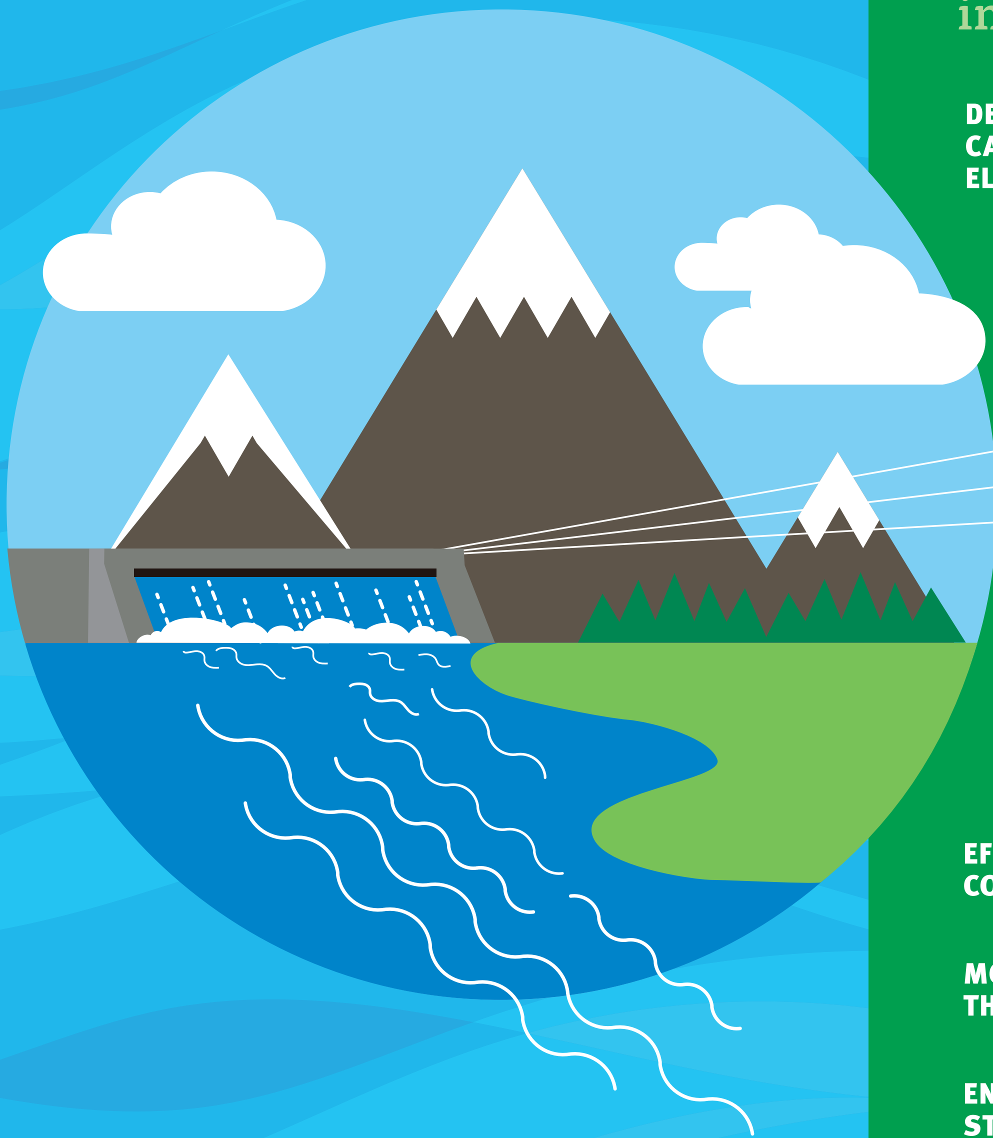
FOLLOWING NATURE'S CURRENT

Hydropower in the Northwest



inside:

FWEE
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FWEE
Foundation for Water & Energy Education

The Foundation for Water and Energy Education (FWEE) is a non-profit organization whose mission is to provide balanced information about the use of water as a renewable energy resource in the Northwest. Visit www.fwee.org to access educational resources and materials for all ages.

The role of hydropower in meeting the Northwest's environmental and social equity goals is more important than ever. The societal benefits of hydropower as a low-cost, affordable source of electricity continue. Residents of the Northwest also take great pride that hydropower is a renewable and clean energy source replenished naturally by the water cycle that does not contribute to air pollution.

Today's generation must address the challenge of climate change and reducing carbon emissions. For this reason, states and utilities across the Northwest are committing to carbon-free electricity. The foundation for accomplishing this goal rests on hydropower. Already, this carbon-free source of power provides over half the Northwest's capacity to generate electricity.

As wind, solar and other carbon-free resources are added to the power grid, hydropower plays another critical role. Because the wind doesn't always blow and the sun doesn't always shine, the ability of many hydropower projects to store and release water when it's most needed makes the supply of electricity across the region far more reliable.

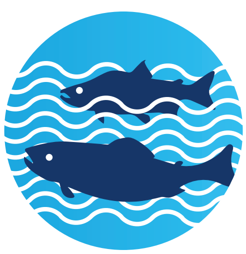
This publication explores the role of hydropower in our quickly evolving power generation future. Part of this exploration includes highlighting and embracing new innovations, technologies, and energy resources. It's an exciting time, rich with possibility and collaboration.

Thank you for being a partner in our clean energy future.

Hydropower in The Northwest

FOLLOWING NATURE'S CURRENT

CLEAN, Carbon-free Hydropower PAGE 4



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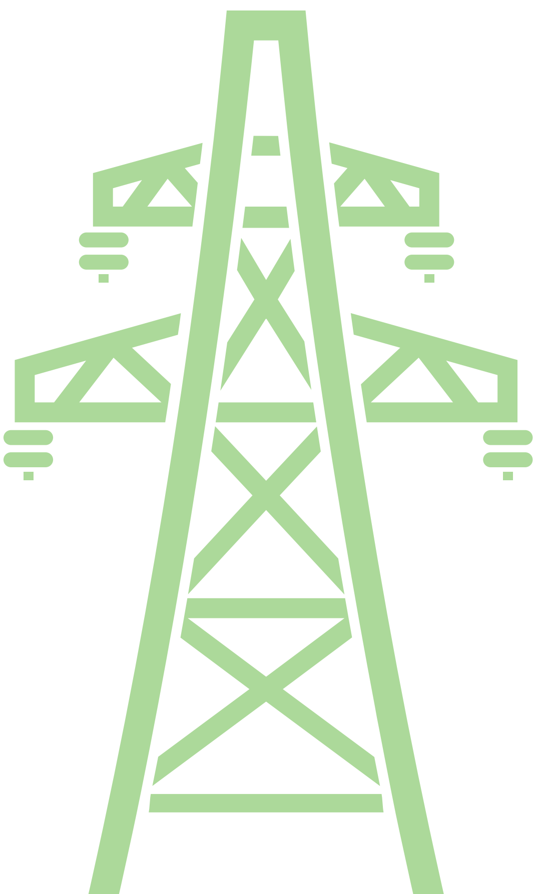
Modern Power Grid PAGE 12



Climate Change & the Northwest's Path to Renewable, Carbon-Free Electricity Generation

CARBON -FREE ELECTRICITY GENERATION

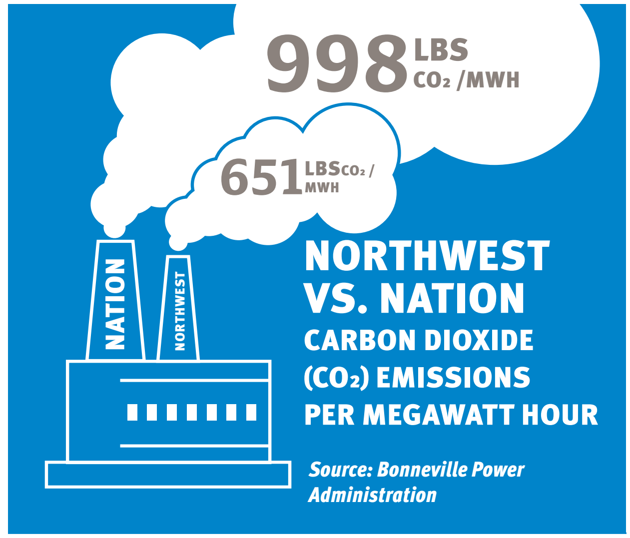
CLIMATE CHANGE

GREENHOUSE GAS EMISSIONS

EXTREME WEATHER

Nationally and regionally people are witnessing increases in the intensity and frequency of weather events like wildfires and droughts; changing weather patterns like the amount and seasonal timing of snowfall and rain; and changing landscapes such as stream flows and receding glaciers.

What we are seeing and experiencing stems from climate change trends. For instance, the average annual temperature in the Northwest rose by about 1.3°F over the last century; and temperatures are projected to increase by 3°F to 10°F by the year 2100. In 2019, the world's oceans were warmer than any other time in recorded human history.



Thanks to the carbon-free nature of hydropower, Northwest carbon dioxide emissions (which account for 81% of greenhouse gases) are dramatically lower than national averages.

According to the University of Washington's Climate Impacts Group, "The combined effects of climate change and climate variability in the Pacific Northwest are expected to result in a wide range of impacts for the region's communities, economy, and natural systems. These include projected changes in water resources, forests, species and ecosystems, oceans and coasts, infrastructure, agriculture, and human health."

THE NORTHWEST'S ELECTRICITY GENERATION CARBON FOOTPRINT IS 45% LESS THAN THE NATIONAL AVERAGE

Elected officials and policy makers are now taking action to reduce human created carbon emissions that contribute to climate change. Electricity generation is key to this effort. In 2018, the Environmental Protection Agency (EPA) found that 27 percent of greenhouse gas emissions result from the generation of electricity.

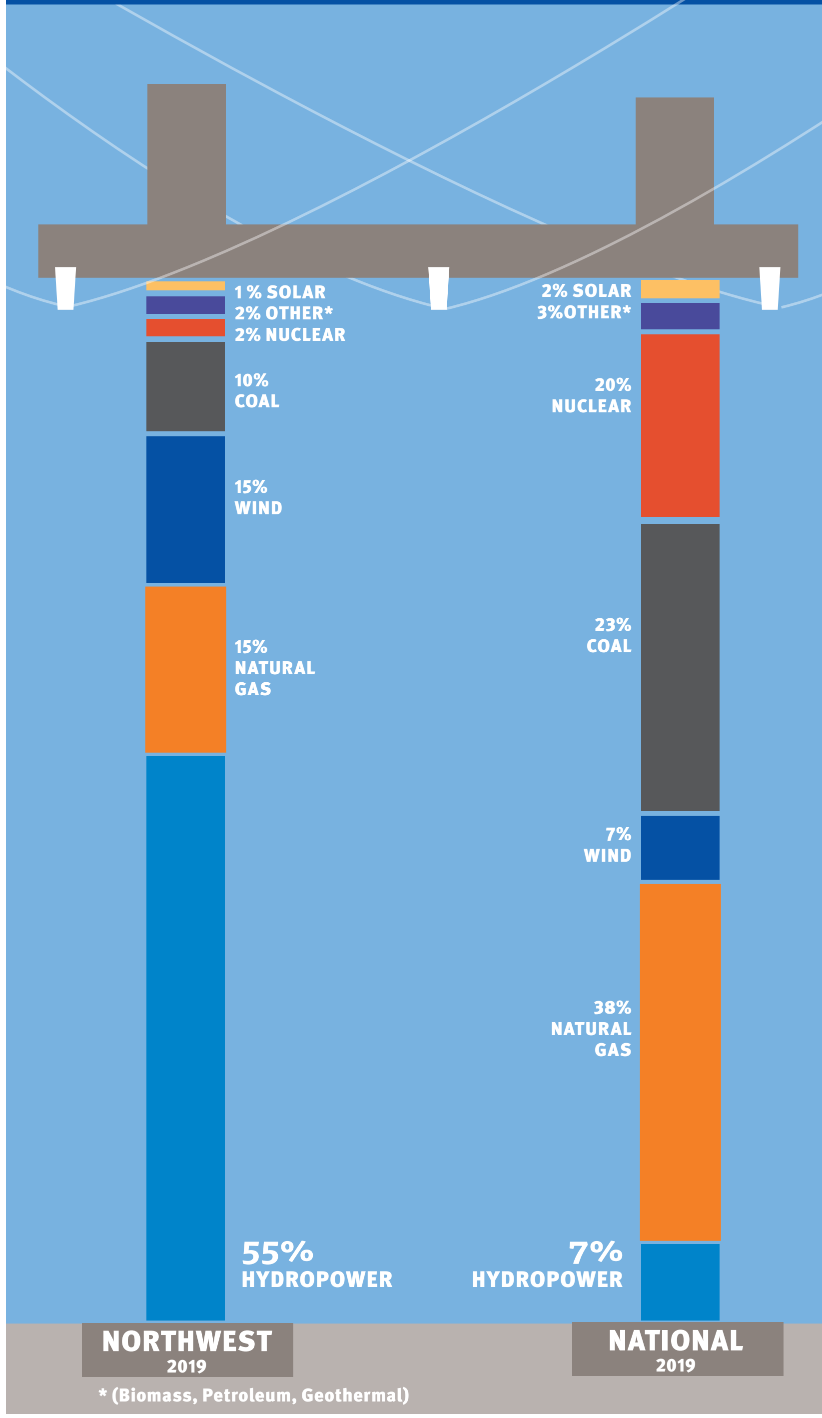
The Northwest, however, is lucky. Thanks to hydropower and other carbon-free resources, our carbon footprint from electricity generation is about 45 percent less than the national average.

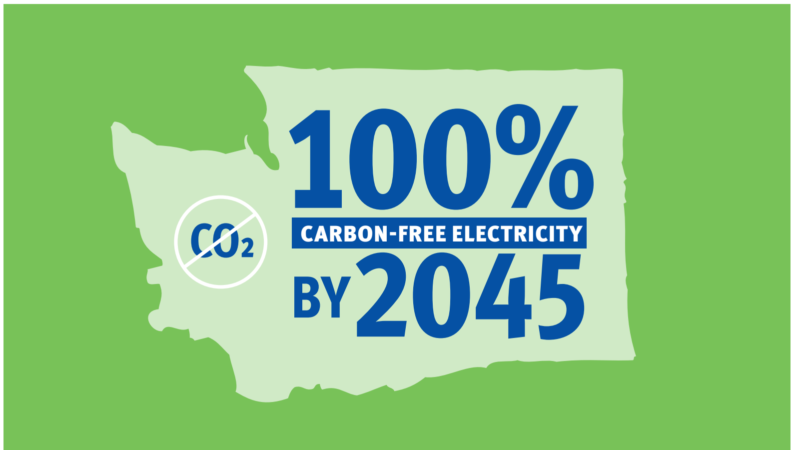
Hydropower is the backbone to our clean energy system by providing 55 percent of the Northwest's capacity to generate electricity. That's a stark contrast to hydropower providing only 7 percent of the nation's capacity to generate electricity.

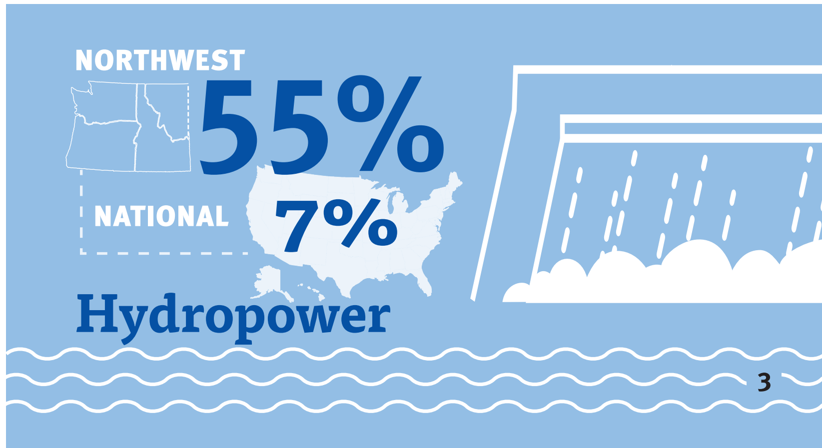
Doing better than the nation is not good enough for us. States and utilities across the Northwest are committing to carbon-free electricity generation. In 2019, Washington State passed legislation to phase out power generation from coal and natural gas power plants in order to generate 100 percent carbon-free electricity by 2045. In Oregon, by 2040 half of the electricity consumed by their citizens must come from renewable resources. And private utilities serving Washington and Idaho have announced plans to provide their customers 100 percent carbon-free electricity by 2045.

NORTHWEST VS. NATIONAL ELECTRIC GENERATION CAPACITY SOURCES

Sources: Northwest Power and Conservation Council, U.S. Energy Information Administration



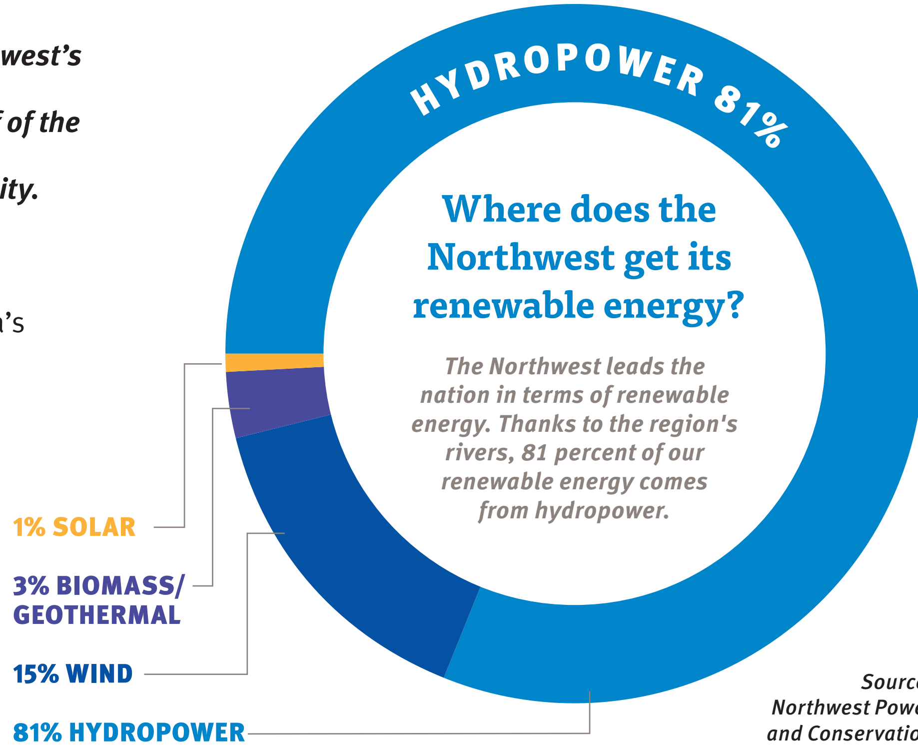




Hydropower:
The Foundation Supporting A Renewable, Carbon-Free Northwest Electricity Future

Hydropower is the backbone of the Northwest's clean energy system, supplying over half of the Northwest's capacity to generate electricity. This foundation, also called baseload, is the key to the Northwest being America's leading producer of renewable, low cost, carbon-free electricity.

Indeed, about 40 percent of the nation's hydropower is in the Northwest.



Source: Northwest Power and Conservation Council

Hydropower CARES

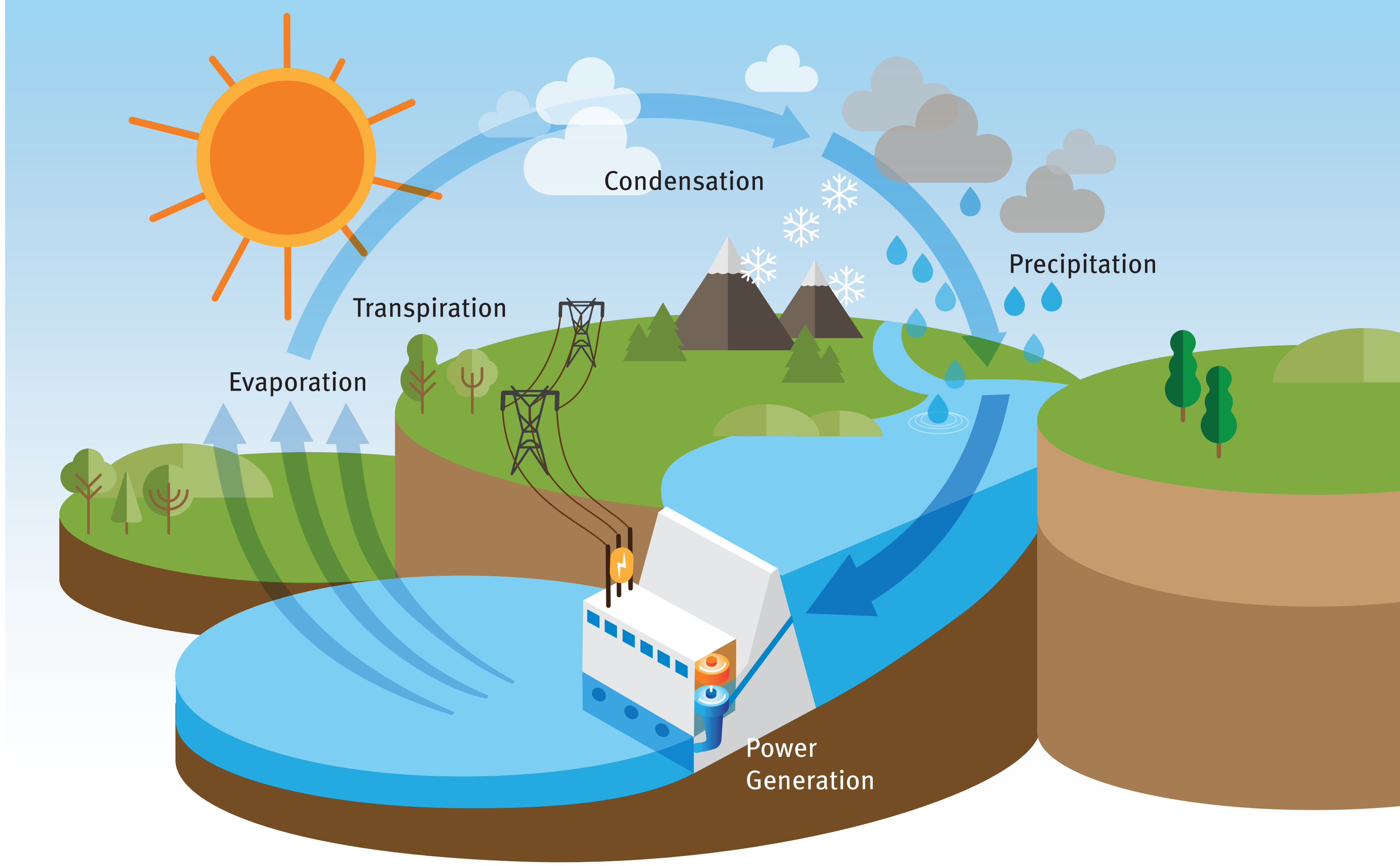
AN EASY WAY TO EXPLAIN THE BENEFITS OF HYDROPOWER

C — CLEAN & CARBON-FREE

Hydropower produces **no emissions**. There are no gases or waste products that contribute to air pollution or climate change.

A — AFFORDABLE

Our rivers provide the "fuel"—water—for **free**. This helps keep operating costs low.



THE WATER CYCLE: PROVIDING HYDROPOWER ITS RENEWABLE FUEL

Energy from the sun powers the water cycle. ***Evaporation*** *from oceans, rivers, lakes and even puddles turns water from a liquid to gas (also called vapor) that rises into the atmosphere.* ***Transpiration,*** *when water is given off through the pores of plants and animals, is another form of evaporation.* ***Condensation*** *happens when the water vapor condenses around and clings to fine particles of air. As the air gets moister, droplets that form clouds get larger and larger. Eventually,* ***precipitation*** *returns these droplets to earth as rain, snow, sleet or hail. The cycle begins again.*

R RENEWABLE

The water cycle assures Mother Nature **replenishes** our rivers with snow and rain every year.

E EFFICIENT

About **90 percent** of the potential energy from falling water flowing through hydropower dams is converted to electricity. Compare this to fossil fuel plants such as natural gas and coal, where only about 50 percent of these fuel sources can be converted to electricity.

S SECURE

The Columbia River is a Canadian and American resource that, as needed, is cooperatively managed. It's free from global geopolitical conflict and **protected** from fluctuating fossil fuel prices.

Challenges to Powering a Renewable, Carbon-Free Future

In 2019, 25 percent of the Northwest's capacity to generate electricity came from power plants burning coal and natural gas. Replacing these plants with new carbon-free energy resources is the challenge.

Between 2020 and 2030, about 6,000 megawatts of electricity powered by coal in the Northwest is expected to be phased-out. This is enough electricity to power more than 4.3 million homes. Further, an additional 9,000 megawatts from natural gas-powered plants would need to be retired in the 2030s and 2040s to fully phase out fossil fuel generation and meet a 100 percent carbon-free generation goal.

Solar and wind power are fast growing, renewable resources the public often considers to replace fossil fuel power plants. Replacing fossil fuel with these renewable resources, however, is not simple.

Think of it as the difference between extraction vs. weather-based generation. Coal and natural gas supplies are extracted from the earth, stored and made continuously available.

But the availability of wind and solar power is based on the weather, which is why they are called intermittent resources.

Hydropower is also weather dependent. But unlike wind and solar, storage of water behind some dams provides much needed flexibility. Further, almost all hydropower facilities can provide some power

SHIFTING THE NORTHWEST TOWARD

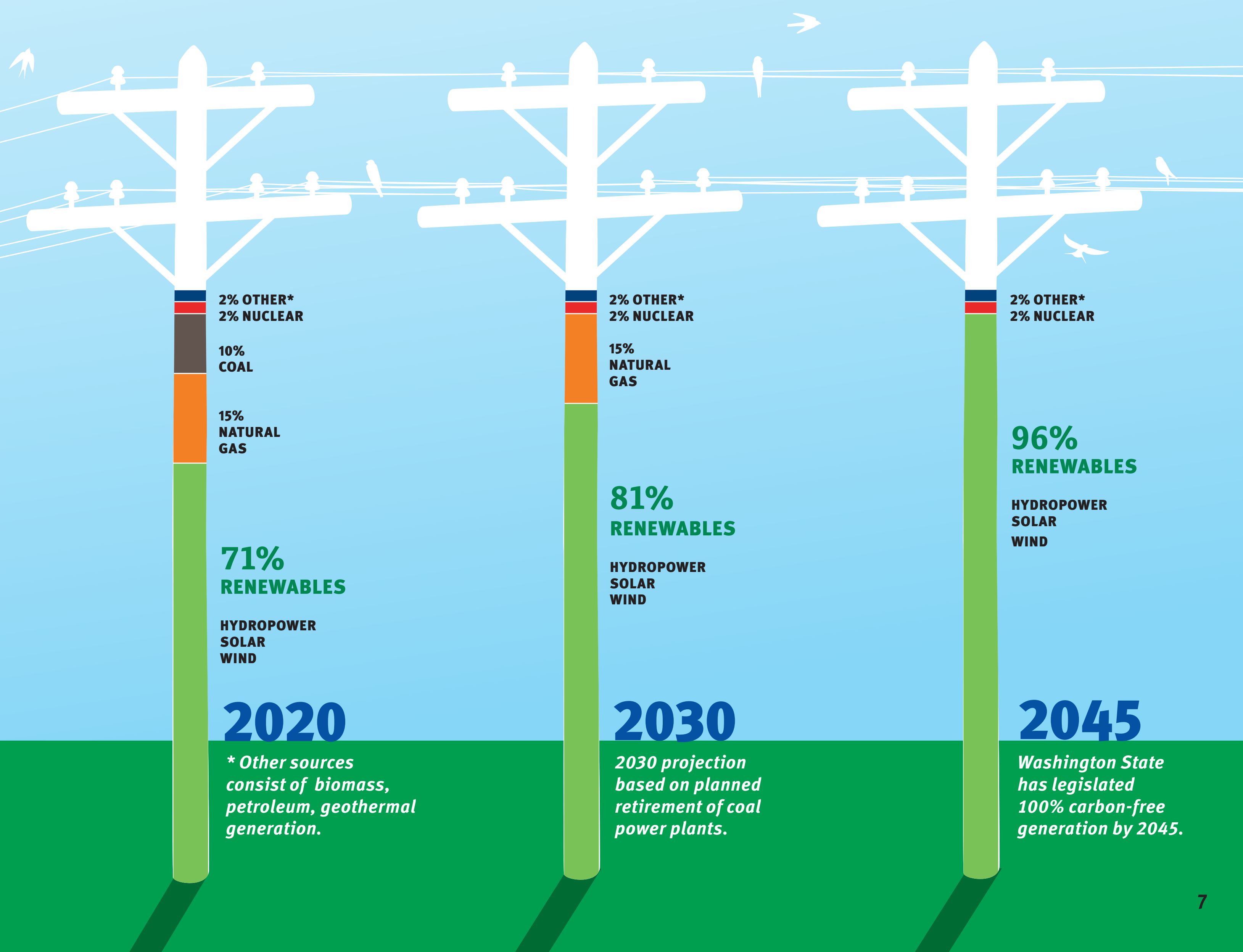
100% RENEWABLE, CARBON-FREE

ELECTRIC GENERATION BY 2045

generation on demand as long as flowing water is available. As a result, hydropower also provides a critical renewable alternative to wind and solar power when the wind isn't blowing, or the sun isn't shining.

When weather dependent (renewable) power isn't available during a heat wave or cold snap, the chances of blackouts and brownouts (meaning no or not enough electricity to homes and businesses) increase. Even if power is available, there can be spikes in the cost resulting in higher bills for electric utility customers.

Research by the Northwest Power and Conservation Council shows the likelihood of this type of shortage, called supply adequacy, skyrocketing from less than 5 percent in 2019 to more than 25 percent by 2026 without additional actions being taken.



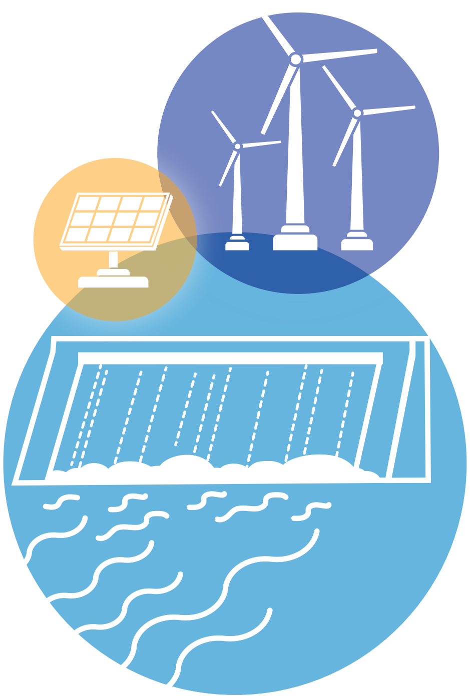
Meeting the Carbon-Free Electricity Generation Challenge:

Building Blocks for a 21st Century Energy Resource Stack

- HYDROPOWER
- WIND AND SOLAR
- EFFICIENCY AND CONSERVATION

With more than 34,000 megawatts of electricity available, hydropower will continue to provide over half the power needed for a carbon-free, renewable energy future in the Pacific Northwest.

RIVERS provide flexible, reliable hydropower when wind and solar power are not available.



HYDROPOWER

Preserving and strengthening this resource base is critical. As important, hydropower provides:

Energy Storage: Hydropower projects with reservoirs, sometimes called lakes, behind them can "store" water to generate electricity when it's most needed. Think of them like giant, clean, carbon-free renewable batteries that provide "peaking" power when electricity demand is highest. For instance, in the morning when people are getting ready for the day with hot showers and other activities. Reservoir storage is also used to balance the availability of river flows from one season to the next. For example, high water flows in the spring can be stored until the summer when river flows slow in unison with less rainfall and melting snowpack.

Flexibility: Because the amount of water flowing through a dam's turbines is easy to adjust, hydropower can be quickly ramped up and down to ensure power is available when customers like you need it.

EFFICIENCY AND CONSERVATION

In many cases, the least expensive way to meet electricity demands is to use less or more efficiently use what already exists. For example:

Conservation: Home improvements such as adding insulation, installing energy efficient window replacements or upgrading to programmable thermostats. Also, changing habits like turning lights and appliances off when not using them.

Efficiency: Installing new appliances like refrigerators, stoves and hot water heaters that use less electricity to produce the same result. Likewise, people are replacing inefficient incandescent and halogen light bulbs with LED lights. Look for the ENERGY STAR® logo when shopping.

Thanks to actions taken between 1978 to 2019, power needs were reduced by more than 7,000 average megawatts. That's enough power savings to meet the annual needs of five cities the size of Seattle. If your household engaged in conservation and/or efficiency, your energy consumption was reduced, helping to reduce your power bills. And better still, each year our power system is avoiding emission of 22 million tons of carbon dioxide (the largest source of greenhouse gas).

Although the Northwest Power and Conservation Council predicts additional conservation and efficiency measures will meet new power demands over the next 20 years, they also project new renewable energy resources will need to be developed to replace retiring fossil fuel power plants.

WIND AND SOLAR

In 2005, wind contributed 1 percent to the Northwest's generating capacity and solar contributed zero. Fast forward to 2019 and wind contributes over 14.5 percent of the Northwest's power generating capacity and solar 1 percent. Wind and solar resources will continue to be added to the system.

Hydropower is the perfect carbon-free renewable partner for wind and solar because it's reliable, available and can quickly be ramped up to meet demand when the wind isn't blowing or the sun isn't shining.

2005-2019

WIND POWER INCREASED from 1% to 14.5% of NORTHWEST GENERATING CAPACITY

Source: Northwest Power and Conservation Council

USING LESS ADDS UP FOR THE NORTHWEST

energy efficiency + conservation ANNUALLY AVOIDS 22M TONS OF CARBON DIOXIDE (a greenhouse gas) EMISSIONS

Source: Northwest Power and Conservation Council

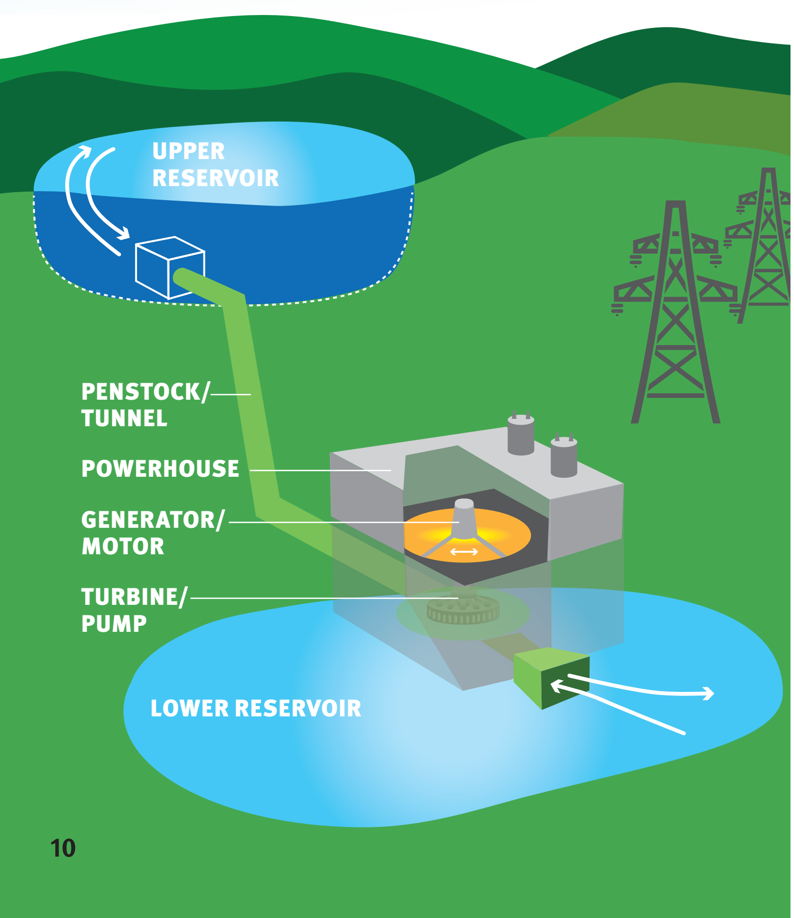
New and Emerging Hydropower and Battery Technologies

Supporting a 21st Century Carbon-Free Energy Stack

Engineers across the country are not just relying on current technologies and tools to meet power generation needs. Their problem solving is introducing new innovations and developing new technologies that create bridges to a carbon-free power generation future.

PUMPED STORAGE HYDROPOWER

Closed loop projects like this are not continuously connected to a flowing river, thus minimizing environmental impacts.



Pumped Storage Hydropower Projects

Pumped storage projects operate like conventional hydropower storage projects, but with a twist.

Water is pumped to an upper reservoir for storage. It's released downhill to turn turbines and generate electricity when demand is highest, also called peak periods, or when other weather dependent sources like wind and solar aren't available. Water is then pumped back to the upper reservoir when power generators normally run below capacity or sit idle.

You can think of pumped storage like a rechargeable battery. It provides energy on demand when needed, and then when energy is no longer needed or is exhausted, the battery can be charged up by another energy source.

Like conventional hydropower, this flexibility makes pumped storage an ideal partner for solar and wind power projects. "Closed loop" pumped storage projects have the added benefit of continuously recirculating water between the lower and upper reservoirs. By largely or completely decoupling operations from river flows, environmental impacts can be minimized.

Currently, the John W. Keys III Pump Generating Plant at Grand Coulee Dam is the Northwest's only pumped storage project. However, there are nine projects with a total capacity of over 4,600 megawatts of electricity being proposed. If all were built, they would provide enough power capacity to largely offset lost power from the retirement of coal projects.

Large pumped storage projects generally take over 10 years to move through the design, permitting and construction process, and cost between $1 to $3 billion to build. The two projects with initial permit approvals could go on-line before the end of this decade.

Battery Storage

Innovations in battery technology are an exciting part of a carbon-free energy future. Whether it's a solar panel on your home or larger utility scale wind and solar projects, battery storage keeps the power flowing when the wind isn't blowing or the sun shining. And like pumped storage projects, power can be stored for use when demand and cost is highest.

The good news is that over the past decade the cost of producing lithium-ion batteries has declined by 90 percent. Another 50 percent drop is considered possible by 2023.

As costs go down, utility-scale battery storage projects are growing quickly as well. Nationally, utility-scale battery storage has grown from 214 megawatts in 2014, to 899 megawatts in 2019, to potentially 2,500 megawatts in 2023. The average length of battery availability, however, is only four hours. This makes it most helpful for smoothing out solar and wind power availability to meet peak demand and short-term supply needs.

OVER THE PAST 10 YEARS

COST of producing lithium-ion batteries has DECLINED by

90%

HYDROPOWER:

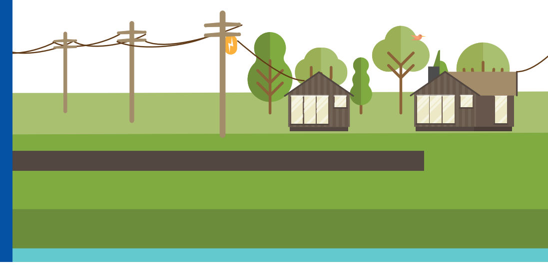
Putting Excess Water Supply to Good Use

Renewable, weather-dependent power generation can also sit idle when there is plenty of supply but not enough electricity demand. When hydropower projects are idle, water goes downstream without the opportunity to generate power.

Douglas County PUD in Central Washington is investigating using their excess supply of hydropower in the spring to create a hydrogen-based, non-polluting, carbon-free fuel. Like a battery, hydrogen fuel cells can be used to operate everything from forklifts, cars and buses, to providing back-up power for buildings and equipment.

This carbon-free power innovation is potentially a perfect marriage in two ways. First, creating hydrogen fuel is very power intensive, making low-cost hydropower an excellent partner. And second, one carbon-free generation resource (hydropower) is being used to create another carbon-free generation resource (fuel cells) that can be exported and stored for later use. This supports regional and national goals to reduce carbon emissions across industries.

Hydropower Services a Modern Power Grid



Moving Electricity from Power Plants to Homes and Businesses

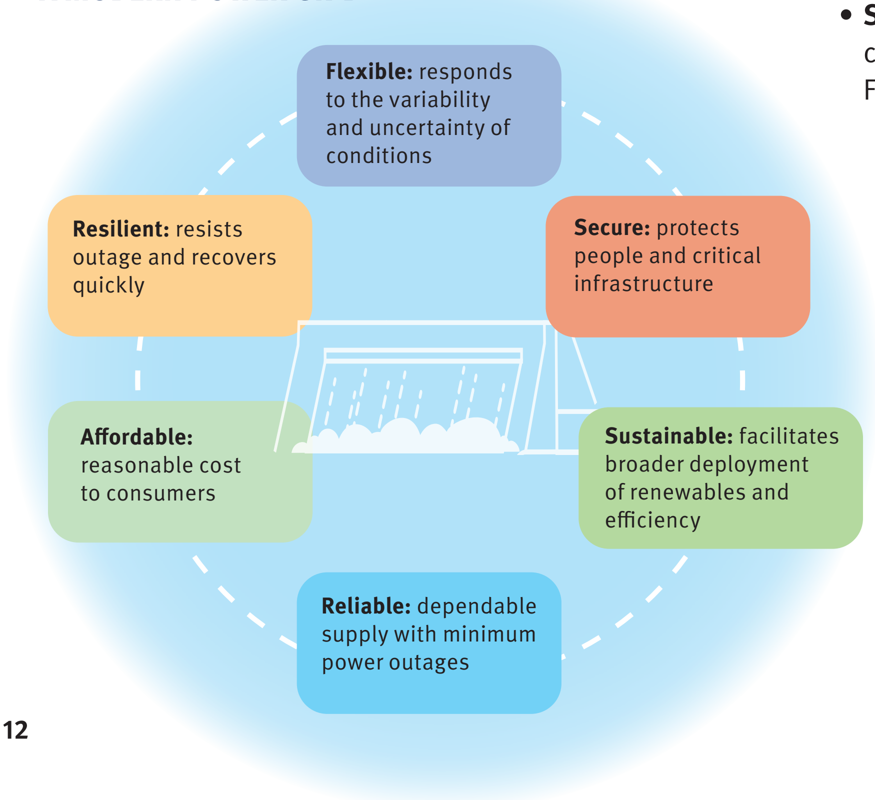
When we turn on a light switch or plug in a computer or other device demanding electricity, we're using the power grid.

Sometimes called the largest machine in the world, today's U.S. power grid comprises over 5,800 power plants, 3,200 utilities and 2.7 million miles of power transmission lines across the nation. The equivalent of 350 million homes can be powered by this awesome machine. Just as amazing, its reliability is over 99 percent.

Millions of dollars are being invested to modernize the power grid. The grid carries the flow of electricity from power plants, to transmission lines, to distribution in your neighborhood, and into your home or business.

Hydropower services a modern grid with power that is efficient, reliable, flexible and affordable. As important, hydropower is the foundation for securing a carbon-free, renewable power generation future.

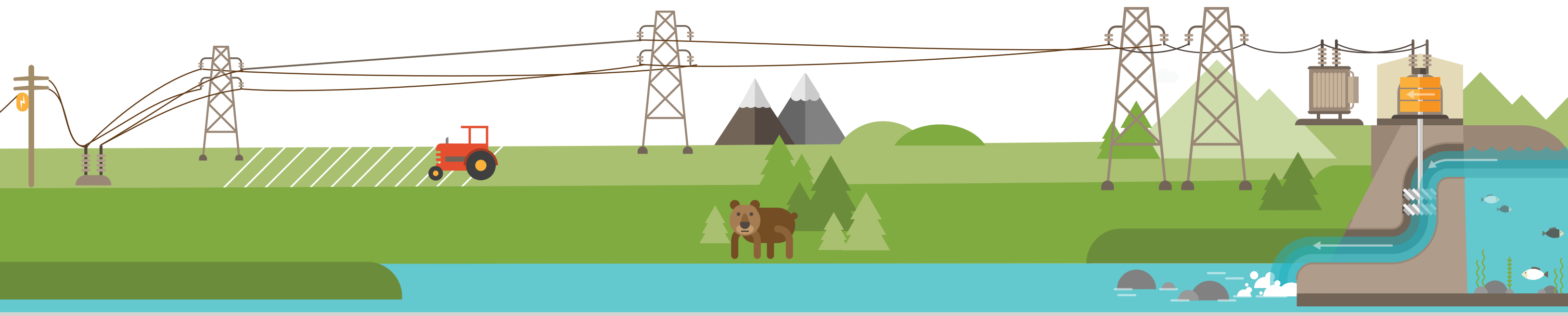
HOW HYDROPOWER SUPPORTS A MODERN POWER GRID



Today's power grid features new technologies being combined with high-speed communications, computers, and software in novel ways. Smart meters, for instance, support two-way communication capability between electric utilities and customers. They are now installed in over half the businesses and homes in the country.

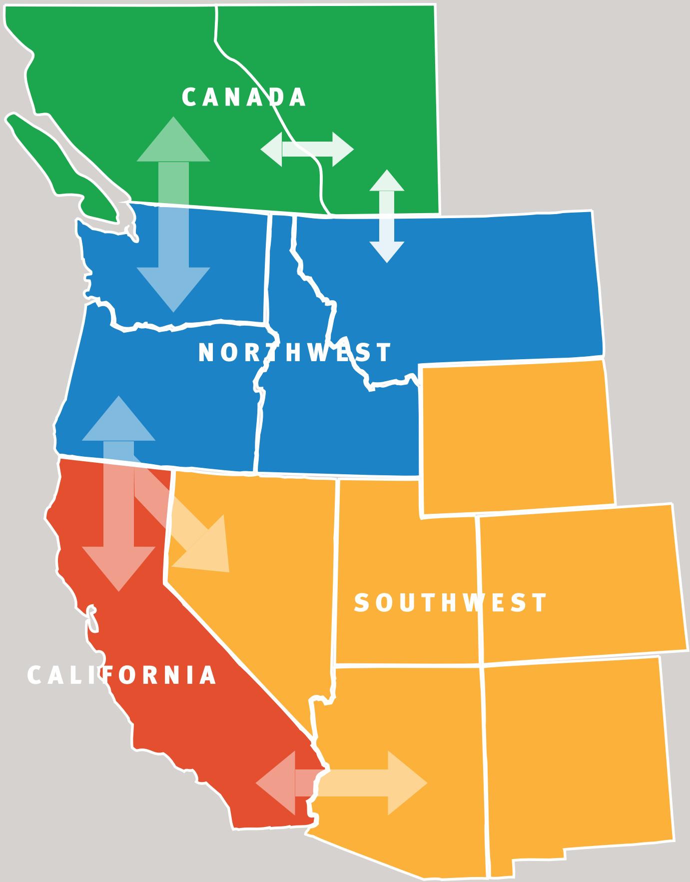
Here are examples of how renewable sources of electricity work in tandem with modern power grid technologies like smart meters and distribution management systems:

- **Software and high-speed communications** can take better account of weather patterns and power demands. This allows operators to optimize bringing power generation resources like hydro, wind and solar on and off-line in a way that keeps costs low and minimizes environmental impacts.
- **Scheduling power needs,** e.g. charging your car or cell phone at night when costs are lower. For utilities and businesses, flexibility is supported with hydropower's ability to store water to generate electricity when it's most needed and large-scale batteries that can be used to reduce costs when demand is highest.
- **Integrate solar powered homes** into the grid by adding what's not used in the home onto the grid.
- **Reduce the length of power outages** with real time communication of who has lost power and what caused the outage.



TRADING POWER ACROSS THE WEST

***The supply of electricity must always match demand because electricity cannot be stored on the power grid.* Across the West, power is imported and exported to meet power demand needs. Hydropower's flexibility helps balance the weather dependent availability and reliability of wind and solar power.**



Electricity in the Northwest is part of a Western Interconnection grid that stretches from British Columbia, Canada to Baja California, in Mexico and eastward over the Rocky Mountains.

Historically, utilities balanced supply and demand needs through various combinations of buying power, using their own generation sources, and trading with each other. In 1970, transmission lines called the Pacific Intertie created more flexibility by enabling operators to move electricity between California and the Northwest.

As the power generation stack shifts toward renewable and weather dependent sources like solar, wind and hydro, the need to find new ways to mix and match supply and demand across the grid has increased dramatically.

One way to ensure supply is to expand the territory of available power in a way that also complements the renewable strengths of each region. Let's use California and the Northwest as an example. In 2018, solar power represented 14 percent of California's and 15 percent of the Northwest's generating capacity. Increased transmission line capacity and trading can support solar power from California being sent to the Northwest during the winter when our electricity demands for heat are high. Likewise, wind power from the Northwest can be shipped to California in the summer when demands for air conditioning are high. Hydropower's flexibility helps balance the weather dependent availability and reliability of wind and solar power.

Another way to support supply is highly sophisticated power trading. Here, operators can trade for power in as fast as 5 to 15-minute intervals, also called real time trading. In addition to saving customers money by finding needed power at the lowest cost, it opens new markets for clean, carbon-free, low cost renewable energy. This is now emerging across the west as utilities and generators join California's Independent System Operator (ISO) Western Energy Imbalance Market.

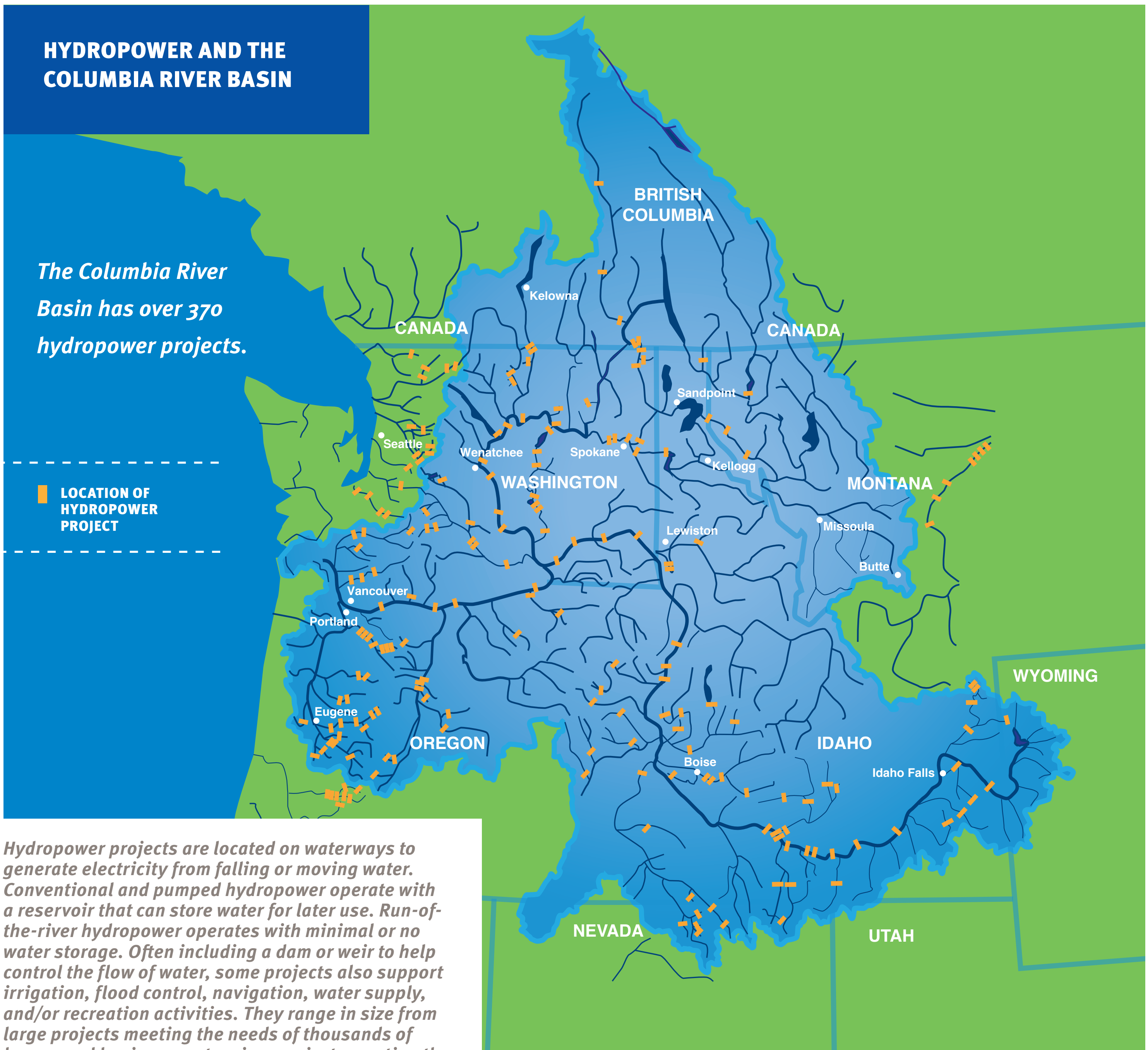
Hydropower in the Northwest

Hydropower is the key to the Northwest attaining a carbon-free generation future.

Hydropower projects provide the baseload of clean, renewable, low cost electricity that other renewable generation resources build from. More than 370 projects provide over 55 percent of the Northwest's electric generation capacity in a normal precipitation year. The 16 largest projects account for 62 percent of the Northwest's hydropower capacity, and all but one is located on the Columbia or Snake rivers.

HYDROPOWER AND THE COLUMBIA RIVER BASIN

The Columbia River Basin has over 370 hydropower projects.

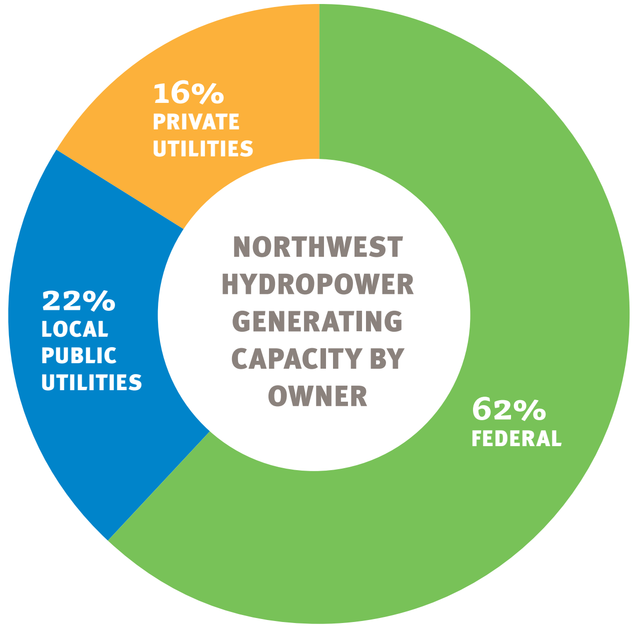


Hydropower projects are located on waterways to generate electricity from falling or moving water. Conventional and pumped hydropower operate with a reservoir that can store water for later use. Run-of-the-river hydropower operates with minimal or no water storage. Often including a dam or weir to help control the flow of water, some projects also support irrigation, flood control, navigation, water supply, and/or recreation activities. They range in size from large projects meeting the needs of thousands of homes and businesses, to micro projects meeting the needs of a home, farm, or business.

Source: Foundation for Water and Energy Education

The unique nature of the Columbia Basin, a 259,000 square mile area the size of France, enables the force of falling water to power these projects. Rivers and streams from parts of seven states and Canada drain into the Columbia River. 1,243 miles in length and 2,690 feet above sea level at its headwaters, the Columbia has the greatest flow of any North American river draining into the Pacific, dropping an average of two feet per mile.

To think about the "force," or potential energy of this water flowing downstream, imagine you are on the Columbia River. Average stream flow at The Dalles Dam is about 190,000 cubic feet per second (cfs). That's like taking a football field and filling it with over three feet of water (or 1,421,000 gallons) and passing it by an imaginary line across the river each second. When the river flow peaks in spring, over twice this amount of water flows by The Dalles Dam.



Source: Foundation for Water and Energy Education

THE COLUMBIA RIVER BASIN: SOURCE OF THE NORTHWEST'S RENEWABLE HYDROPOWER BOUNTY

The Columbia River is 1,243 miles long

25 PERCENT of the river flow comes from Canada

The Columbia River falls an average of more than TWO FEET PER MILE before reaching the ocean

Average annual runoff at the Columbia's mouth is 192 MILLION ACRE FEET, enough to cover the state of Texas more than one foot deep in water

In the spring, water flows are the highest when SNOW MELTS into the rivers

The LARGEST TRIBUTARY to the Columbia is the Snake River, which is 1,036 miles long

EIGHT NAVIGATION LOCKS at dams on the Columbia and Snake rivers support a 465-mile corridor that ships millions of tons of cargo annually

Reservoirs at dams divert 6 percent of yearly runoff to IRRIGATE 8 MILLION ACRES of crops

Reservoirs store 55 million acre feet of water to provide flood control that SAVES BILLIONS OF DOLLARS in property damage

CLEAN, GREEN, AFFORDABLE hydropower helps keep worldwide internet cloud computing services flowing for Microsoft, Apple, Facebook, Amazon and others

A diverse group of public and private entities own and operate hydroelectric projects. The 31 federal government projects located on the Columbia River and major tributaries account for the majority of the Northwest's hydropower generating capacity. They are owned and operated by the U.S. Army Corps of Engineers and Bureau of Reclamation. Many of these also serve flood control, navigation and/or irrigation needs. The Bonneville Power Administration markets this power, with proceeds going toward financing construction, operations and maintenance costs.

Public ownership also exists at the local level, primarily via public utility districts (PUDs), cooperatives and municipal governments. These projects are owned and operated by the local citizens they serve. There are 61 such projects that contribute 22 percent of the Northwest's hydropower generating capacity. Private utilities, often called independent or investor-owned utilities, also own and operate projects. There are 264 private projects that contribute 16 percent of the Northwest's hydropower generating capacity.

How Hydropower Works

Each hydropower project is unique. The equipment and design reflect when it was built, the landscape and the geologic character of the location.

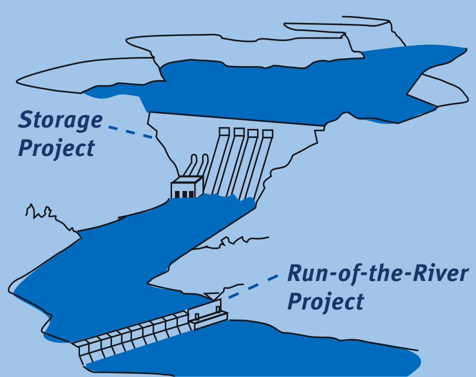
And like our homes, equipment and designs are regularly updated. Hundreds of millions of dollars have been invested since the 1990s to replace turbines and rewind generators. These investments are used to help projects generate more power, use less water to generate the same amount of power, improve water quality and/or increase juvenile fish passage downstream.

From a power generation perspective, the other big difference between projects is “run-of-the-river” vs. “storage” projects. Run-of-the-river projects allow water to pass through a facility at about the same rate the river naturally flows.

Storage projects have a reservoir, sometimes called a lake, behind the dam. By “storing” water, operators can adjust the river’s natural water flow to meet one or more needs. For instance, releasing water when more electricity is needed, capturing runoff to assist with flood control and supporting irrigation.

Storage between May and July also helps equalize river runoff over the course of the year. In fact, in the Northwest 60 percent of runoff occurs during this time. By storing water in U.S. and Canadian reservoirs, it can be released for power, irrigation and other needs when supply is less plentiful during the late summer, fall and winter months.

STORAGE VS. RUN-OF-THE-RIVER

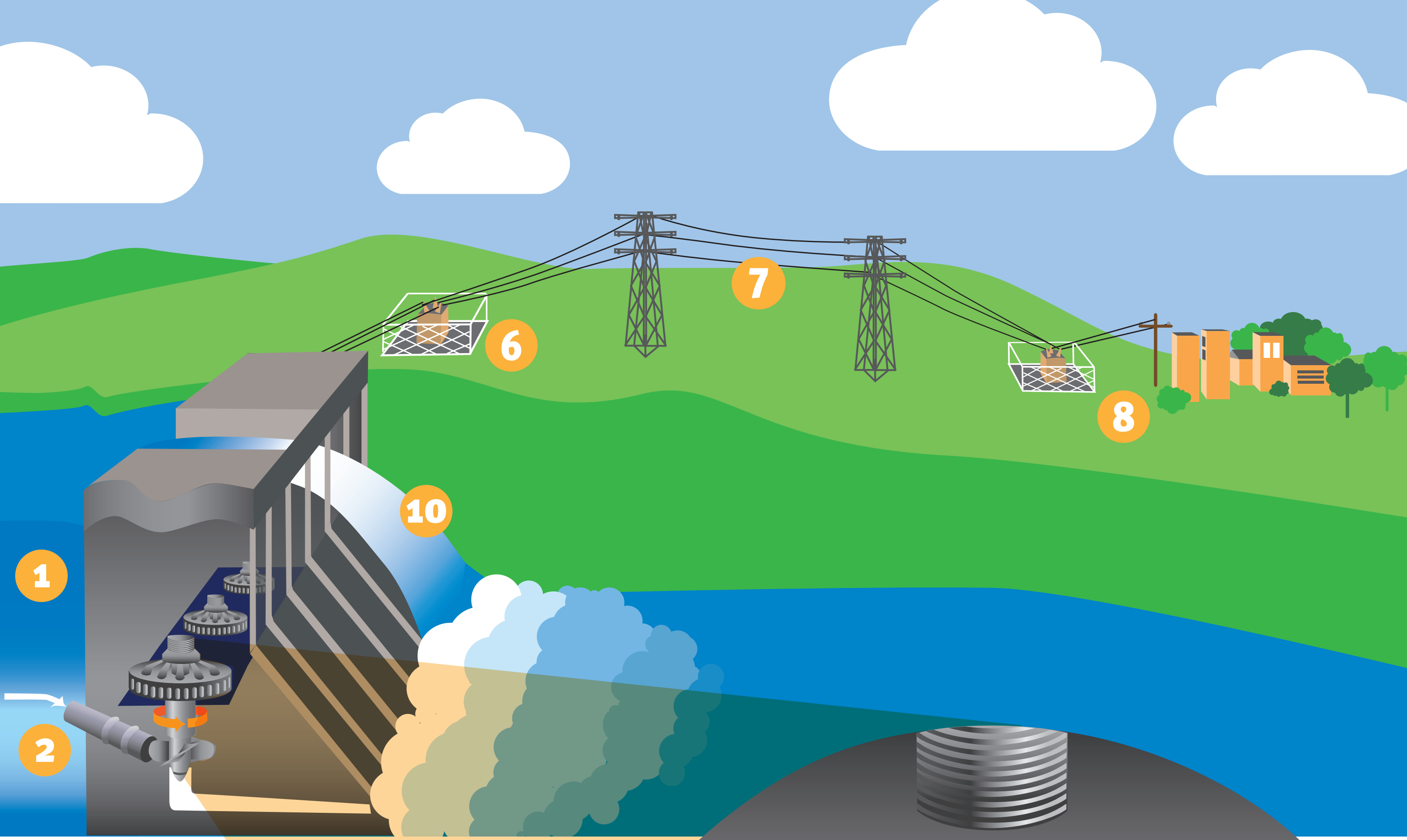


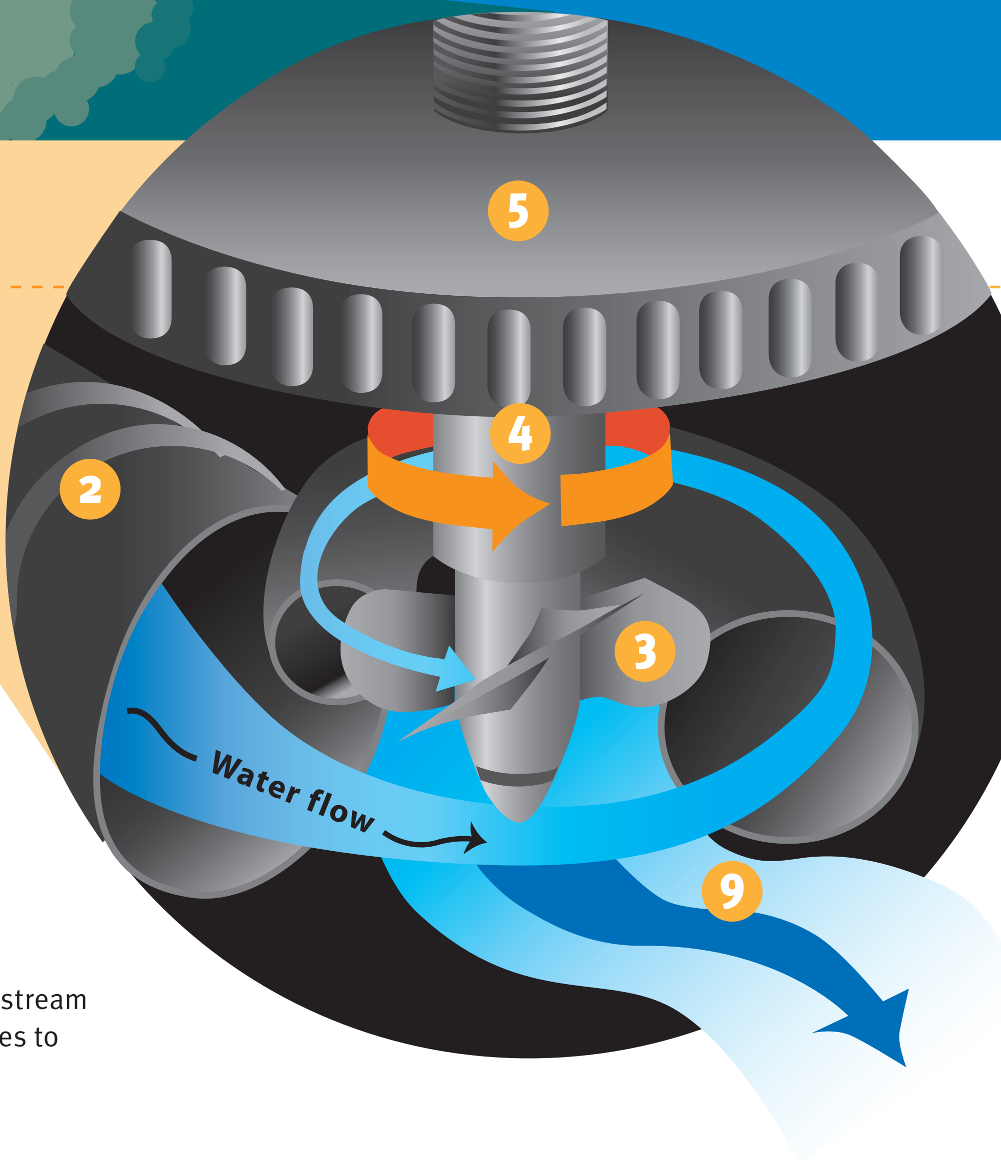
In the Northwest, 60 percent of runoff occurs from May through July. Storage projects allow water to be released when supply is less plentiful during the late summer, fall and winter months. Spring water is helpful in meeting flows for fish, irrigation and flood control needs. It also enables intermittent resources such as wind and solar to be used on the power grid.

Run-of-the-river projects allow water to pass through a project at about the same rate the river naturally flows. Some run-of-the-river dams include the flexibility to reserve some river flows for release during hours when power is most needed. This hydropower flexibility provides critical support to wind, solar power and other variable sources of energy that are becoming more prominent on the power grid.

Take a Walk through a Hydroelectric Project

1. **WATER** from a river or reservoir flows into a penstock.
2. The **PENSTOCK**, a large pipe above or below ground, is commonly used to direct the water flow.
3. **TURBINE BLADES** are pushed by the force of water exiting the penstock, causing them to transfer the energy of falling water to rotate the shaft.
4. The **SHAFT** connects the turbine to the generator, turning at the same speed as the turbine.
5. Inside the **GENERATOR**, the spinning shaft turns electromagnets (called a rotor) inside a stationary ring of copper (called a stator), moving electrons to produce electricity.
6. **STEP UP TRANSFORMERS** increase the voltage of electricity produced by the generator.





7 **TRANSMISSION LINES** carry high voltage electricity to substations in our communities.

8 At **SUBSTATIONS** (which house step down transformers), the voltage is decreased. Electricity is then distributed to homes and businesses.

9 **WATER FLOW** used to turn the turbines returns to the river.

10 **SPILLWAYS** release water downstream that is not directed to the turbines to generate electricity.

Hydropower and the Environment

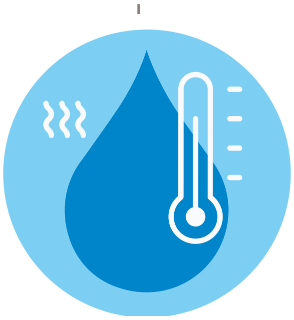
There is an environmental impact whenever electricity is generated.

The hydropower industry continues to innovate and collaborate to deploy environment-friendly technologies and strategies to address impacts. Since 1978, federal investments to support fish and wildlife needs are more than $7.5 billion. In addition, billions of dollars are being invested by public utilities and private operators.

INNOVATION AND COLLABORATION TO MEET ENVIRONMENTAL RESPONSIBILITIES

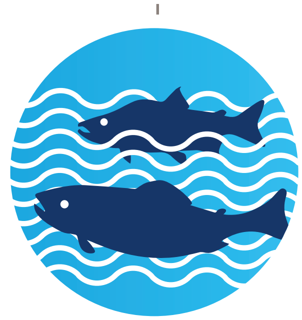
These examples highlight some of the environmental protection, mitigation and enhancement activities found at many hydropower projects across the Northwest. Many are collaboratively developed and/or managed with tribes, private landowners, and local, state and federal agencies.

Snohomish County PUD helps the growth and productivity of fish in the Sultan River by using their **Culmback Dam** to blend warm water near the reservoir surface with cold water near the reservoir bottom. This provides optimal water temperatures during a typical summer, or under drought and climate change scenarios when water becomes too warm for the fish.

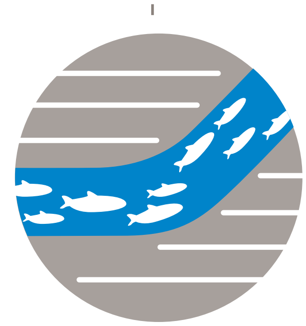


Seattle City Light manages river flows through their three **Skagit Project dams** to support downstream salmon. Flows through the dams are adjusted on a seasonal, monthly, and daily basis to supply the right amount of water for spawning, incubation, and protection of juvenile salmon.

Tacoma Power releases chinook, coho, steelhead and sea-run cutthroat at two hatcheries that are part of their **Cowlitz River Project,** and they stock kokanee in Alder Lake as part of their **Nisqually River Project.**



At **Grant County PUD's Wanapum** and **Priest Rapids projects,** fish bypass facilities allow downstream migrating juvenile salmon to pass by each dam without going through a spillway or turbine, thus ensuring more than 95 percent of smolts successfully pass each dam.



When avoiding impacts is not possible, protection, mitigation, and enhancement are three broad strategies used by hydropower generators to meet their environmental responsibilities.

- **Protection** preserves areas that are ecologically important, healthy and intact, e.g.—protecting natural spawning grounds and wetlands to help with overall watershed health.
- **Mitigation** offsets losses where environmental impacts are unavoidable, e.g.— building a fish hatchery.
- **Enhancements** improve preexisting project conditions, e.g.—planting riparian areas lacking vegetation to stabilize streambanks.

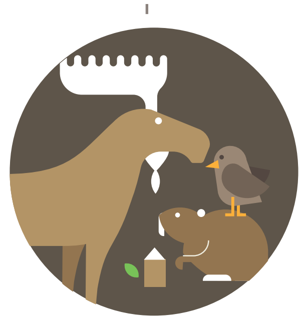
When demand for power generation affects river flows, hydropower operators use these strategies and technology to balance water quality, fish, and other environmental needs. For instance, as water passes through a dam and powerhouse, technologies are employed to address water quality effects to temperature and dissolved gases like nitrogen and oxygen.

Successfully using these strategies to meet environmental responsibility is made much more complicated by other human practices like farming, fishing, logging, cattle grazing, mining, and land development occurring adjacent to or upstream of a project. This is one reason natural resource managers often take a watershed planning approach to characterize conditions, prioritize needs, create management objectives, and implement protection and restoration strategies.

The **Pend Oreille PUD** collaborates with the **Pend Oreille Conservation District** to provide landowners with technical and financial assistance for bank stabilization projects. This effort collaboratively addresses erosion control along the **Box Canyon Reservoir.**

Chelan County PUD works collaboratively to support and fund projects that protect and enhance salmon and steelhead habitat in the **mid-Columbia** and its tributaries. Projects include bank and shoreline restoration, removing fish migration barriers, native riparian plantings, constructing in-stream habitat structures and acquiring conservation easements.

Douglas County PUD's Wells Hydroelectric Project Wildlife and Botanical Management Plan protects and enhances the habitat of rare, threatened and endangered wildlife and botanical species on Project lands. The PUD funds an additional 8,000+ acres known as **Wells Wildlife Area** that is managed by the **Washington Department of Fish and Wildlife** to protect and enhance mule deer winter range, upland bird habitat and waterfowl winter food resources. Bald eagle perching opportunities are also protected and increased around the Reservoir.



In 2020, the **U.S. Army Corps of Engineers** installed advance turbines at **Ice Harbor Lock and Dam** on the Snake River. Early testing showed a juvenile Chinook salmon survival rate of a little more than 98 percent. Combined with passage through fish bypass facilities, spillways and other methods, 93 to 96 percent of all young salmon and steelhead now survive passage at each dam in the Federal Columbia River Power System.

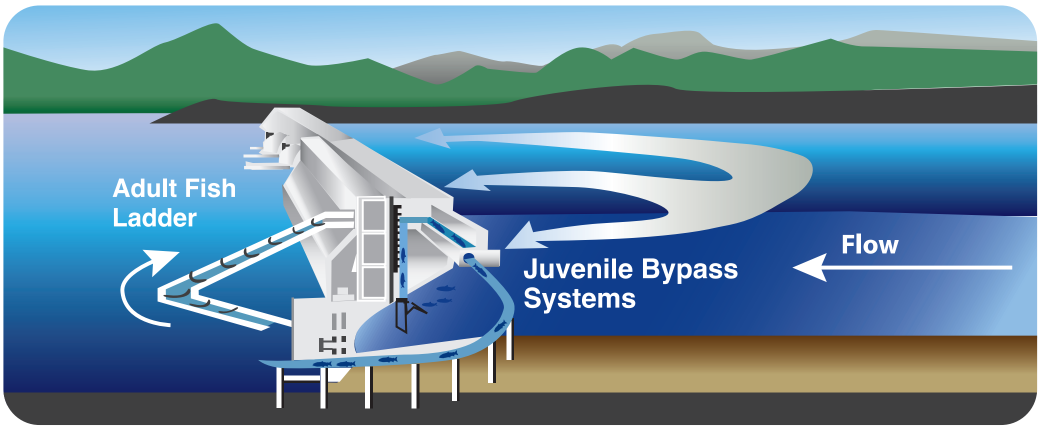
Hydropower and Fish Protection

Fish, particularly salmon and steelhead that travel long distances between fresh and ocean waters, pass through multiple environments during their life cycle.

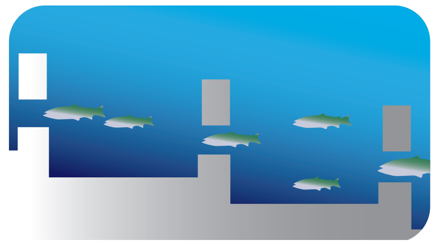
Since 1991, 13 specific populations of salmon and steelhead have been listed as threatened or endangered in the Columbia River Basin. In addition, bull trout and Kootenai River white sturgeon (resident fish that migrate only within freshwater), have been listed for protection.

For salmon and steelhead on the Columbia River, federal performance standards call for 96 percent of spring fish migrating downstream to successfully pass through each hydropower project, and 93 percent for summer migrants. Thanks to fish bypass systems, turbine design, spillway improvements and other efforts, hydropower projects are meeting these standards.

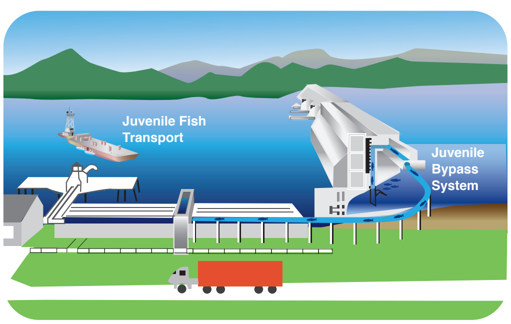
Fish Passage Tour



When young salmon (smolts) migrating downstream encounter a hydroelectric project, they will either pass over a spillway, through the turbine area, be transported around a dam or enter a bypass system.

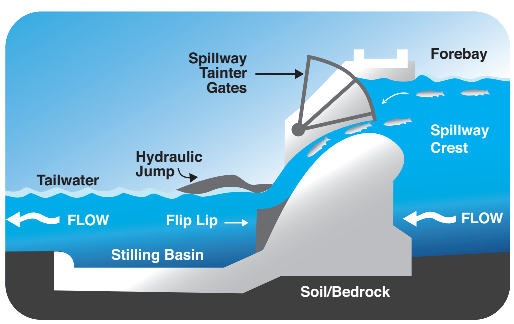


***Fish Ladders** are the most common way for adult salmon to migrate upstream as they journey to their spawning grounds. Upstream options also include trap-and-haul, bypass channels and other innovations.*



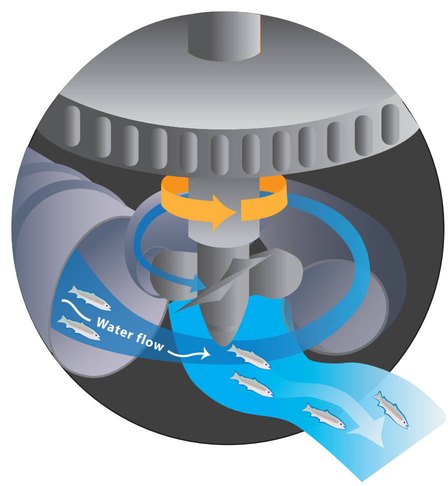
***Fish Bypass Systems and Transportation:** Surface collectors are a common means of guiding juvenile salmon around a project.*

One method is to use fish screens to guide fish into a bypass system. Another method is to use a surface collector to channel fish into a bypass system. Along the main stem of the Columbia and Snake rivers, some migrating smolts are collected in barges and then transported up to several hundred miles downstream.



***Spillway Improvements:** Migrating smolts can pass over a spillway, fall into the pool of water below, and then continue their journey downstream. Some weirs now provide a water ramp that allow fish to slide down to the river below.*

Flip lips, also called spill deflectors, are sometimes used to reduce the effect of total dissolved gas, or TDG, which can cause gas bubble disease in fish.



***Advanced Turbine Designs:** Migrating smolts can pass into the turbine area and exit via the tail race. A new generation of turbines include minimum gap runners to increase turbine efficiency while decreasing the likelihood of smolts being trapped, bruised, stressed or disoriented.*

The fish passage tour shows upstream and downstream migration. These investments, combined with managing river flows, have dramatically improved salmon survival past dams.

Beginning in 2017, however, returns dipped to levels common in the 1990s. Scientists believe that poor ocean conditions related to Pacific Decadal Oscillation (multi-year patterns of variation in sea surface temperature), El Niño (abnormal warming of the Pacific Ocean off northern Peru and Ecuador causing nutrient-poor water), and marine heatwaves are major contributors to lower salmon returns.

NOAA's Northwest Science Fisheries Center is researching these patterns, noting that "The listing of several salmon stocks as threatened or endangered under the U.S. Endangered Species Act coincides with a prolonged period of poor ocean conditions that began in the early 1990s. …Returns of both spring and fall Chinook declined from 2017 to present, likely from poor ocean conditions associated with the marine heatwave that affected feeding conditions for out-migrating juveniles in 2015 onward."

Climate change is also contributing to less snowpack and hotter summers, thus raising river temperatures to levels that negatively affect adult salmon survival. This is further impacted by extensive fish harvesting in international waters and growing predation from sea lions, terns and other species.

The complex era of climate change makes supporting hydropower more important than ever. Generators of hydropower are investing millions of dollars annually to support and ensure fish survival while providing the foundation for a renewable, carbon-free power generation future.

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