Piping Progress: How Irrigation Modernization Can Build Energy Resilience in Rural Communities

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ABSTRACT

Irrigation modernization sits at the intersection of energy and water conservation, offering rural communities a pathway to achieve energy savings and build resilience through on-site energy generation. These projects replace open canals with pressurized piping and improve water delivery reliability, while enabling the potential for in-conduit hydropower (electricity generated from inside pressurized pipes) that strengthens local grid resilience and supports rural energy independence.

An irrigation modernization program in Oregon aims to support adoption of irrigation modernization by combining early technical assistance, braided state and federal funding, and a replicable project development model to overcome barriers that historically prevented widespread implementation.

This paper presents an overview of the irrigation modernization landscape in Oregon and evaluates program progress through interviews with irrigation districts and partner organizations, data analysis, and estimations of energy savings from completed and proposed modernization projects. Findings reveal that modernized systems can reduce energy use by eliminating pumping requirements, generate renewable electricity through small-scale hydropower, and attract substantial co-investment from utilities and federal partners.

By linking water infrastructure improvements with energy benefits, irrigation modernization provides a scalable template for other states and rural regions. This research offers valuable insights into how market influence programs can drive systemic change in underserved markets, advancing both climate adaptation and rural economic development. The model demonstrates that effective market influence requires not only technical solutions, but also strategic partnerships and funding mechanisms that address real-world implementation barriers.

Introduction

Across the western United States, irrigation infrastructure is both essential and aging. According to Pacific Northwest National Laboratory (PNNL), the century-old network of nearly 150,000 miles of open canals and pipelines transports irrigation water from rivers and reservoirs to producers across 17 western states, serving nearly 40 million acres and supporting approximately half of U.S. crop revenues. Across this system, earthen canals remain common, and PNNL estimates that they can lose 16 to 26 percent or more of conveyed water to seepage or evaporation before water reaches agricultural users (PNNL 2026).

The modernization challenge is particularly acute in Oregon, where Energy Trust of Oregon (Energy Trust) reports that 73 irrigation districts serve thousands of farmers across nearly 480,000 acres and that many systems were installed 75 to 150 years ago. Open canals and ditches can be costly to maintain, vulnerable to drought and wildfire conditions, and difficult to

operate with the precision expected of modern agricultural water management (Energy Trust of Oregon 2023).

Irrigation modernization upgrades these inefficient systems through various strategies: reducing seepage and evaporation by lining canals with concrete or other materials or replacing them with pipes, and using the water pressure produced from the system to generate hydropower. Beyond water conservation, irrigation modernization can provide economic and energy resilience for rural communities. Modernized systems reduce on-farm pumping energy use and costs, and hydropower generation can provide both a revenue stream and renewable energy, allowing districts to be less dependent on electricity and diesel.

Despite these benefits, irrigation modernization projects are complex, capital-intensive, and difficult for individual districts to advance on their own. Many irrigation districts are small with limited staff. Even when district leaders understand the benefits of modernization, they may lack the engineering capacity, grant-writing resources, stakeholder engagement support, and matching funds required to move projects through planning, permitting, design, and construction. This paper uses Energy Trust's Irrigation Modernization Program (IMP) as a case study in how programs can help address these barriers and accelerate modernization.

Program Background

Energy Trust launched its IMP in 2015 following more than a decade of work with irrigation districts on small hydropower and water efficiency opportunities (Energy Trust of Oregon 2026). Early feasibility studies identified potential hydropower sites but failed to produce projects that advanced beyond the planning stage. A 2013 study by Farmers Conservation Alliance (FCA) shifted the approach by emphasizing that hydropower and modernization opportunities needed to be aligned with the long-term infrastructure needs of irrigation districts via new system improvement plans (Perkins 2013). This reframing led Energy Trust to support districts in undertaking comprehensive planning for modernization (Evergreen Economics 2025).

The program, implemented by FCA with additional support from federal, state, and non-profit partners, seeks to accelerate modernization timelines by replacing open ditches and canals with pressurized piping systems. The IMP provides planning and funding assistance to irrigation districts by helping districts identify infrastructure improvements, potential funding sources, and stakeholders who benefit from and could support projects. The IMP helps districts create action plans with defined next steps that reduce the cost and time required for project planning and implementation, address regulatory and institutional barriers, leverage funding, and demonstrate how modern agricultural water management can respond to drought and other agricultural and environmental challenges (FCA 2026). Ultimately, the IMP aims to help irrigation districts conserve water, support fish-friendly renewable hydropower development, and reduce the energy required for on-farm pumping.

This structure matters because the IMP is not simply a construction grant program. It is a project-development and market-enablement model. Energy Trust supports early-stage planning and analysis, and FCA works with districts to develop system improvement plans (SIPs), define project packages, engage stakeholders, and identify funding pathways; districts use those plans to apply for larger state and federal construction funds. A PNNL review of funding mechanisms for irrigation modernization and conduit hydropower found that many federal and state funding programs are competitive, open only periodically, require matching funds, and often do not support early-stage development or comprehensive planning. By comparison, Energy Trust's

project-development support was highlighted for features such as flexible early-stage development assistance, direct communication with project proponents, and staff expertise in hydropower and irrigation modernization (Jorgensen et al. 2023).

The model has become increasingly important as Oregon has expanded public investment in irrigation modernization. In 2023, the Oregon Legislature directed $50 million toward upgrading outdated irrigation systems, with Energy Trust describing the investment as a way to help districts leverage federal water-infrastructure dollars (Energy Trust of Oregon 2023).

Federal programs also provide additional construction pathways. The Natural Resources Conservation Service Watershed Protection and Flood Prevention Operations Program provides technical and financial assistance to state, local, and Tribal project sponsors to plan and implement watershed projects, including agricultural water management projects (USDA NRCS 2026). The U.S. Bureau of Reclamation's WaterSMART Water and Energy Efficiency Grants provide 50/50 cost-share funding to irrigation and water districts, Tribes, states, and other entities with water or power delivery authority for projects that conserve water, increase hydropower production, reduce conflict risk, and improve water-supply reliability in the West (USBR 2026). These sources make braided funding possible, but they also create the administrative complexity that the IMP helps districts navigate.

Throughout the duration of the program, Energy Trust has commissioned studies to assess the effectiveness of the IMP at supporting irrigation modernization. A 2022 assessment found that the energy savings from pressurizing irrigation systems are substantial and are attributable to the program. Findings further indicated that district boards, staff, and water users were generally supportive of modernization efforts, and many districts had developed advanced SIPs, secured outside funding, and implemented at least some improvements on the ground (Apex Analytics 2022). By 2024, the program had engaged with 30 irrigation districts representing roughly 60 percent of the acreage in Oregon served by irrigation districts.

This paper provides a 2025 assessment of program progress supporting irrigation modernization and further applies methods for estimating energy savings from reduced pumping.

Methods

The study team conducted interviews with irrigation districts and partner organizations, conducted data analysis, and reviewed estimates of energy savings from both completed and proposed modernization projects (Evergreen Economics 2025).

Interviews

We conducted interviews with irrigation district staff and partner organizations to understand the participant experience with the IMP and the program’s market influence. We completed 22 interviews with staff from 20 participating irrigation districts in Oregon including district managers, general managers, executive directors, and board members as well as eight interviews with various partner organizations, including elected officials, funders, and stakeholders, to learn more about the irrigation modernization landscape and ways they support irrigation modernization. Table 1 lists the number of interviews completed with each group.

Table 1. Interviews with irrigation district staff and partner organizations

Group	Subgroup	Interviewees	Response rate
Participating irrigation districts	NA	22	88%
Partner organization	Elected official	3	100%
	Funder	2	100%
	Stakeholder	3	100%
Total	NA	30	

Data Review and Analysis

In addition to interviews, we reviewed various other program data sources to address program progress supporting irrigation modernization. These resources included irrigation district evaluation and screening for hydropower feasibility, status of district in the IMP, annual reports, and funding allocation reports. These data sources were used to update market progress indicators that interviews did not directly measure.

Energy Savings Calculations

We assessed the energy savings for irrigation modernization projects that were complete or near complete by first reviewing available data and finalizing the energy savings methodology proposed in the 2022 market transformation assessment. We then applied that methodology to calculate the savings for relevant irrigation district projects. We also assessed the input assumptions of the methodology, adjusted those input assumptions to better reflect Oregon pumping conditions, and recommended updates to the methodology to provide more accurate savings estimates. This analysis will be further described in the findings section of this paper.

Findings

Status on Selected Program Metrics

The IMP helps irrigation districts advance their projects. Table 2 shows the program effects on project development. The majority of irrigation districts in Oregon remain actively enrolled in the program and have completed program screening for hydropower viability and SIPs.

Table 2. Program effects on project development

Metric	Status
Engagement: Districts remain responsive to program outreach and engaged with program	Of the 34 irrigation districts in Oregon with a relationship with the program, 25 are actively enrolled with the program, eight are inactive, and one withdrew enrollment when they had a change in district management and board membership.
Screened: Number of districts and irrigated acreage passing program screening for viability and hydro potential	23 districts passed program screening for hydro viability, serving approximately 366,000 acres.
Planned: SIPs completed	22 districts completed an SIP, serving approximately 404,000 acres.
Acting: Districts making improvements	15 districts, serving approximately 346,000 acres, are modernized or in progress.
Funding: Amount of funding provided	Irrigation modernization funding in Oregon has expanded to $229M in 2025, up from $97M in 2021.

Combined, these metrics indicate that the program is building and maintaining relationships with irrigation districts and that the work is translating to projects being successfully funded across the state.

This research also explored the general landscape and perspectives surrounding irrigation modernization. Table 3 shows that interviews indicated there is support for irrigation modernization, with more than half of irrigation districts reporting that securing internal and external support was easy and 13 organizations providing funding for irrigation modernization in Oregon.

While there is support for irrigation modernization, district staff also revealed concerns among stakeholders. Concerns of internal stakeholders (e.g., boards of directors) are primarily related to the scale—time invested, cost, and complexity—of modernization projects, while the concerns of external stakeholders (e.g., water users, environmental groups) revolve around water rights, instream flow (the amount of water left in a stream or river), aesthetics, and property value impacts. Irrigation districts reported that transparent communication and providing information about the benefits of modernization helped to ease concerns.

Table 3. Support for irrigation modernization

Metric	Status
Internal stakeholder support	Of the 20 irrigation districts interviewed, 13 reported that it was easy to gain internal stakeholder support.
External stakeholder support	Of the 20 irrigation districts interviewed, 11 reported that it was easy to gain external stakeholder support.
Organizations supporting modernization	As of November 2023, FCA reported that 13 organizations were providing funding for modernization, excluding Energy Trust and participating irrigation districts.

Table 4 shows that while there is increasingly more funding available for irrigation modernization projects, and the majority of districts have the information they need to apply for funding, many districts lack the resources needed to complete their projects.

Interviews revealed that while district staff understand the priorities and next steps in their projects, over half of them reported experiencing resource constraints that limited their ability to move projects forward. Many irrigation districts have limited access to funding or still need to secure the funding to complete their projects. While most districts remained confident in their ability to eventually obtain the necessary funding, they acknowledged that navigating the funding process can be time consuming and complex. Many district staff reported that securing funding could be a "full-time job" and they had limited staff resources to pursue funding opportunities on their own.

Table 4. Irrigation modernization funding ecosystem

Metric	Status
Districts are able to advance modernization projects	Of the 20 irrigation districts interviewed, 13 of them do not have sufficient resources to carry out tasks to advance modernization projects.
External funding access	Of the 20 irrigation districts interviewed, 14 have applied for funding outside FCA, including NRCS, state grants, the US Bureau of Reclamation, county funding, and conservation organizations.

Role of the Program

Many irrigation districts understand modernization opportunities but do not have the staff capacity or experience needed to move from concept to construction. All 22 interviewees understood the next steps needed in their modernization projects, but 13 reported that they did not have sufficient resources to carry out those tasks. The IMP plays an essential role in making irrigation modernization projects feasible for districts that lack the capacity to pursue such projects on their own, providing critical support in several ways including the following:

- **Providing foundational pre-development support** – Interviewees highlighted the importance of the IMP's role in assembling each district's SIP. These SIPs demonstrate that a project is feasible and allow districts to move on to applying for funding.
- **Navigating bureaucratic requirements and grant applications** – The IMP works with districts to understand how to put together successful grant applications. Irrigation districts that can answer basic questions about their projects are better positioned to complete grant applications. The IMP is also effective in securing funding because it works with state senators to help districts understand application requirements.
- **Engaging diverse stakeholders** – Unlike state and federal agencies, FCA is allowed to lobby for farmers and demonstrate the impact of funded programs. This advocacy work helps smaller nonprofits effectively take action across the state and address community needs.

While many districts are aware of modernization opportunities before participating in the program, they often lack the technical and administrative capacity to pursue modernization as capably as FCA. IMP support addresses specific capacity gaps that often challenge districts and enables districts to make improvements with one interviewee reporting that their project "wouldn't have happened without FCA's involvement."

Characteristics of Successful Projects

While the IMP provides essential support for irrigation modernization, certain district characteristics influence program effectiveness.

Irrigation districts with the most resources were the ones most likely to successfully complete modernization projects. Irrigation districts vary widely in size and staffing levels, with the districts that have many staff and effective management being best positioned to explore program options and successfully complete projects (though the program is designed to help irrigation districts of any size advance irrigation modernization projects). Two interviewees mentioned the significance of flexible and engaged leadership and the importance of having an innovative, forward-thinking district manager who is willing to push boundaries. One interviewee with an organization that provides funding to irrigation districts for irrigation modernization projects also noted the benefit provided by outside consultants (such as FCA) who helped irrigation districts prepare and submit applications for funding, as those districts were the ones most successful in receiving funding.

Financial capacity also affects project success. Larger irrigation districts also benefit from having more patrons (property owners and water users) paying assessments, giving them greater resources for project implementation. Interviewees reported that securing matching funds is essential to funding these projects and that districts need to move quickly to avoid cost increases as system upgrades get more expensive over time.

Baseline Trajectory of Irrigation Modernization Without the IMP

Prior to program engagement, levels of awareness of modernization varied, with 11 interviewees reporting prior knowledge, four reporting limited awareness that expanded with FCA engagement, and six having no prior awareness. Interviewees reported learning about modernization through peer networks and organizations such as the Oregon Water Resources Congress, NRCS, the Bureau of Reclamation, and Energy Trust. Districts were also already

motivated to pursue modernization because of aging infrastructure, drought, climate pressures, and wildfire risks, and recognized the benefits modernization could bring from water conservation, drought resilience, operational efficiency, reduced maintenance costs, reliable delivery to patrons, and environmental stewardship.

However, awareness and motivation did not automatically translate into implementation. Rather, IMP serves as a catalyst that amplifies these efforts by accelerating the transition from awareness to action by converting broad modernization interest into technically defined projects, stakeholder-supported plans, and fundable implementation pathways.

Energy Savings Calculations

Irrigation modernization projects often include transitioning from transporting water through open canals to piped systems. In closed-pipe systems, pressure develops in the pipe with decreases in elevation. Pressure differentials developed from source water at higher elevation than farmlands can partially or fully offset the need for patrons to pump water for irrigation, which saves energy.

As part of the program, FCA used the US Environmental Protection Agency's (EPA's) EPANET hydraulic modeling software to develop on-farm energy savings estimates as part of SIP development. FCA describes this phase as the "10% engineering design stage," and energy impacts are documented in project SIPs. FCA estimates the energy savings for each patron by taking the difference between the baseline energy requirements for pumping (in an open system) and the proposed case pumping energy (after transitioning to a closed-pipe system).

In this analysis, we assessed the energy savings for irrigation modernization projects that were complete or near complete including those in design-ready (engineering plans finalized), shovel-ready (permits and funding secured), and in construction phases. We compared the energy savings for these projects that we calculated using our analysis methods to the energy savings using the existing method used by FCA and found that FCA's engineering approach is sound and appropriate for this application, particularly because available pressure depends on system head, pipe losses, flow, and demand assumptions that are difficult to estimate accurately without hydraulic simulation. We also identified methodological limitations. FCA's SIP estimates assumed all pumps were electric, although a small share of Oregon irrigation pumps are non-electric (e.g., diesel, propane) and are generally less efficient. As shown in Table 5, we therefore recommended applying a 90 percent adjustment to SIP-reported savings, using updated assumptions of 96 percent electric pumping, 4 percent non-electric pumping, 80 percent electric pump efficiency, and 30 percent non-electric pump efficiency. In addition, adjusted energy savings were split between electric and non-electric savings.

Table 5. Recommended updates to irrigation pump assumptions

Value	Fraction of pumping types		Pump efficiencies	
	Current assumption	Recommended assumption	Current assumption	Recommended assumption
Electric pumping	100%	96%	70%	80%
Non-electric pumping	0%	4%	NA	30%

Table 6 provides a comparison of reported energy savings from SIPs and adjusted energy savings following the analysis presented here. Adjusted energy savings were split between electric and non-electric savings based on the recommended fraction of pumping types (96% electric, 4% non-electric). Non-electric savings are provided in kWh per year for comparison and in gallons of fuel (i.e., diesel and gasoline) saved per year. Across the design-ready, shovel-ready, and in-construction projects summarized in the 2025 study, SIPs reported about 8.09 million kWh per year of savings. After adjustment, the estimate becomes approximately 6.98 million kWh per year of electric savings plus 263,400 kWh-equivalent per year of non-electric savings, equal to roughly 6,810 gallons of fuel saved annually.

Table 6. Reported and adjusted energy savings estimates

Project stage	Reported energy savings (kWh/year)	Adjusted electric energy savings (kWh/year)	Adjusted non-electric energy savings	
			Equiv. kWh/year	Gal of fuel/year
Design-ready	43,900	37,900	1,400	40
Shovel-ready	435,721	375,900	14,200	370
In-construction	7,612,402	6,567,900	247,800	6,400
Total	8,092,023	6,981,700	263,400	6,810

To help contextualize these savings for districts considering similar projects, Table 7 presents energy savings normalized by irrigated acreage. North Unit Irrigation District, the largest project, saves approximately 78.4 kWh per acre annually, while Arnold Irrigation District, a smaller project, saves approximately 25.3 kWh per acre annually.

Table 7. Reported and adjusted energy savings estimates by project

Irrigation district	Adjusted electric energy savings (kWh/year)	Irrigated Acreage	Adjusted electric energy savings by acreage (kWh/year/acre)
North Unit Irrigation District	4,743,200	60,474	78.4
Arnold Irrigation District	111,100	4,384	25.3

In addition to energy savings from reduced pumping, energy generation from hydropower remains an important but site-specific benefit. Among the 20 interviewed districts, five already had hydropower installed, five were researching or planning hydropower, three were considering it for the future, and seven did not plan to install hydropower. Some districts view hydropower as a revenue source that can help offset future modernization costs. Others ruled it out because of

insufficient elevation drop, limited pressure, or unfavorable power-purchase agreements. While not applicable for every district, where possible, hydropower generation through irrigation modernization has the potential to support revenue generation and energy resilience through local, reliable energy generation (Energy Trust of Oregon 2026).

Conclusions

Based on the results of our assessment, we found that the IMP appears to be fulfilling its mission of advancing irrigation modernization efforts in Oregon. Program metrics—such as the number of completed SIPs, the number of organizations supporting modernization, and the number of districts making modernization improvements—demonstrate statewide progress.

While the IMP is a helpful resource for districts pursuing irrigation modernization projects, interviews with irrigation district staff revealed that 13 interviewees reported lacking sufficient resources to carry out modernization projects and that a lack of funding was the main challenge. While many were optimistic that they would ultimately be able to secure funding in the future, navigating complicated or inaccessible bureaucratic processes to access this funding limited some districts' ability to move their projects to the next stage. In many instances, interviewees identified IMP's assistance in navigating these processes, as well as its general aid in accessing these funds, as crucial, as districts often lack the time or budget to complete these processes and pursue these funds themselves.

IMP assistance addresses these resource constraints, allowing districts to implement irrigation modernization projects to improve their economic and energy resilience by reducing water loss, lowering energy costs, and enabling hydropower generation. The IMP plays an essential role in making modernization projects feasible for districts that lack the capacity to pursue them independently.

We found that while the engineering approach to calculating savings is sound, we recommend applying a 90 percent adjustment to the values reported in the IMP SIPs to account for the portion of irrigation pumps in Oregon that are non-electric and for an updated electric pump efficiency. This can help provide a better estimate of energy savings.

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AI-assisted Tools Disclosure

AI-assisted tools used: Claude, ChatGPT
Used for: Drafting text, literature review
Extent: Light editing, drafting sections
Human review: The authors reviewed and verified all content, calculations, and citations.