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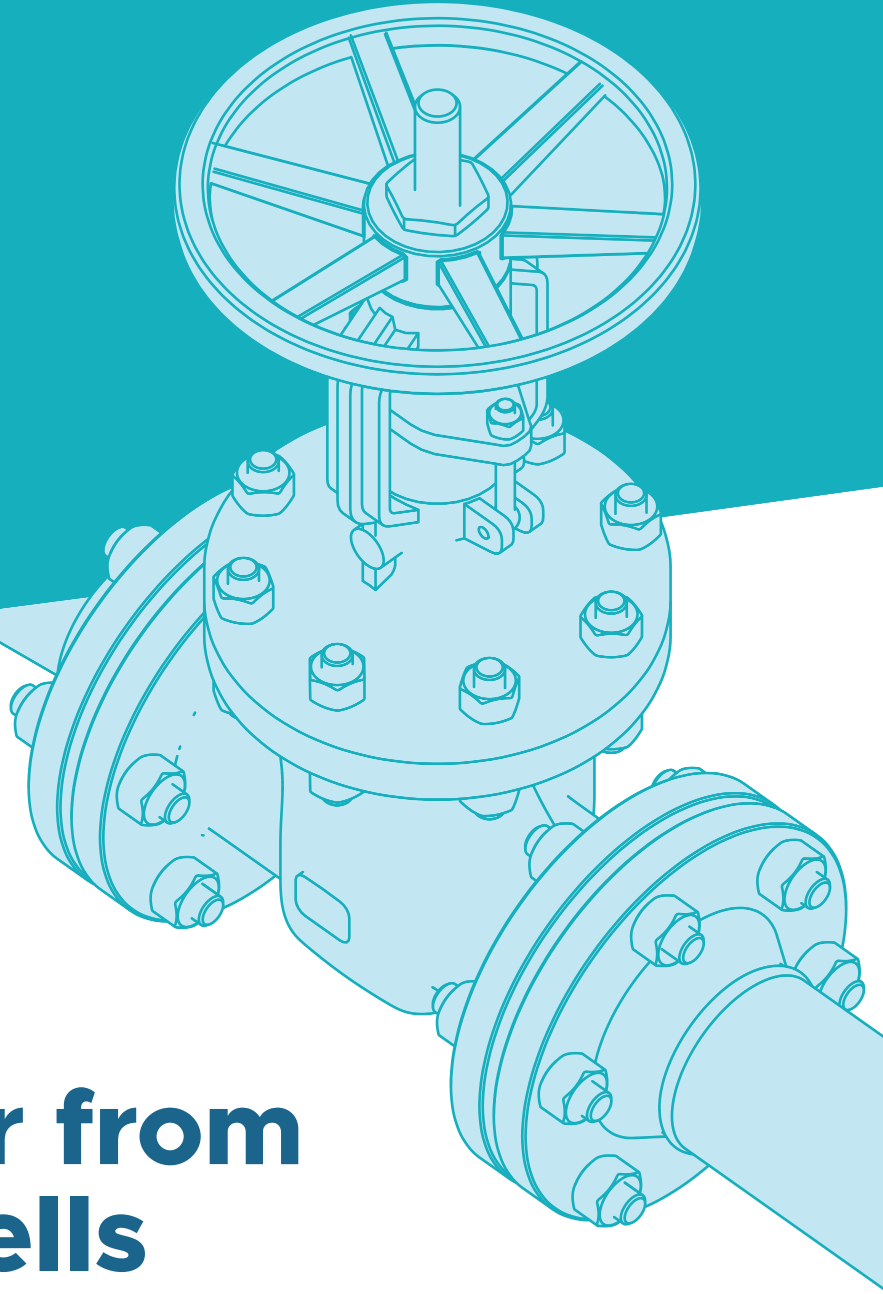

Generating Hydropower from Injection Wells

If you own or operate a well that injects water into an underground aquifer, or are considering such an installation in the future, you may have an opportunity to incorporate conduit hydropower!

Conduit hydropower uses existing pipelines, like injection wells and other human-made water conveyances, to generate power. Adding conduit hydropower may be a cost-effective option for on-site renewable energy generation, reducing electricity costs or adding a new revenue stream, with the potential to provide protection to your system from grid outages.

THIS GUIDE WILL HELP YOU UNDERSTAND:

- How it works – System overview and common equipment for injection well hydropower
- Things to consider – Development and permitting considerations
- Whether your site is suitable – See the flow chart to determine whether your site merits further review
- What success can look like – A case study in Pendleton, Oregon

HOW IT WORKS

Conduit hydropower projects generate electricity by capturing surplus pressure in pipes with flowing water. At injection wells, a pump, variable frequency drive, regenerative drive, and downhole flow control valve work together to enable hydropower while water is injected into the aquifer. This pump-spinning-in-reverse operation generates renewable energy, while maintaining the ability of the pump to work normally. Importantly, if pumping is required to inject the water, hydropower is not possible.

The amount of **power** that can be produced depends on the amount of water **flow** (in cubic feet per second or cfs), the pressure difference—also known as **head** (in ft)—and the overall energy conversion **efficiency** of the system:

$$\text{Power (kW)} = \frac{\text{Flow (cfs)} \times \text{Head (ft)} \times \text{Efficiency}}{\text{11.81 (a constant)}}$$

The total head available for energy generation is the height from the well head to the pump bowls at the bottom of the well (see Figure 1). A higher head well (i.e., deeper) means higher water pressures and increased generation potential. A constant accounts for gravity, the density of the water, and unit conversion.

While hydropower turbines can exceed 80–90 percent efficiency, pumps operating as turbines are often less efficient. After accounting for different sources of loss, system efficiencies may range from 50–70 percent.

The total annual **energy** a system produces depends on the head and flow conditions (power) while the system is running (**operating hours**).

$$\text{Energy} = \text{Power} \times \text{Operating Hours}$$

Run time is dependent on the underlying needs and uses of the well and may be influenced by seasonality, temperature, and water availability. The feasibility of injection well hydropower is highly site specific.

In practice, the financial feasibility of hydroelectric systems can be challenging below 10 kW and for heads of less than 30 feet. Larger, higher head projects tend to gain economies of scale and are often more cost-effective.

COMMON APPLICATIONS

- Aquifer storage and recovery (ASR) to temporarily store water for later retrieval and use.
- Aquifers used for thermal energy storage and retrieval for heating, ventilation, and air conditioning.
- Aquifer recharge systems that are a part of watershed management activities, or to prevent saltwater intrusion along coastal regions.

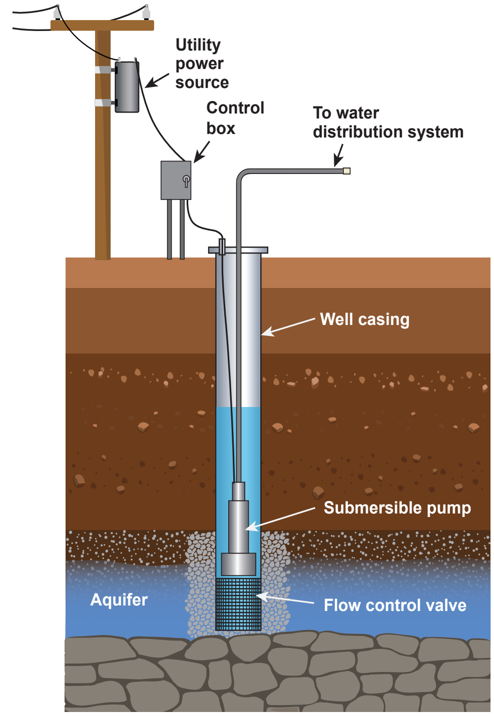

Figure 1. Anatomy of an injection well hydropower system

TYPICAL SYSTEM COMPONENTS

The designs of injection wells can differ, but adding hydropower requires common features.

Pumps

To generate hydropower from an injection well, a three-phase electric pump is required. Two categories of vertical turbine pumps are commonly used in injection well applications: line shaft or submersible, as shown in Fig. 2. Pump choice is typically site specific and decided upon through hydrology, engineering reviews, or feasibility studies.

Line Shaft Pump	Submersible Pump
Motor at the surface is connected to the pump bowls by a vertical shaft	Motor located in the well, below the pump bowl
Cavitation more likely	Less likely to suffer cavitation
Maximum depth of 500–1,000 ft	Can go as deep as 2,500 ft
Lower installation and maintenance costs	Maintenance is more challenging since the pump and motor must be removed from the well
Requires a pump house and may be noisier	Quieter and more compact; pump house may not be necessary

Variable Frequency Drives and Regenerative Drives

To add hydropower to an injection well pump, a variable frequency drive (VFD) and a regenerative drive are used, working in tandem. The VFD senses the local electric utility's line voltage and frequency and adjusts the electricity produced to match it—a requirement to interconnect to the local electrical grid—while the regenerative drive allows a pump motor to spin in reverse and act as a generator.

The speed regulation of the VFD also controls the flow rate of water through the pump, enabling energy efficiency savings during pumping by matching water flows to demand rather than using a constant pump flow.

Downhole Flow Control Valve

Downhole flow control valves keep the well water column under positive pressure when source water flows are variable. This may improve the well and pump's operational lifespan by preventing air bubbles from becoming entrained in the injection water, which can plug the aquifer and cause cavitation, increasing wear on the pump bowls. Downhole flow control valves can also set a maximum flow rate into an aquifer and change that maximum flow over time.

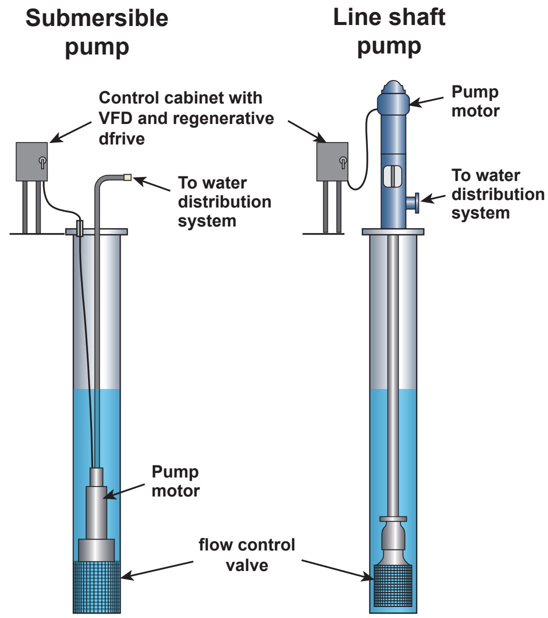

Figure 2. Submersible pump vs line shaft pump

SITE SUITABILITY

Is pumping required to inject water into the aquifer?

- Yes → If pumping is required, hydropower is not possible
- No → **How deep is the well?**
  - <30 ft? → Shorter wells (<30 ft) with <10 kW of potential power are less likely to be financially feasible.
  - >30 ft? → **Does the site have an existing three-phase utility connection?**
    - Yes → You may have a suitable site for hydropower! Work with an engineer to investigate further.
    - No → **How far is it to the nearest three-phase utility pole?**
      - >0.25 miles? → Connecting to the grid may be financially challenging. Work with the utility or an electrical engineer to estimate potential line extension costs.
      - <0.25 miles? → You may have a suitable site for hydropower! Work with an engineer to investigate further.

FOR DETAILS ABOUT DEVELOPMENT AND PERMITTING, SCAN HERE:

CASE STUDY – PENDLETON, OREGON

The city of Pendleton, Oregon has operated an ASR program since 2003, when the city added aquifer storage capabilities to several existing municipal drinking water wells. The city chose to use ASR to avoid the costs and potential environmental effects associated with surface water storage and to address regional goals to reverse groundwater depletion.

Pendleton has a long history of supporting renewable energy projects at city-owned infrastructure and among its residents. Water system staff saw the potential to generate electricity using surplus pressure available at their ASR wells and explored the opportunity to further the city's sustainability goals.

Pendleton began adding hydropower in 2012 through a test at one ASR well, installing a VFD, regenerative drive, and relay required by the electric utility for interconnection. When the test was successful, the city added hydropower to three more wells in 2014, with the total hydropower potential across all the wells ranging from 28 kW to 68 kW.

The city's ASR well locations are at a lower elevation than its water filtration plant, meaning that significant pressure is available at some of the ASR wellheads. Typically, this surplus pressure would be eliminated through a pressure reduction valve (PRV). Through the ASR hydropower systems, the city was able to capture the energy that would normally be dissipated by pressure reduction valves, increasing the available head.

Well #14 Hydropower Installation. Photo credit City of Pendleton, Oregon

Pendleton's local utility offers annualized net metering, enabling the city to use the electricity generated in the winter to offset the costs of pumping each summer.

Based on operational data from 2014 to 2022, annual generation has averaged 326,000 kWh, helping the city to offset approximately $25,000 in energy costs each year.

DID YOU KNOW?

The Environmental Protection Agency estimates there may be more than 10,000 injection wells used for aquifer recharge, storage, and recovery and cooling water, with many thousands more used for other purposes.

HYDROPOWER BENEFITS

- Reduced electricity costs
- New revenue streams
- Improved energy reliability
- Opportunities to mitigate outages
- Lower carbon footprint

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WATER + POWER RESILIENCE

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