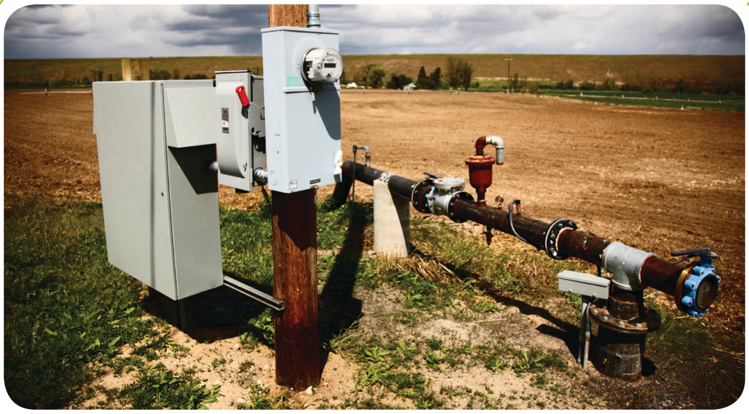


GENERATE HYDROPOWER FROM AQUIFER STORAGE AND RECOVERY

REGENERATIVE DRIVE TECHNOLOGY CAN RECAPTURE MUCH OF THE ENERGY LOST IN THE STORAGE AND RECOVERY PROCESS

REGENERATIVE DRIVE HYDRO GENERATION IS APPROPRIATE FOR:

- Municipal and other water suppliers that use aquifer storage for treated water
- Commercial and industrial facilities that use aquifers for thermal energy storage and retrieval for HVAC or other purposes
- Irrigation districts and agriculture businesses that capture and store water in aquifers for later use during dry seasons

Using aquifers to store and recover water for later use is becoming more common for potable water suppliers, large commercial and industrial facilities, irrigation districts and agricultural operations. Until recently, the energy required to inject water into an aquifer was simply an expensive, but necessary, cost of doing business. Now, a promising new technology offers the opportunity to generate hydroelectric power during the injection process. Regenerative drive technology can help reduce your operating costs by recovering some of the energy lost during injection, making aquifer storage and recovery a more cost-effective option.

Tap into new regenerative drive technology

Aquifer storage and recovery uses an injection well and pump. By installing a regenerative drive module on the electrical components of your injection well, you may be able to generate electrical energy using the head pressure of the water flowing back into the aquifer. The regenerative drive module works in tandem with a variable frequency drive, VFD, and under sufficient pressure it allows a 480-volt, 3-phase induction pump motor to spin in reverse and act as a generator. This technology is not unlike that used in electric vehicles: When the electric vehicle brakes, the energy dissipated by braking runs the motor in reverse to generate power and recharge the car's electric battery. Research suggests pumps working in reverse can generate energy with approximately 47 percent efficiency.

The regenerative drive modules used in aquifer storage and recovery are available in a variety of sizes to match different needs and head pressure. Sizing a module varies with head pressure and water flow. Electronics in the VFD sense the local electric utility's line voltage and frequency and adjust the electricity produced to match it. This allows operators of aquifer storage and recovery systems to use the generated hydropower on site.

Adding a regenerative drive during design and construction of your aquifer storage and recovery project can be highly cost-effective and may add only 20 percent to the cost of electrical components. The most cost-effective applications are those with the highest head pressure. Some projects pay for themselves in as little as two years.

Energy Trust of Oregon

ENERGY TRUST OF OREGON CAN HELP BRING YOUR PROJECT TO FRUITION:

- **Project Development Assistance:** Energy Trust may provide support for expert project development assistance such as grant writing, feasibility studies, final design, permitting, utility interconnection and construction management. We may pay up to 50 percent of the cost of hiring a consultant to provide expert assistance for these activities, up to a maximum of $40,000.
- **Hydroelectric installations:** We may provide an incentive based on a project's costs in comparison to the market value of the energy produced (above-market cost). There is no cap or fixed percentage of the amount of above-market costs that we will pay. In return for our funding contribution, we ask for a negotiated share of the project's Renewable Energy Certificates, which are held in trust for the ratepayers who contribute to Energy Trust.

DEMONSTRATION PROJECT: REGENERATIVE DRIVE HYDROPOWER AT MADISON FARMS

Under a demonstration grant from Energy Trust, Madison Farms in Echo, Oregon tested the use of regenerative drive technology to generate electric power from a shallow well. Source water was from a shallow pit supplied by a 40-horsepower, HP, motor driving a Cornell 4rb40 pump, lifting water five feet and delivering 542 gallons per minute, GPM, at 47 pounds per square inch, PSI, to the inlet of the regenerating pump. Madison Farms metered the water through an ABB 6-inch duel direction mag flow meter.

Equipment used in demonstration

The regenerating pump and line shaft turbine were in a 20-foot well. The regenerating pump was a US motor Holloshaft 75-HP, 480-volt, 3-phase, 92-amp, 1770-rpm motor set on top of 15 feet of six-inch column with four six-inch bowls and a water level five feet below ground surface (see photo A). This provided a total head of 118 feet.

Madison Farms used a US Drives, Inc. AC Line Regenerative Module (model #RG-0400-0060-N1) rated at 50 HP to capture the DC line voltage created during the regenerative process (see photo B). Madison connected the regenerative module to a 125-HP US Drives, Inc. Phoenix VFD (model # D4-0125-N1). The US Drives and the 75-HP line shaft turbine pump were connected to the local utility service provided by Umatilla Electric Coop. The US Drives VFD was capable of recording key data during the test.

Photo A: Regenerating pump and line shaft turbine

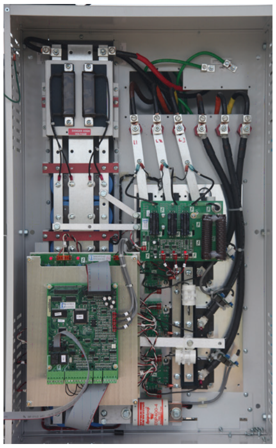


Photo B: Regenerative drive module

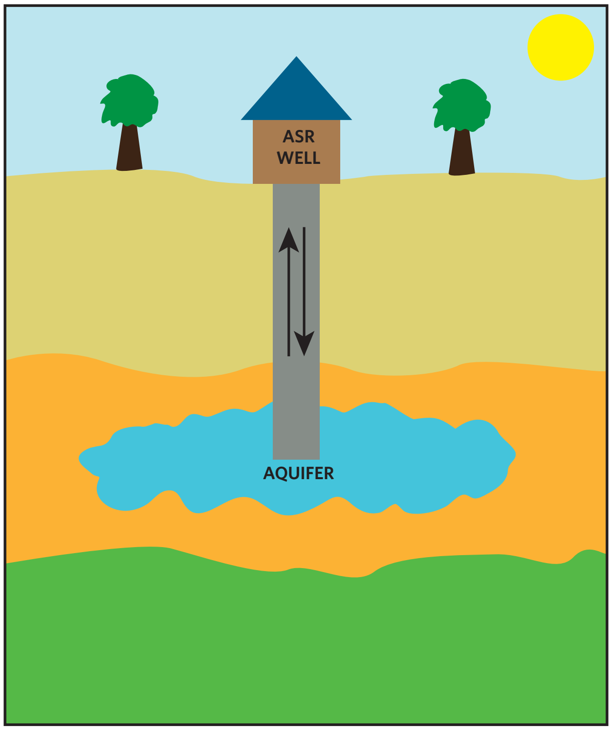
During the test, a 100-HP pump located in the same well as the line shaft turbine was pumping at a continuous rate into a nearby irrigation system. Madison Farms kept this pump running to provide an electric load, avoiding feeding power back onto the utility grid during the test. Madison used a clip-on amp meter to record the reduction in amps provided by the utility during the test.

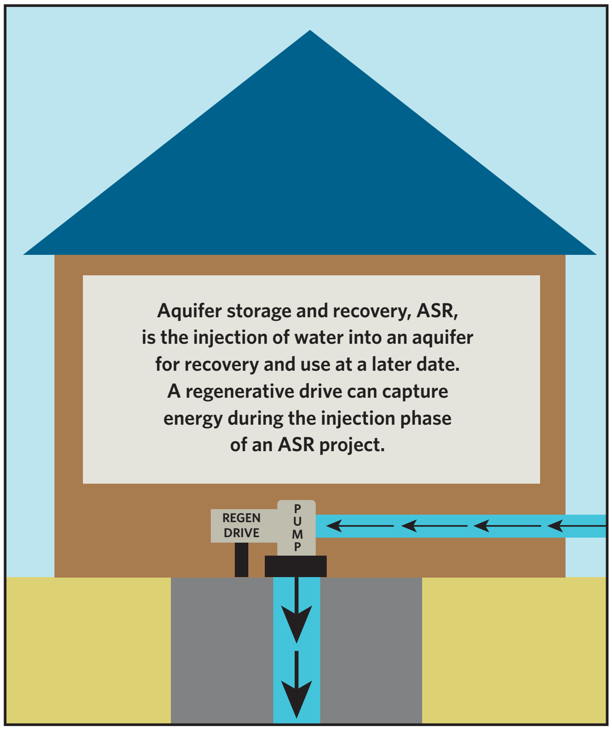
Results show a 48 percent energy recovery and 20-month ROI

Madison Farms allowed the regenerating pump to spin backwards, driven by the 542 GPM of water and the 118 feet of head. Applying a 30-hz reverse input to the drive magnetized the stator, forcing the motor's rotor to slow from 46 to 30 hz. This electronic braking caused the DC bus to produce energy, which the regenerative module converted to AC power at 480 volts, 3 phase. A reduction of amps across the three legs of the incoming utility power supply showed that the regenerative drive supplied some of the energy needed to run the 100-HP irrigation pump.

Applying the formula of brake horsepower, the demonstration test used 16.1 HP to deliver water to the regeneration site (542GPM*118TDH/3960=16.1). This represents 12,015 watts (16.1HP*744watts/HP). With 5,800 watts recovered during regeneration, the demonstration generated 48 percent of the energy needed to deliver water to the regeneration site.

The cost of the regenerative equipment was $5,796. Assuming 24/7 operation, the return on investment at 6 percent interest is 20 months at $0.07/kilowatt hour.





Rules of thumb for regenerative drive hydropower

- For maximum return on investment, the head and flow at the injection well should be equal or greater than the source water.
- Projects using surface water as the source may require a Federal Energy Regulatory Commission (FERC) permit, which can add significant time and cost to the project.
- Projects using ground water as the source may be exempt from FERC and may have a favorable return.
- When the system uses a VFD to control the pump, the only added capital cost is for the regenerative module, which can be sized smaller than the VFD depending on the head and flow.
- If the source water supply is variable, such as from a HVAC system, consider placing a down-hole control valve below the pump bowls to keep the well column under positive pressure. This avoids air bubbles from becoming entrained in the injection water and either plugging the receiving aquifer or causing cavitation at the pump bowls.

To learn more about how we can help your business, contact Lily Xu at **503.205.0975** or **lily.xu@energytrust.org**.