess the utility's expected load-resource balance assumed an average annual growth rate of roughly 0.41 percent for the 20-year period of the IRP. As expected, the inclusion of warmer temperature data from projected future climate scenarios did result in forecasted lower growth of system load. This was expected given that the utility's service area uses more energy in winter, in part, because of the relatively mild summers experienced in the service area. Thus, because the utility experiences greater load demand in winter (fairly consistent 28 percent of annual load over the past fifteen years) relative to any other season, the inclusion of warmer temperatures in forecasting 20-year demand did result in lower load growth for each of the three climate models used. Also as expected, the magnitude of change in load growth varied with each model's respective temperature projections. Of the three models, CNRM-CM5 with the mildest amount of warming resulted in a decrease of forecasted average annual load growth of about .01 percentage points when compared to the IRP Base Load Model. The model (NorESM1-M) with temperature projections closest to the 8-model ensemble resulted in load growth .03 percentage points lower than the IRP Base Load Model. The HadGEM2-CC model with the warmest projection resulted in load growth .04 percentage points lower than the IRP Base Load Model. This model resulted in a decrease of approximately 9 aMW in 2035, the final year of the IRP, when compared to the IRP Base Load Model. For context, 9 aMW is equal to roughly 0.8 percent of City Light's 2015 system load and 0.7 percent of 2035's forecasted load from the IRP Base Load Model.

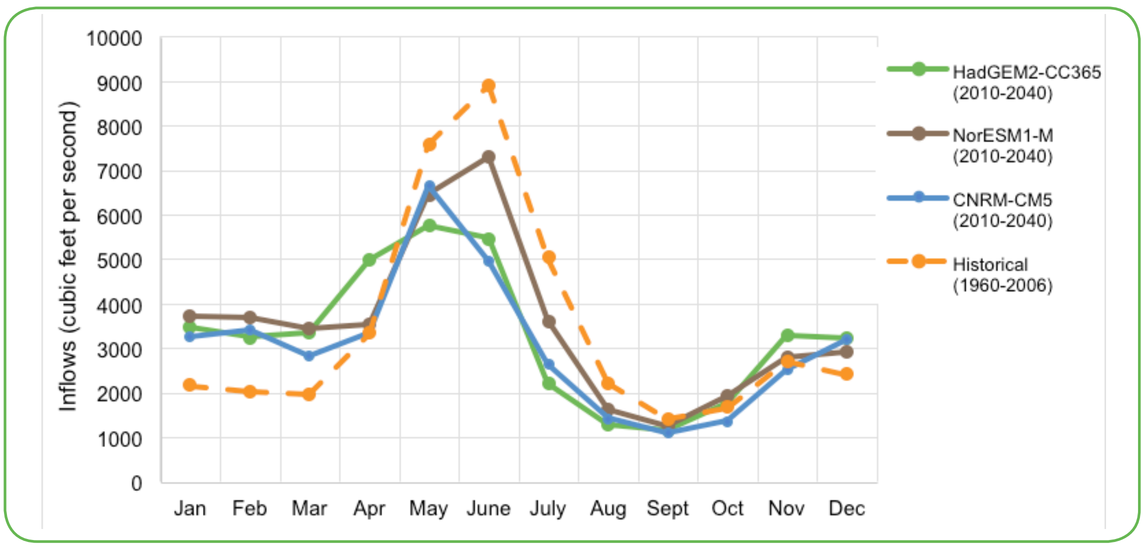
As mentioned previously, City Light has higher load in winter due to relatively mild summers. This differs from warmer regions of the nation where, due to abundant of air-conditioning use, electricity consumption is highest during summer months. Air-conditioning use is currently low in City Light's residential sector, at only about 5 percent according to the most recent Residential Building Stock Assessment[3]. Temperature projections indicate warming in all seasons, but it remains unknown if summers will warm sufficiently to cause an increase in air-conditioning use or a significant increase in summer energy consumption in City Light's service area. Currently, the 30-year normal for cooling degree days in Seattle is 190. For comparison, cooling degree days in cities in eastern Washington are three to five times greater (710 in Pasco, 850 in Wenatchee, and 950 in Kennewick). For the 2010 to 2040 period, cooling degree days in Seattle are projected to increase to about 325 (+/- 50). Studies suggest this warming could correspond to an increase in air-conditioning use to about 25 percent, which is roughly equivalent to the current residential air-conditioning use in San Francisco, CA and Buffalo, NY.[4]

Climate Change Effects on Hydropower Supply

Hydropower Supply Methods

City Light used the three climate model scenarios for inflows to estimate hydropower projections for the utility's total generation relative to the expected case based on historical inflows. All three models show a similar shift in the seasonal pattern of inflows toward greater inflows in December through March and lower inflows in May through September (Figure 2)[5] . This seasonal change is the result of more winter precipitation falling as rain, a decline in snowpack, and an earlier snowmelt and runoff period.

FIGURE 2. Mean Monthly Inflows to Ross Resevoir for Historical Conditions (1960-2006) and Three Climate Change Scenarios



Total generation for the analysis included generation from all hydropower projects owned by the utility, as well generation for the sections of the Columbia River system from which City Light purchases power through contracts with Bonneville Power Administration (BPA). For each of the three climate models, City Light applied changes for monthly inflows to estimate changes for monthly hydropower generation, assuming that current dam capacity and operating constraints for flood control, fish protection, and reservoir levels remain the same in the future as they are today. Therefore, future monthly changes in generation were constrained to the current operating conditions imposed by existing capacity, operating licenses, and the current biological opinion, so that generation could not increase or decrease below the lowest or highest value in the historical range.

Changes in inflows at Ross Reservoir were used to estimate changes in generation at the other dams, subject to the capacity and operating constraints of those dams, because of limited data in those locations. Although there are likely to be some variations by location, this method assumes that climate change affects water availability at the other locations in a similar way. This assumption is reasonable given that 99 percent of utility-owned hydropower generation and contract purchases are from snow-dominated systems in Washington for which seasonal water availability is expected to respond similarly to climate change. The River Management Joint Operating Committee (RMJOC, composed of BPA, Bureau of Reclamation, and Army Corps of Engineers) is collaborating with the University of Washington (UW) to project changes in streamflow and hydropower generation for the Columbia River system. The results of the RMJOC research are expected to be available in late 2016.

Generation for the climate change models were compared with the base case generation for the IRP “do nothing” portfolio. The “do nothing” portfolio assumes that the current BPA contracts are extended, but no new resources or contracts are added as others expire, therefore relying on wholesale market purchases to meet additional power supply needs.

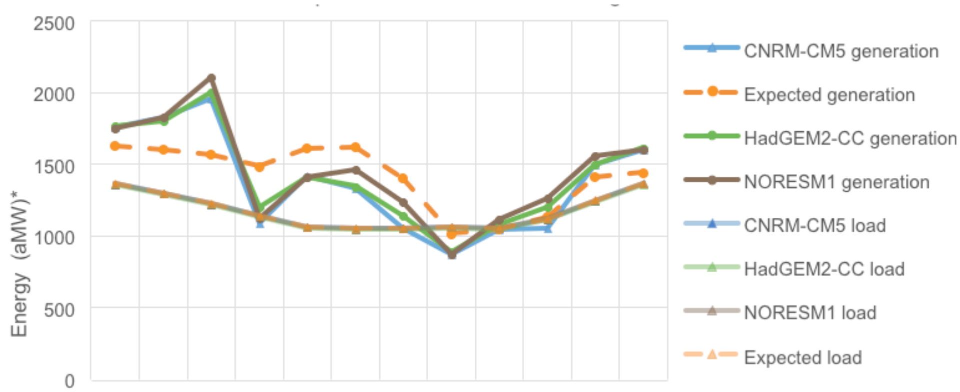
Hydropower Supply Results

Projected seasonal and annual changes in energy generation reflect the seasonal and annual changes in streamflow (Figure 3). All three climate change models show decreases in energy generation in April through August and increases in November through March. The largest decreases in generation are projected for April and the largest increases are projected for March as a result of the snowpack runoff shifting early in the year.

For the expected base case, average monthly generation exceeds average monthly load in all months except August and September. However, as noted above, total generation in Figure 3 does not include new programmatic energy efficiency, wholesale market purchases, or any new resources added after existing contracts expire (except BPA which remains in place). These resources are regularly used to fill gaps between supply and demand. For all three climate change scenarios, the deficit between average generation and demand increases in August, but the difference is within the range of what the utility has experienced in the past. Differences between supply and demand in other months vary depending on the model, but generally show less of a deficit in September and less of a surplus (or deficit for two models) in April.

Total annual generation increases (decreases) consistent with the models that show increases (decreases) in annual inflows, but the relationship is not one-to-one. The NORESM1 model, which shows a 6.3 percent increase in annual inflows, results in a 2.3 percent increase in annual generation. The CNRN-CM5 scenario, which shows a 7.6 percent decrease in annual inflows, shows a 2.6 percent decrease in generation. This suggests a “rule of thumb”: for every 1 percent change in annual inflows, the system has about a 0.35 percent change in generation, assuming capacity and operating constraints for flood control, reservoir levels, and fisheries remain the same.

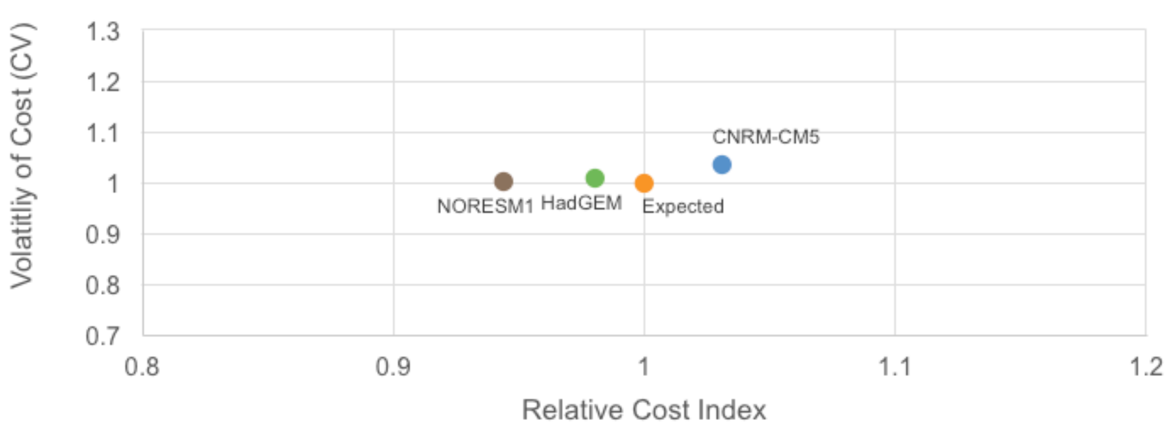
FIGURE 3. Energy Generation and Load (2016 - 2036): Expected Base Case Compared to Three Climate Change Scenarios



*Note: Energy excludes new programattic conservation, wholesale market purchases, and replacement contracts for resources other than BPA for the 20-year period.

City Light compared generation from the three climate change models with the expected base case generation in terms of relative cost and volatility of cost (Figure 4). All three models generally show little change in cost or volatility of cost. The CNRN-CM5 model (lower inflows) results in higher cost and relative to the expected condition, whereas the NORESM1 model (higher inflows) results in lower cost. The HadGEM-CC model, which had little change in annual inflow and is most similar to the eight climate model median, showed little change in cost or volatility.

FIGURE 4. Relative Cost and Volatility of Cost: Expected Base Case compared to Three Climate Change Models



Future Climate Change Research and Analysis

In addition to this assessment, City Light evaluated other risks associated with climate change through the development of a Climate Change *Vulnerability Assessment and Adaptation Plan*, available online at http://www.seattle.gov/light/enviro/climatechg.htm. This report assesses potential impacts to utility operations and infrastructure caused by sea level rise, warming temperatures, changes in extreme weather patterns, more frequent natural hazards, and changes in snowpack and streamflow. City Light will continue to evaluate climate change effects on demand and supply, as well as other potential impacts through the utility's climate change research program. Future research on demand may include potential changes in air-conditioning use associated with warming and the indirect effect that population growth and climate migration could have on residential air-conditioning use. City Light will continue to collaborate with UW and the RMJOC to evaluate potential effects of climate change on water availability and hydropower generation for the Columbia River system. The results of the RMJOC study will increase City Light's understanding of potential changes in generation and operations of the Boundary Project and Columbia River dams from which City Light receives power. City Light's assessment of climate change effects on supply and demand will be updated as necessary based on the results of the forthcoming RMJOC climate change research project and other new research on climate change effects in the region.

[1]MACA Climate Downscaling. Prepared by Katherine Hegewisch & John Abatzoglou Department of Geography, University of Idaho Pacific Northwest Climate Impacts Research Consortium for Ron Tressler, Crystal Raymond, and Seattle City Light research team.

[2] Hydrologic Impacts of Climate Change in the Skagit River Basin. Prepared by Christina Bandaragoda, Chris Frans, Erkan Istanbulluoglu Crystal Raymond and Larry Wasserman. Final report prepared for: Skagit Climate Science Consortium, Mt Vernon, WA and Seattle City Light, Seattle, WA 12/31/2015

[3] Seattle City Light Residential Building Stock Assessment: single-family characteristics and energy use. Prepared by Ecotope Inc. 2014.

[4] Sailor, D.J. and A.A. Pavlova. 2003. Air conditioning market saturation and long-term response of residential cooling energy demand to climate change. Energy 28: 941-951.

[5] Hydrologic Impacts of Climate Change in the Skagit River Basin. Prepared by Christina Bandaragoda, Chris Frans, Erkan Istanbulluoglu, Crystal Raymond and Larry Wasserman Final report prepared for: Skagit Climate Science Consortium, Mt Vernon, WA and Seattle City Light, Seattle, WA 12/31/2015.