Irrigation Modernization Program

Market Transformation Assessment

Final Report

Submitted by Apex Analytics LLC

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Contents

Executive Summary

This report presents findings from a review of Energy Trust of Oregon's Irrigation Modernization Program (IMP). Energy Trust contracted with Apex Analytics to conduct this review in order to understand the program's outcomes and potential from a market transformation perspective.

Irrigation modernization improvements can include transitioning from transporting water to farms through open canals to delivering pressurized water through pipes, improving monitoring and control capabilities, and other things. This transition has the potential to create opportunities for renewable generation since excess pressure in the pipes can be used to generate hydropower. There are also potential efficiency benefits since providing pressurized water would eliminate the need for farmers to pump water from ditches or ponds to irrigate their fields.

Through the IMP, Energy Trust works with the Farmers' Conservation Alliance (FCA) to support irrigation districts across Oregon in modernizing their irrigation systems. The program helps irrigation districts assess opportunities and develop comprehensive plans to modernize their systems. This analysis and support prepare districts to apply to the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) and other potential partners that the FCA helps districts identify for funding to support modernization projects. FCA also provides communication support to help districts inform their members and other stakeholders about modernization. Energy Trust anticipates that this support will accelerate the process of modernization for irrigation districts.

The assessment addressed five research objectives related to the IMP:

- What are the key market progress indicators (MPIs) that show the program's progress toward market transformation? Are there MPIs that are currently not being collected?
- How is the IMP influencing the development and trajectory of irrigation modernization in: (1) Energy Trust's service territory; (2) Oregon and the western USA?
- What would the baseline and trajectory of irrigation modernization have been without the IMP?
- At what point will irrigation modernization be incorporated as a standard practice for irrigation districts?
- How can Energy Trust estimate energy savings from reduced on-farm pumping due to irrigation modernization?

Research Approach

Rather than seeking to influence individual purchases or practices of program participants, a market transformation program seeks to achieve a change in

practices more broadly. This evaluation took a market transformation-based approach, focused on tracking the program's progress toward those broader outcomes. Specifically, Apex conducted the following tasks:

- **Articulated program theory and developed MPIs:** Apex reviewed a wide range of documents related to program efforts and irrigation modernization more broadly and conducted interviews with Energy Trust and Farmers Conservation Alliance (FCA) program staff. We then developed a logic model describing the program's activities and desired outcomes and a set of MPIs to track the program's progress against those outcomes. We refined the program logic model and MPIs with input from Energy Trust staff.
- **Interviewed irrigation districts:** Apex interviewed 18 irrigation districts, with respondents segmented by their progress toward modernization, ranging from non-participants to districts that had completed large modernization projects.
- **Interviewed stakeholders:** Apex conducted seven interviews with organizations outside the program providing funding for irrigation modernization projects or otherwise involved in efforts to promote irrigation modernization in Oregon.

Key Findings

Market transformation programs seek to bring about lasting change in a market by helping market actors overcome barriers that prevent uptake of the targeted efficient product or practice. The IMP helps irrigation districts overcome barriers to modernization improvements in three ways:

- **By providing technical support and analysis to prioritize and scope modernization improvements.** Irrigation district managers are aware of the potential benefits of modernization, and some have made small-scale modernization improvements. District managers typically do not, however, have the capacity or technical resources to assess and prioritize the modernization opportunities in their districts and develop a comprehensive plan to address those opportunities. District managers valued the program's support in providing technical assistance and developing plans.
- **By providing communications support to the internal and external audiences impacted by modernization projects.** Program staff and interviewed stakeholders reported that a proactive manager and a supportive board were important to the success of an irrigation modernization project, and all of the interviewed district managers reported their boards were supportive of modernization. District managers reported a more mixed reception to modernization among water users. According to district managers, some water users recognize water saving and potential energy efficiency benefits

of modernization, while others are more concerned about costs or technical issues. District managers reported that external stakeholder attitudes toward modernization were also mixed, with general support from conservation groups but opposition from some property owners, primarily due to aesthetics of converting from canals to pipes.

- **By facilitating access to external funding sources to pay for modernization improvements.** The IMP both provides irrigation districts with support in accessing existing funding sources to pay for modernization improvements and, critically, works to expand the pool of available funding and support for irrigation modernization. The technical analysis and plans the program creates provide irrigation districts with information funders require, and the program helps districts identify potential funders and complete applications. By demonstrating the potential for irrigation modernization and creating a pipeline of viable modernization projects, the program has also helped capture funders' attention and increase the funding and support available for modernization. Most notably, interview findings suggest the program played a role in the reauthorization of a large federal funding program that supports irrigation modernization and in the allocation of program funds to Oregon.

Consistent with its six years of experience in the market, the IMP is meeting its short-term and medium-term MPIs, with districts engaging with the program and progressing through the process of creating Watershed Plans – the comprehensive documents needed to apply for funding to support installation of large-scale modernization improvements.

The program is beginning to achieve its long-term MPIs, with a small number of districts completing installation of in-conduit hydroelectric generation. Findings suggest hydroelectric generation faces additional barriers, beyond modernization improvements themselves, with district managers concerned about cost effectiveness and the prices they could receive for generated electricity.

Additionally, the program is working to develop a process to measure energy savings due to the reduced need for pumping on farms. Irrigation district managers see energy cost savings as a key benefit of modernization for their patrons. This report includes a proposed methodology for estimating pump energy savings.

Conclusions & Recommendations

Apex draws the following conclusions and associated recommendations from this research.

Conclusion 1: The IMP functions as a market transformation program, and its potential to expand available funding and support for irrigation modernization is central to its market transformation objectives. The scope of irrigation modernization projects is typically too large for an irrigation district to complete

independently in a timely and comprehensive way. As a result, the most effective way to meet the market transformation objective of generating market-wide adoption that will extend beyond the program's support is to build a network of organizations and funders working to support irrigation modernization. The IMP has done this successfully by demonstrating the specific benefits of irrigation modernization projects and generating a pipeline of projects ready to receive available support. Most notably, these efforts contributed to the reauthorization of the NRCS Watershed Protection and Flood Prevention Program (PL 83-566) funding, which has supported large numbers of irrigation modernization projects in Oregon and other states.

- **Recommendation 1: Energy Trust and FCA should continue to build relationships with stakeholder organizations and encourage increased support for irrigation modernization.** The program should continue working to identify funders and organizations whose missions align with the many energy and non-energy benefits of irrigation modernization and encourage them to support modernization efforts with funding or technical support. Broadening the range of organizations providing support can help ensure resources are available that align with the unique needs of each irrigation district.

Conclusion 2: Energy savings are an important benefit of modernization improvements. The potential to reduce energy consumption from on-farm pumping was one of the most frequently cited benefits of irrigation modernization for irrigation districts. District managers saw energy savings as a clear benefit for their patrons, allowing them to use funds that would have gone to energy costs in other ways, with further positive effects for the local economy. There is also potential that districts would need to choose between energy savings benefits and hydroelectric generation. Installing in-conduit generation could reduce water pressure, and some district managers indicated they were inclined to prioritize providing pressurized water over installing generation capabilities.

- **Recommendation 2: Energy Trust should continue to develop an approach to claim energy savings from irrigation modernization.** Adopting a high-level energy savings methodology, like the one described in Section 5, could help Energy Trust better capture the benefits of irrigation modernization. To the extent irrigation districts must choose between delivering pressurized water to farms or using it for hydroelectric generation, a methodology to claim energy savings could help ensure Energy Trust benefits from all of the modernization projects it supports. Pump energy savings are also a compelling benefit for program communications to address.

MEMO

To: Board of Directors
From: Phil Degens, Sarah Castor and Dave Modal

Date: 5/20/2022
Re: Staff response to The Irrigation Modernization Program Market Transformation Assessment

A major goal of the Irrigation Modernization Program (IMP) Market Transformation (MT) Assessment was to determine if the IMP qualified as a MT program. Using interviews, document review and development of a formal logic model, the report findings support the concept of IMP being engaged in market transformation. The irrigation infrastructure market that IMP is transforming is different from your standard consumer product market. However, many other market transformation programs have worked in nonstandard markets. Many of these MT programs have developed a market-funded organization that has a role similar to that of the Farmers Conservation Alliance, that continue many of a program's support functions and are an integral part of the MT exit strategy. An example of this is the regional commissioning effort that led to the creation of the Building Commissioning Association.

Energy Trust plans on monitoring IMP's market progress using the market progress indicators identified in this study and reporting the results in 2024. . Energy Trust is planning to further develop the energy savings methodology proposed in the report in 2023. This will enable Energy Trust to obtain an estimate of irrigation pumping savings that are achieved by pressurizing the irrigation pipes at an irrigation district level and claim those savings.

1. Introduction

This report presents findings from an assessment of the market transformation outcomes and potential of the Irrigation Modernization Program, which Energy Trust funds and the Farmers Conservation Alliance implements.

1.1 Program Description

Through the IMP, Energy Trust works with the Farmers' Conservation Alliance (FCA) to support irrigation districts across Oregon in modernizing their irrigation systems. Irrigation modernization involves proactive planning, assessments, and improvements to increase an irrigation system's performance and efficiency to meet the goals of the district and its community. Modernization improvements can include transitioning from transporting water to farms through open canals to delivering pressurized water through pipes, improving monitoring and control capabilities, and other things. This transition has the potential to create opportunities for renewable generation since excess pressure in the pipes can be used to generate hydropower. There are also potential efficiency benefits since providing pressurized water would eliminate the need for farmers to pump water from ditches or ponds to irrigate their fields.

There are significant non-energy benefits associated with irrigation modernization, including reduced water losses to seepage and evaporation, which allow for improved stream flows as less water needs to be diverted from streams or other bodies of water. Recognizing these benefits, the IMP seeks to leverage support from a variety of sources with diverse interests in irrigation modernization benefits. With the support of Energy Trust and other funders, the FCA helps irrigation districts assess opportunities and develop comprehensive plans to modernize their systems. The FCA conducts technical analysis and develops documentation necessary for irrigation districts to meet the requirements of the National Environmental Policy Act (NEPA). This analysis and support prepares districts to apply to the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) and other potential partners that the FCA helps districts identify for funding to support modernization projects. FCA also provides communication support to help districts inform their members and other stakeholders about modernization. Energy Trust anticipates that this support will accelerate the process of modernization for irrigation districts.

1.2 Research Objectives

Energy Trust defined four research objectives for this study. Apex identified a series of more specific research questions to operationalize each objective (Table 1).

Table 1: Research Objectives and Associated Questions

Research Objective	Research Questions
What are the key MPIs that show the program's progress towards market transformation? Are there MPIs that are currently not being collected?	What are the key barriers to irrigation modernization?
	What are key program activities, and how does the program anticipate they will address the key barriers identified or otherwise bring about irrigation modernization?
	What interim changes in the market, short of installed projects, would indicate the program is addressing the key barriers?
	What data are program staff currently tracking that could indicate market influence?
How is the IMP influencing the development and trajectory of irrigation modernization in: (1) Energy Trust's service territory; (2) Oregon and the western USA?	To what extent is the program achieving its MPIs?
	What are examples of successful engagements that led to modernization projects? What characteristics of those projects made them successful?
	What role did the IMP play in motivating and/or enabling irrigation modernization projects? How did the IMP's support relate to and/or complement other enabling factors?
What would the baseline and trajectory of irrigation modernization have been without the IMP?	To what extent are water districts aware of irrigation modernization opportunities?
	What benefits of irrigation modernization are irrigation districts aware of? Which of those benefits are most compelling to them?
	To what extent were water/irrigation districts actively pursuing irrigation modernization over the past three decades, in Oregon, the Northwest and elsewhere?
	What are the key triggers for irrigation modernization projects, outside the IMP? What are key triggers for irrigation upgrades?
	What resources are available to support irrigation modernization outside of the IMP? What is the scope of these resources and how easily accessible are they?
When will irrigation modernization become a standard process for irrigation districts?	What market changes are necessary to bring about widespread adoption of irrigation modernization without program support?
	How will program activities bring about those changes?
How can Energy Trust estimate energy savings from reduced on-farm pumping due to irrigation modernization?	What methods have irrigation modernization advocates used to estimate energy savings from on-farm pumps? To what extent could those approaches inform Energy Trust?
	What metrics are available that could help Energy Trust estimate pump usage of farms within its territory (e.g., irrigated acreage, gallons of water supplied)?
	What additional data would be necessary to associate energy usage data with those metrics, and how could Energy Trust obtain it?

1.3 Research Approach

Market transformation programs seek to achieve broad, long-term changes to whole markets, in contrast to traditional programs' focus on influencing the individual transactions or behaviors of specific participants. As this evaluation sought to assess the IMP from a market transformation perspective, Apex took a market transformation evaluation approach, focused on assessing the program's progress against a defined theory of how its activities would bring about its desired outcomes.

Specifically, Apex conducted three broad research activities to address this project's research objectives: program logic and MPI development, irrigation district interviews, and funder and stakeholder interviews. The following sections describe each activity.

1.3.1 Program Logic and MPI Development

Apex developed a logic model to describe IMP program activities and the anticipated short, medium, and long-term outcomes anticipated to follow from those activities. We drafted MPIs associated with each logic model outcome.[1] We developed the logic model based on a review of program documents and other documents related to irrigation modernization as well as in-depth interviews with Energy Trust and FCA staff involved in managing and delivering the program.[2] In total, we conducted interviews with six staff members in October and November of 2021. Apex held a working session with Energy Trust staff to review our draft logic model and the associated MPIs and revised them based on the feedback received.

1.3.2 Irrigation District Interviews

Apex conducted 18 interviews with irrigation district managers, including managers of 14 districts participating in the IMP and four managers of districts not participating in IMP. As described in Table 2, irrigation district manager interviews segmented participating districts by modernization status in order to include perspectives of districts at various stages in the process of modernizing their systems. Two of the interviewed non-participating districts included larger districts in Washington State, which provided a perspective of districts for whom the Energy Trust-supported IMP was not available.[3] The other two interviewed non-participants were Oregon districts that had not engaged with the program.

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[1] The IMP logic model and MPIs are presented in Appendix A.

[2] Appendix B provides a complete list of documents reviewed.

[3] FCA provides irrigation modernization support to irrigation districts outside of Oregon using non-Energy Trust funding. The two interviewed Washington districts had not taken advantage of this support.

Table 2: Irrigation District Interview Sample

Modernization Status		Population Size	Complete Interviews
Participants	Construction complete on at least some modernization improvements	7	4
	Planning and research complete to pursue funding for construction of modernization improvements	5	4
	System Improvement Plan complete, other planning and research needed to pursue funding underway	7	3
	Initial stages of planning and research: System Improvement Plan not yet complete	4	3
Non-Participants	Oregon irrigation districts	25[a]	2
	Washington irrigation districts	35[b]	2
Total		83	18

[a] Based on Oregon Water Resources Congress member list.

[b] Based on Washington State Water Resources Association member list.

Table 3 provides a list of the regions of Oregon and Washington with corresponding sample size.

Table 3: Regions of Oregon/Washington State and Corresponding Interviews

Basin	Number of Irrigation Districts	Interview Respondents	
		Participants	Non-Participants
Deschutes	11	7	0
Klamath	6	1	0
Malheur	6	0	0
Rogue	6	1	0
Umatilla	6	2	1
Willamette	6	0	0
Hood River	4	1	1
Grand Ronde	3	1	0
Walla Walla	1	1	0
Out of State (Washington)	35	0	2

1.3.3 Funder and Stakeholder Interviews

Apex interviewed seven stakeholders involved with irrigation modernization efforts in Oregon. Table 4 lists these stakeholders and their roles related to irrigation modernization.

Table 4: Funder and Stakeholder Interview Sample

Organization	Involvement in Irrigation Modernization
US Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS)	Provides technical support and funding for irrigation modernization projects
Bureau of Reclamation	Offers grants that can support irrigation modernization projects
Oregon Clean Water State Revolving Fund	Provides loans to support projects that reduce water pollution
Oregon Water Resources Department	Oversees distribution of irrigation water and offers grants for water conservation

Organization	Involvement in Irrigation Modernization
Office of US Senator Jeff Merkley	Advocates for water conservation efforts, including support for congressional reauthorization of NRCS grant funding
Oregon State Representative Ken Helm	Chair of House Energy and Environment Committee, involved in water conservation issues
Oregon State Representative Pam Marsh	Representative of Rogue River Valley, involved in water conservation issues

2. Market Transformation Progress

Market transformation programs seek to overcome barriers to efficient products or practices in a target market so that installation of those products or use of those practices will continue once program support is no longer available.[4] Interview findings with program staff, irrigation districts, and stakeholders indicated three key barriers to irrigation modernization projects that the IMP seeks to address:

- Irrigation districts have limited capacity to undertake the technical analysis needed to identify and prioritize specific modernization opportunities and scope out projects to address them.
- Irrigation districts must address a diverse set of interests and concerns from a wide range of stakeholders, who may not all support irrigation efforts.
- Irrigation districts often serve a relatively small numbers of water users, who are unable to take on a significant increase in rates to cover the cost of modernization.

This section provides interview findings related to each of these barriers and assesses the IMP's efforts to overcome these barriers in a way that will bring about lasting change in uptake of irrigation modernization.

2.1 Barrier 1: Identifying Opportunities and Planning

Interviewed funders and stakeholders reported that irrigation districts are generally aware of irrigation modernization and its potential benefits. According to one stakeholder, "One of the hardest things an irrigation district has to do is tell a farmer they can't fill their allotment of water, so they can't farm. [Districts] are

[4] Ken Keating, "Guidance on Designing and Implementing Energy Efficiency Market Transformation Initiatives" (Sacramento, CA: California Public Utilities Commission, December 9, 2014).

motivated to find ways to keep [farmers] in business, keep them growing and feeding the community."

Irrigation district interviews generally support this perspective. All of the interviewed district managers were familiar with irrigation modernization, and five interviewed districts reported they had begun making improvements as long ago as the early 2000's. Those early improvements were generally on a smaller scale than improvements made through the program, with districts typically reporting they had piped fewer than 10 miles of canals prior to becoming involved in the program. These districts also reported the improvements they had made had occurred over the course of several years, using their own funds as well as some grant funding.

While irrigation districts were aware of irrigation modernization generally and some had undertaken small scale improvements, interview findings suggest the IMP plays an important role in helping districts prioritize improvements and identify a path forward to make large scale improvements. Multiple districts reported that the program had provided valuable support to help them identify the modernization opportunities likely to provide the greatest benefits.

District managers reported the program had conducted or facilitated studies to support modernization planning efforts. According to one district manager, "We could not have gone through and done all of the work that [the program] did…when they came through and were able to tell us where our losses were in our system, that was a huge impact for us." Other district managers noted that the program was able to leverage previous studies conducted in their area or help them interpret existing studies their districts had previously completed.

While irrigation districts were generally aware of, and interested in, modernization improvements broadly, the interviewed district managers expressed mixed views on installation of in-conduit hydropower. Some district managers reported that hydropower installations were appealing as a potential source of revenue that could offset costs to their water users. According to one district manager, "I don't charge farmers for water; I charge them for operation and maintenance of the district…those costs are increasing, and if I can help offset those costs by modernizing, if I can offset those costs through hydroelectric power generation…then I'm benefiting not only the farmers and ranchers, but I'm benefiting our economic foundation here."

Other district managers noted that they would need to see a sufficient return on investment to pursue hydroelectric generation, and some expressed concern that the price at which they could sell the power they generate was too low. In particular, district managers were aware of the experience of a district with existing hydro generation that recently had to renegotiate power purchase agreements and accept a lower price for their generated electricity. As a result, some district managers perceived hydro installation as somewhat risky or potentially not cost-

effective. Some districts also reported concerns that installing hydroelectric generation would prevent them from delivering pressurized water to water users.[5]

The most common reason district managers reported they were unlikely to install hydro generation (four districts) was that their districts did not have enough elevation change to build up the necessary water pressure. Individual districts reported unique challenges around building fish screens to support their hydro and bad experiences with experimental hydro technologies.

2.2 Barrier 2: Internal & External Support for Modernization

A diverse range of program staff and stakeholders agreed that internal support and strong management were key drivers of success for irrigation modernization projects. According to one stakeholder, "the thing that is consistent across all [districts successfully undertaking modernization projects] is a supportive board and a manager that is willing to go out and do the work." Program staff reported that support from a district's board was one of the criteria they consider when determining whether to engage with a district on a modernization project.

Stakeholders reported that the support of a district's board and water users, and effective communication with other stakeholders, could help to overcome any opposition that might arise to modernization improvements. The IMP supports participating irrigation districts in their communications with stakeholders.

2.2.1 Irrigation District Boards of Directors

All of the interviewed irrigation district managers, regardless of participation status, reported their boards were generally supportive of modernization. Some managers noted that their boards included the largest farmers in their districts, who recognized that modernization would provide significant benefits to their own farms, as well as the district more broadly. According to one district manager, board members "support [modernization] big time because most of them are large farmers and it not only helps them, but it helps everybody."

One district manager noted that, while his board was supportive, the volunteer members were not actively involved in modernization efforts. Illustrating the potential benefits of an engaged board, this manager reported that he would feel more confident in making decisions around modernization improvements if he were not the only one responsible for reviewing and approving technical reports and plans.

[5] Program staff confirmed that installing in-conduit hydroelectric generation reduces the water pressure available to deliver to farmers. Each district's topography would determine the extent to which it could deliver hydroelectric generation and provide pressurized water to farms.

2.2.2 Water Users

While interviewed district managers reported their boards were generally supportive of modernization, they described a wider range of reactions from the broader population of water users they serve. Several districts reported that their users were supportive of modernization efforts, noting that the potential to receive pressurized water and reduce energy costs from pumping was particularly appealing. Four district managers noted that the farms that used the largest amount of water and were most dependent on that water had the greatest potential to benefit from modernization and thus were the most supportive of modernization efforts. These managers reported it could be more difficult to gain support from smaller, hobby farmers whose livelihoods were less impacted by water availability.

Cost was the primary concern district managers reported water users raising about modernization, with five managers noting that many users were not closely involved with the operations of the district and were mainly concerned about costs. Interviewed district managers also described a variety of more specific concerns that water users had expressed with modernization projects, including:

- Concerns about the impact of reduced seepage from canals on ground water supplies: Three district managers noted that some users supplemented the water they received from the district with on-farm wells. These users were concerned that piping canals would reduce the ground water available in their wells. Program staff confirmed that piping canals could affect groundwater availability in some watersheds.
- Concerns about the compatibility of existing irrigation equipment with a pressurized water supply: One district manager noted that water users wanted details about the pressurized water they would receive, and that, for some, switching to a pressurized system would likely require replacing existing irrigation equipment.
- Privacy concerns related to water use monitoring and telemetry: One district manager noted that water users had opposed the district's efforts to establish telemetry to monitor water use due to privacy concerns, saying "[the farmers] dig their heels in and they don't want people to know what's going on. Even if they are not doing anything wrong, they just don't want everybody involved in their business."

2.2.3 Other External Stakeholders

Irrigation districts reported working with a wide range of external stakeholders in completing their modernization projects. Four districts noted that tribes could be a particularly important group to work with since they have water rights in the same watersheds as the irrigation districts. Two district managers reported that it had been somewhat challenging to coordinate with their local tribes, while a third

reported they had a strong relationship with the tribe in their area and the tribe planned to pursue irrigation modernization improvements as well.

District managers reported that modernization projects provide an opportunity for districts to cooperate with environmental organizations and other groups with whom they have historically had contentious relationships. According to one district manager, "We don't always see eye-to-eye on different things, but the way in which we went about this process and the way we have managed the resource, I think everyone saw this was a win-win for everyone." District managers noted that the diverse group of stakeholders that support irrigation modernization can help to build political support and gain funding for modernization. One district manager said, "whenever you are undertaking some kind of a conservation project, getting a respected, influential conservation group alongside you to undertake that, I think is wise."

Other stakeholders that interviewees reported as involved in modernization efforts include:

- Local governments (5 districts): Irrigation districts generally reported that local governments were supportive of modernization as a water conservation effort. One respondent also noted that eliminating canal seepage would increase the amount of land available for development in their municipality.
- Landowners (2 districts): District managers, as well as stakeholders and program staff, noted that some homeowners whose properties border canals oppose modernization because they do not want to lose the aesthetic benefits of the canal. According to one respondent, "there are a lot of homes right on canals. Those canals are, from an aesthetic standpoint, people bought homes on a canal because they wanted to be on a canal."
- Other districts (2 districts): One district manager noted that multiple irrigation districts may operate in the same watershed, and one district's modernization efforts can impact the operation of neighboring districts.

2.3 Barrier 3: Modernization Costs

As noted above, cost is a primary concern for water users, and funding large-scale modernization improvements is a key challenge the IMP works to overcome. Supporting irrigation districts in identifying outside funding sources to support modernization improvements, conducting the research and planning work required to qualify for that funding, and navigating the application process is central to the IMP. Irrigation districts often serve a relatively small number of water users, who are unable to take on a significant increase in rates to cover the cost of modernization improvements on their own. As one district manager explained, "With an irrigation district of 20,000 acres, to raise the assessment by one dollar raises $20,000. For us to pay off a $12-to-$13 million project like we're undertaking right now, there is just no way for us to do that internally."

The IMP works to overcome cost barriers by helping districts access existing funding sources and by developing partnerships to expand access to outside funding for modernization projects. The program's support of hydropower generation can also help districts address cost barriers by creating a revenue stream districts can use to pay for improvements.

2.3.1 Support in Accessing Funds

Interviewed irrigation districts described a range of ways that the IMP has supported them in accessing external funding to support their irrigation projects. This support begins with identifying funding sources and navigating the application processes. As one district manager described, "In order to go out and find the money, which is usually through grants from the Federal Government or the State, you have to have help from people that know those sources, and that's what FCA provides." Another district manager said, "For me, as a new general manager [the most helpful element] has been slowing down the train and explaining the process."

Irrigation district managers also reported that the Watershed Plans the program produced were helpful in securing external funding. Managers reported that the plans both provide content they can use to complete funding applications and make those applications more attractive to funders. According to one district manager, "There is plenty of money, but [funders] want to see what they are going to get for their money and the best bang for their buck. The modernization plan spells it out." District managers also reported the program had provided more direct support in preparing funding applications. Some districts reported that FCA staff had reviewed draft funding applications for them or had helped them with grant writing directly.

Irrigation districts valued the program's support in identifying and accessing outside funding. Some interviewed districts nonetheless reported that some funders' requirements to provide matching funds posed challenges. One district manager said, "Over the next three years, where am I going to come up with $5 million to $6 million [in matching funds]?"

Interviewed district managers noted that the USDA NRCS Watershed Protection and Flood Prevention Program (PL 83-566) requirement that districts provide 25% of project costs in matching funds made projects more accessible than the Bureau of Reclamation's Water Smart grants, which require a 50% match. According to one district manager, "for us to be able to have the 75%/25% match, that's huge."

2.3.2 Expanding Funding Availability

As noted above, the PL 83-566 program has been a key outside source of funding for irrigation modernization projects. Congress reauthorized funding for the PL 83-566 program in 2016, with support from Oregon Senator Jeff Merkley and former Mississippi Senator Thad Cochran. In interviews, program staff indicated that the program had contributed to the reauthorization of PL 83-566 and the disproportionate share of PL 83-566 funds allocated to Oregon. Program staff explained that the work the program had done to help irrigation districts develop

system improvement plans and watershed plans illustrated concrete benefits of irrigation modernization projects, which helped gain support for expanded funding.

Stakeholders involved in the reauthorization of PL 83-566 funding confirmed program staff members' assessments. One interviewed stakeholder said the work the program had done with irrigation districts "showed there was a need" for PL 83-566 funding, which had not been authorized for several years. According to this stakeholder, "the fact that [Oregon irrigation districts] already had the system improvement plans nearing completion at the time we started to push for PL 83-566 and got it across the finish line was super beneficial."

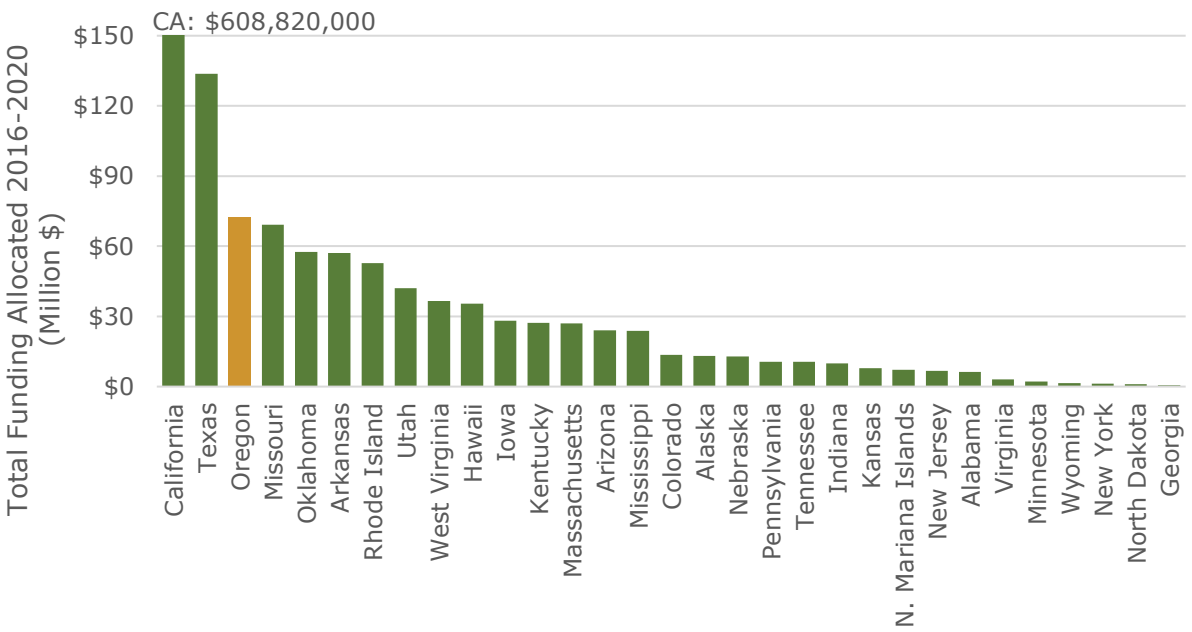
In addition to authorizing the PL 83-566 funding, stakeholders reported that the program had played an important role in increasing the volume of irrigation modernization projects NRCS can support. One stakeholder noted that, while NRCS provides both funding and technical support for planning modernization improvements, the program's involvement has allowed it to work with a larger number of districts and complete plans more quickly. This stakeholder reported that the program's impact had been "huge – without them, there would be no way. It's the whole workload – the sheer amount of interest out there."

Data on PL 83-566 funding support program staff and stakeholders' suggestions that the program has increased the funding in Oregon.[6] Between 2016 and 2020, the program allocated approximately $1.4 billion across the country. More than $72 million of that funding went to projects in Oregon, making Oregon the third-largest recipient of PL 83-566 funding following California and Texas (Figure 1).[7]

[6] Data on PL 83-566 funding allocations comes the "Small Watershed Infrastructure: Continuing the Mission, Building Upon Success" hearing before the Subcommittee on Conservation and Forestry of the Committee on Agriculture, House of Representatives, 115th Congress, June 13, 2017. Available at: https://www.govinfo.gov/content/pkg/CHRG-115hhrg25913/html/CHRG-115hhrg25913.htm

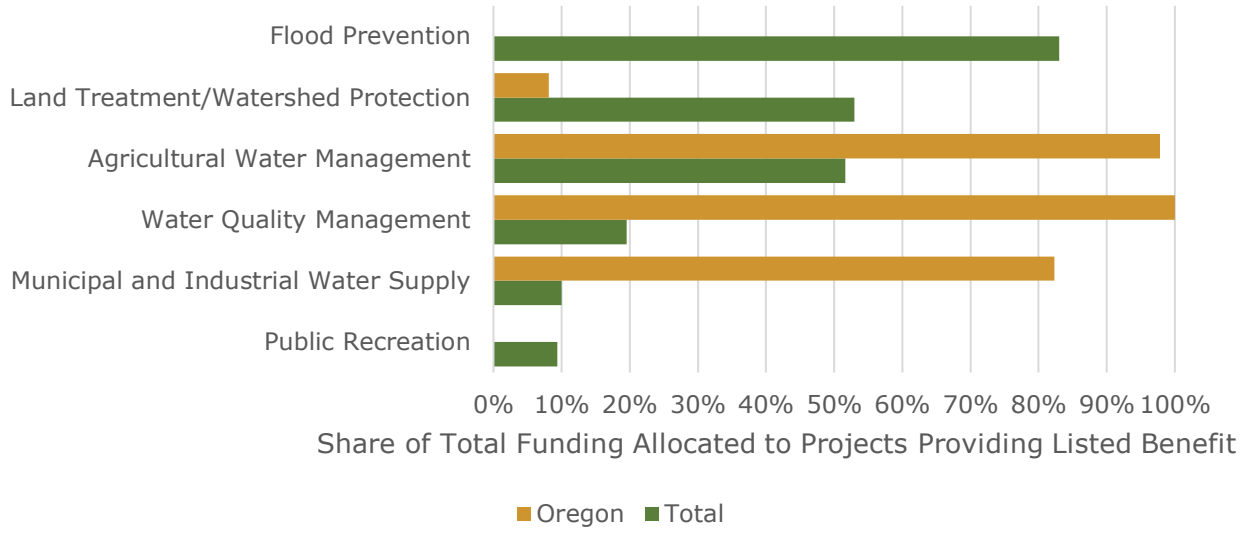
[7] California received the largest share of funding, at more than $600 million, with more than half of that going to two very large projects (Llagas Creek: $274.5 million, and Oasis $100 million).

Figure 1: PL 83-566 Total Funding by State 2016-2020



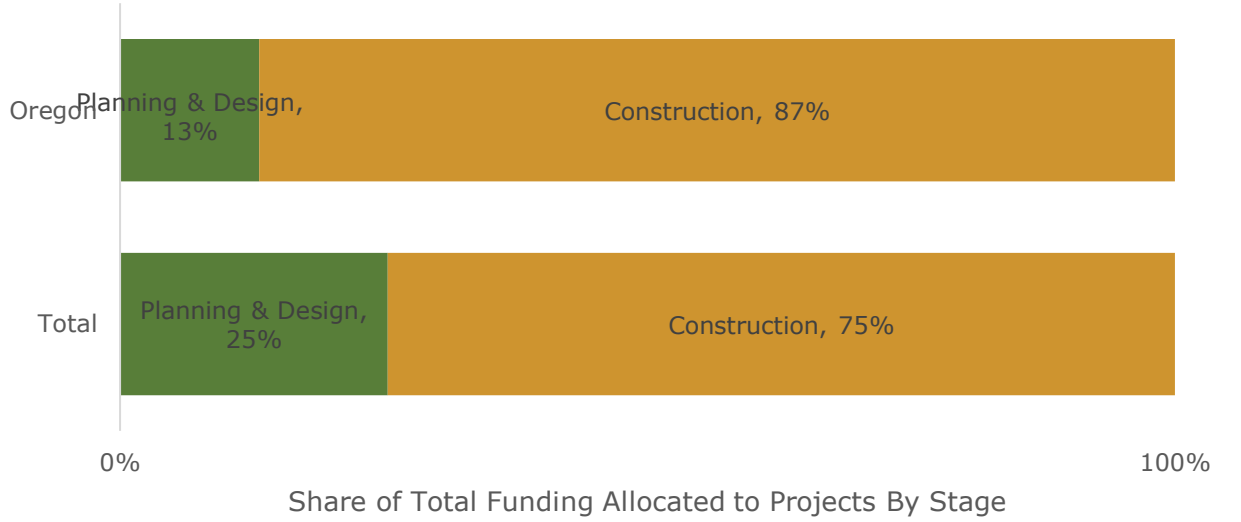
The types of projects receiving PL 83-566 funding differed notably between Oregon and the nation-wide average, consistent with an increased focus on irrigation modernization projects in Oregon. Almost all Oregon funding was classified as providing agricultural water management and water quality management benefits and most provided municipal and industrial water supply benefits. In contrast, nationwide PL 83-566 funding primarily supported projects providing flood prevention benefits. Notably smaller shares of national funding went to projects providing the agricultural water management, water quality management, and municipal and industrial water supply benefits most prominent in Oregon (Figure 2).

Figure 2: PL 83-566 Funding Allocation by Project Benefit 2016-2020



PL 83-566 data are also consistent with program staff members' reports that program support has increased the number of construction-ready projects in Oregon. Roughly half as much PL 83-566 funding went to projects in the planning and design phases in Oregon relative to the nation-wide average (Figure 3).

Figure 3: PL 83-566 Funding Allocation by Project Stage 2016-2020



In addition to PL 83-566 funding, stakeholders reported that the Oregon Clean Water State Revolving Fund had begun working more closely with irrigation districts in recent years. The fund, which traditionally has supported improvements to municipal wastewater treatment plants and other point source pollution sources,

has increased its focus on non-point source pollution reduction, which includes irrigation modernization projects.

3. Market Progress Assessment

Changing practices at a market-wide scale is often a long-term effort. As a result, it may take several years for market transformation programs to achieve their objectives in a meaningful and measurable way. Identifying market progress indicators (MPIs) that measure program progress against short- and medium-term outcomes provides an approach to measure program progress in the interim.

Apex worked with Energy Trust to develop a logic model for IMP and identified a series of MPIs based on the IMP's program logic. Figure 4 illustrates the IMP's logic model.

Figure 4: IMP Logic Model

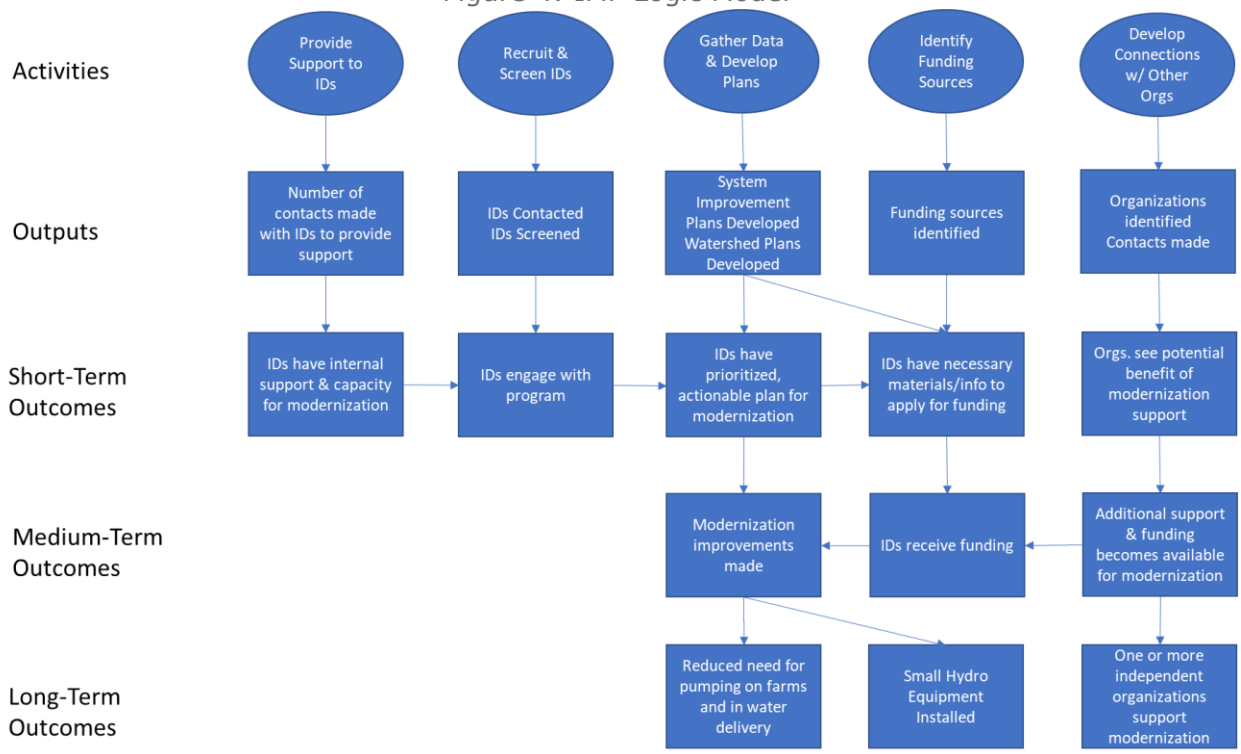


Table 5 lists the MPIs associated with the IMP logic model.

Table 5: IMP Market Progress Indicators

Timeframe	Outcome	MPIs
Short-Term	Irrigation districts have internal support and	Districts remain responsive to program outreach and engaged with program.

Timeframe	Outcome	MPIs
	capacity for modernization.	District stakeholders support modernization.
		District staff are able to carry out tasks necessary to advance modernization projects.
	Irrigation districts engage with program	Number & irrigated acreage of districts passing program screening for viability and hydro potential.
	Irrigation districts have prioritized, actionable plan for modernization	System improvement plans completed
		District staff understand priorities and next steps.
	Irrigation districts have necessary materials and information to apply for outside funding	Number of funding applications completed and dollar amount of funding requested
		District staff ability to provide information needed for funding
	Potential partners and funding organizations see potential benefits of modernization	Number of organizations aware of benefits modernization and considering developing or expanding support
Medium-Term	Irrigation districts make modernization improvements	Number of districts making improvements, length of canal piped or otherwise modernized, irrigated acreage affected by modernization improvements
	Irrigation districts receive outside funding	Number of sources providing funding, amount of funding provided
	Additional outside support and funding becomes available for modernization	Number of organizations developing or expanding funding support for modernization and dollar amount of new funding available
Long-Term	Reduced need for pumping on farms and in water delivery	Amount (gallons or acre-feet) of pumped water reduced
	Small hydro equipment installed	Number of districts with hydro installations; number of hydro installations; MWh of hydro generation

The remainder of this section summarizes Apex's findings related to the MPIs. We present detailed findings on each MPI in Appendix B.

The IMP's short-term outcomes focus on irrigation districts engaging with the program and developing the tools and knowledge necessary to move forward with modernization projects.

- As of late 2021, 26 districts, collectively serving more than 60% of statewide acreage served by irrigation districts, were participating in the program. Most of these districts (19) had completed or substantially completed system improvement plans.
- Most participating districts had either substantially completed the process of developing a watershed plan or appeared to be making progress. Interviewed district staff reported they were aware of, and able to complete, the tasks to advance their projects.
- District staff reported that Watershed Plans and other program-supported documents were helpful in preparing funding applications. Districts, with program support, had secured $168 million in funding from 12 different organizations as of early 2021, with an additional $39 million pending from 14 organizations.

The IMP's medium-term outcomes focus on districts installing modernization improvements.

- Ten districts, collectively serving more than 20% of the total statewide acreage served by irrigation districts have installed modernization improvements.
- Participating irrigation districts secured $70.7 million for irrigation modernization projects in 2020, including funding from the PL 83-566 program, which stakeholders credited the program with helping to reauthorize.

The IMP's long-term outcomes focus on realizing the benefits of irrigation modernization improvements.

- Two interviewed districts had installed new hydroelectric generation as part of their modernization projects, while seven additional districts had identified hydro opportunities but had not yet installed systems.
- The program is still working to develop processes to track energy savings from reduced pumping.

4. Irrigation Modernization Baseline

Because market transformation programs seek to influence the market as a whole, rather than individual transactions, their outcomes are measured against a theoretical baseline of predicted market activity absent market intervention. Apex estimates that, without the IMP’s intervention, irrigation modernization activity

would take place in Oregon, but at a smaller scale and at a slower pace than has occurred with program support.

We predict that irrigation modernization activity would occur without the program for three reasons:

- A small number of irrigation districts made substantial progress on modernization projects in the years leading up to the program's launch. In addition, interviewed districts, including non-participating districts, reported completing small-scale modernization improvements independent of the program. It is important to note that some of these districts received incentives from Energy Trust for hydroelectric installations or reduced pumping, although this support was less comprehensive than the support offered through the IMP.
- Irrigation districts are motivated to use water more efficiently so they can meet the needs of their patrons. Interviewed district managers and stakeholders reported that years of drought and changing climates are forcing districts to reduce losses so their patrons can maintain their agricultural operations.
- Outside sources offer funding and technical assistance for irrigation modernization projects, although on a smaller scale than the IMP. These organizations might expand their support over time in a baseline scenario as they gain experience with, and recognizing the benefits of, irrigation modernization.

We predict that modernization activity would be less in a baseline scenario because:

- Few irrigation districts have the staff capacity and technical resources to pursue modernization projects independently, including identifying and applying for grants and other funding sources.
- Other organizations supporting irrigation modernization do not have the staff capacity to provide the level of technical support that the IMP offers to irrigation districts.
- Outside funding levels would likely be lower without the IMP, which has demonstrated the need for, and benefits of, modernization, and provided a pipeline of viable projects for funders to support.

As a result, we anticipate that, relative to a curve of actual irrigation modernization activity, a baseline curve would be both shifted to the right – indicating that modernization activity would have occurred later than it did with program support – and would have a shallower slope – reflecting a slower uptake of modernization improvements.

5. On-Farm Pumping Energy Savings Approach

By shifting water delivery from canals to pressurized pipes, irrigation modernization projects have the potential to reduce the need for farmers to pump water to irrigate their crops. As noted in Section 2.2.2, the resulting energy cost savings were a key benefit water users saw in modernization improvements. Estimating these energy savings poses a challenge, since, like many market transformation programs, the market actors with whom the IMP primarily works operate upstream of the end-users who experience the energy savings.[8]

Energy Trust asked Apex to develop an approach to estimate energy savings from irrigation modernization at the irrigation district level that minimizes the inputs required that are specific to the farms served. This section describes the approach Apex developed and discusses potential data sources to collect the input data required.

5.1 Approach to Estimating Energy Savings

The annual energy savings provided by piping the water carried from an open ditch to a field are a function of three variables:

- The increase in pressure at the pipe inlet
- The efficiency of the pump
- The total, annual amount of water delivered by the pump

The potential energy of any elevated mass (including an annual mass of water delivered from an elevated ditch to a pump inlet) is given by:

$$Potential\ Energy = m*g*h$$

Where:

Potential energy is measured in joules

m = mass (kg)

g = acceleration of gravity = 9.8 meters/second^2

h = difference in elevation in meters

As a result, a piped connection from an elevated ditch will deliver energy to the pipe equal to this potential energy, minus any pipe losses along the way.

[8] From a market transformation program perspective, one market actor is "upstream" of another market actor if their position in the supply chain is closer to the manufacturer. In this context, an irrigation district, as a supplier of water, is upstream of the end-user receiving that water. The irrigation district is also upstream of the end-user in a more literal sense (in terms of the movement of water).

Energy delivered to pipe = Potential energy – Pipe losses

The actual pump electricity savings are a function of the electricity delivered to the pipe and the efficiency of the pump/motor combination.

Electricity Energy Savings = Energy delivered to pipe / pump efficiency

Grouping and rearranging terms:

*Electric Energy Savings (J) = (Mass of water (kg) * 9.8 m/s^2 * Ditch elevation above pump (meters) – Pipe losses)/(Pump efficiency)*

Converting to kWh:

*Electric Energy Savings (kWh) = Mass of water (kg) * 9.8 m/s^2 * (Ditch elevation (head) (meters) – Pipe losses (in meters of head))/(Pump efficiency) * 1 kWh / 3,600,000 J*

An example of this calculation conducted for a hypothetical irrigation district is described in Appendix C.

5.2 Approach to Estimating Input Values

Table 6 lists the input values required for the energy savings approach described above, as well as potential approaches to obtaining or estimating those values.

Table 6: Energy Savings Approach Input Values

Value	Description	Approach
Mass of water	Total mass of water delivered annually by canals being piped	Available through irrigation district tracking (customer water allotments)
Difference in elevation	Difference in elevation from the start of the piped canal to the pump	Could be estimated through GIS mapping of a representative group of irrigated fields and canals
Pipe losses (in lost head)	Energy lost due to friction as water moves through a pipe	Use an industry average value or estimate through a combination of representative example projects and engineering equations. Pipe losses will be a function of: • Flow rate • Pipe diameter • Pipe length These can be measured for example projects and added together for representative sections of pipe (e.g. a trunk line leading from the canal outlet and feed lines to pumps in individual fields). This approach could use a combination of GIS mapping to estimate pipe lengths and

		typical pipe sizing and flow rate estimates from expert interviews identifying the most common pump configurations.
Pump efficiency	Share of electric energy entering pump converted to kinetic energy	Could be estimated using secondary sources to identify an industry average value and/or typical pump efficiency values for pump sizes and flow rates identified in expert interviews, or through expert interviews directly exploring most commonly installed pumps.

6. Conclusions and Recommendations

Apex draws the following conclusions and recommendations from this research:

Conclusion 1: The IMP functions as a market transformation program, and its potential to expand available funding and support for irrigation modernization is central to its market transformation objectives. The scope of irrigation modernization projects is typically too large for an irrigation district to complete independently in a timely and comprehensive way. As a result, the most effective way to meet the market transformation objective of generating market-wide adoption that will extend beyond the program's support is to build a network of organizations and funders working to support irrigation modernization. The IMP has done this successfully by demonstrating the specific benefits of irrigation modernization projects and generating a pipeline of projects ready to receive available support. Most notably, these efforts contributed to the reauthorization of PL 83-566 funding, which has supported large numbers of irrigation modernization projects in Oregon and other states.

- **Recommendation 1: Energy Trust and FCA should continue to build relationships with stakeholder organizations and encourage increased support for irrigation modernization.** The program should continue working to identify funders and organizations whose missions align with the many energy and non-energy benefits of irrigation modernization and encourage them to support modernization efforts with funding or technical support. Broadening the range of organizations providing support can help ensure resources are available that align with the unique needs of each irrigation district.

Conclusion 2: Energy savings are an important benefit of modernization improvements. The potential to reduce energy consumption from on-farm pumping was one of the most frequently cited benefits of irrigation modernization for irrigation districts. District managers saw energy savings as a clear benefit for their patrons, allowing them to use funds that would have gone to energy costs in other ways, with further positive effects for the local economy. There is also potential that

districts would need to choose between energy savings benefits and hydroelectric generation. Installing in-conduit generation could reduce water pressure, and some district managers indicated they were inclined to prioritize providing pressurized water over installing generation capabilities.

- **Recommendation 2: Energy Trust should continue to develop an approach to claim energy savings from irrigation modernization.** Adopting a high-level energy savings methodology, like the one described in Section 5, could help Energy Trust better capture the benefits of irrigation modernization. To the extent irrigation districts must choose between delivering pressurized water to farms or using it for hydroelectric generation, a methodology to claim savings could help ensure Energy Trust benefits from all of the modernization projects it supports. Pump energy savings are also a compelling benefit for program communications to address.

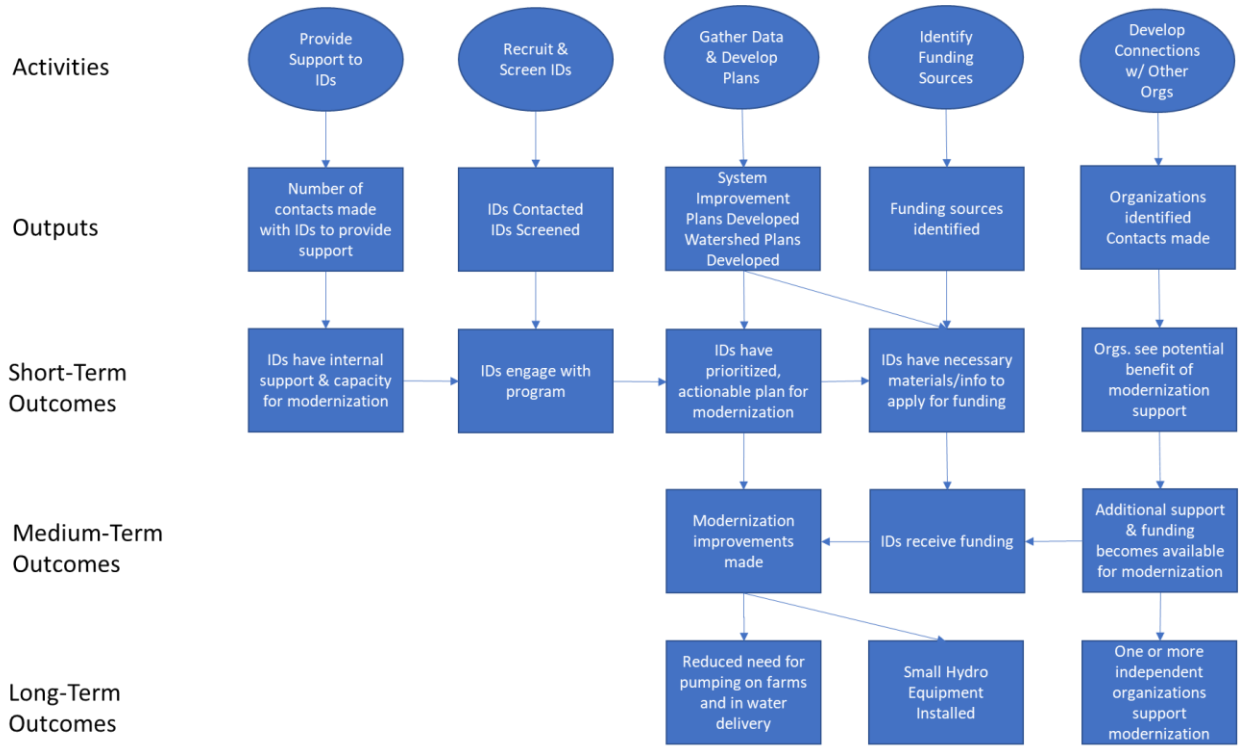
Appendix A: IMP Logic Model and MPIs

Logic Model

A logic model describes the actions a program carries out, the outputs directly resulting from those actions, and the logical connections linking those activities and outputs to market outcomes, ultimately leading to achievement of the program's ultimate objectives. Articulating the program logic in this way allows programs and evaluators to identify specific, interim outcomes they can use to assess program progress.

The Apex team defined five key activities that make up the IMP. These activities and the corresponding outputs and outcomes are listed in Figure 5.

Figure 5: IMP Logic Model



As Figure 5 describes, the program recruits irrigation districts and screens them for both the feasibility of completing modernization projects (in terms of interest, capacity, and commitment of key stakeholders) and the potential for hydro power generation in their systems. The program then provides support to participating districts to gather the necessary data to scope and prioritize modernization opportunities. The program also helps districts identify outside funding sources that can support their modernization projects. Using the information they have gathered, districts are then able to apply for and receive this outside funding to support their modernization improvements, which provide opportunities for small hydro generation and energy savings from reduced need for pumping

on farms. The program has also worked with other organizations to increase availability of funding and support for modernization projects.

Market Progress Indicators

Market Progress Indicators (MPIs) are measurable indicators that the outcomes theorized in a logic model are taking place. Tracking MPIs provides an opportunity to assess program progress even if the program has not yet achieved its ultimate objectives at a significant scale. Tracking MPIs also provides an opportunity to identify any breakdowns in program logic that prevent anticipated outcomes from taking place. Table 7, on the following page, describes the MPIs Apex has identified related to each outcome listed in the IMP logic model, as well as potential data sources to assess those MPIs.

Table 7: Proposed Market Progress Indicators (MPIs)

Timeframe	Outcome	MPIs	Data Sources
Short-Term	Irrigation districts have internal support and capacity for modernization.	Districts remain responsive to program outreach and engaged with program.	FCA contact tracking with districts: Number of districts not responding to messages and/or completing tasks in set period.
		District stakeholders support modernization.	Interviews with district staff, probing on stakeholder support.
		District staff are able to carry out tasks necessary to advance modernization projects.	Interviews with district staff, probing on difficulty of, and capacity to complete, tasks necessary to advance modernization projects.
	Irrigation districts engage with program	Number & irrigated acreage of districts passing program screening for viability and hydro potential.	FCA reporting on number of districts engaged with program and district progress
	Irrigation districts have prioritized, actionable plan for modernization	System improvement plans completed	Count and review of completed system improvement plans
		District staff understand priorities and next steps.	Interviews with district staff, probing on utility of system improvement plans.
	Irrigation districts have necessary materials and information to apply for outside funding	Number of funding applications completed and dollar amount of funding requested	FCA tracking of district support, district records
		District staff ability to provide information needed for funding	Interviews with district staff, probing on experience applying for funding and adequacy of available information

Timeframe	Outcome	MPIs	Data Sources
	Potential partners and funding organizations see potential benefits of modernization	Number of organizations aware of benefits modernization and considering developing or expanding support	FCA contact tracking with organizations; interviews with partner organization staff, probing on efforts developed and motivations for development
Medium-Term	Irrigation districts make modernization improvements	Number of districts making improvements, length of canal piped or otherwise modernized, irrigated acreage affected by modernization improvements	FCA tracking data
	Irrigation districts receive outside funding	Number of sources providing funding, amount of funding provided	FCA tracking data and/or participating irrigation district data requests
	Additional outside support and funding becomes available for modernization	Number of organizations developing or expanding funding support for modernization and dollar amount of new funding available	FCA tracking data; interviews and/or data requests with partner organization staff
Long-Term	Reduced need for pumping on farms and in water delivery	Amount (gallons or acre-feet) of pumped water reduced	Estimated as function of irrigated acreage, crop type, irrigation approach; confirmed with periodic surveys of water users
	Small hydro equipment installed	Number of districts with hydro installations; number of hydro installations; MWh of hydro generation	Irrigation district reporting

Appendix B: Detailed Assessment of MPIs

Indicators Associated with Short-Term Outcomes

Energy Trust and FCA have been operating the IMP in its current form since 2015, a time period that should be sufficient for the program to make substantial progress toward its anticipated short-term outcomes. As summarized in Table 8**Error! Reference source not found.**, this evaluation confirmed that the program is achieving its short-term outcomes, engaging with districts that represent a majority of the acreage in Oregon served by irrigation districts.

Table 8: Assessment of Short-Term MPIs

Outcome	MPI	Finding
Irrigation districts have internal support and capacity for modernization.	Districts remain responsive to program outreach and engaged with program.	According to FCA tracking (District Progress Charts), of 48 irrigation districts in Oregon: • Eleven had substantially completed the process of developing a Watershed Plan by March 2020. • Nine Oregon districts progressed in the process of developing a Watershed Plan between March 2020 and September 2021. • Six Oregon districts did not show progress in FCA's District Progress Chart for September 2021, relative to the March 2020 chart. In assessing progress based on FCA reporting to Energy Trust, it is important to acknowledge that some milestones may take longer to reach than others. None of the interviewed districts indicated they had deliberately stopped program activity.
	District stakeholders support modernization.	As described in Section 2.2: • All interviewed districts reported their boards were supportive of modernization efforts. • Interviewed districts reported water users, particularly the largest users were generally supportive, although some users had concerns about modernization. • Other external stakeholders were generally supportive

Outcome	MPI	Finding
	District staff are able to carry out tasks necessary to advance modernization projects.	All interviewed participating districts reported they were able to complete tasks to advance their projects. Participating districts were appreciative of program support, particularly in engineering and grant writing.
Irrigation districts engage with program	Number & irrigated acreage of districts passing program screening for viability and hydro potential.	As of Q3 2021: 26 districts had completed initial program assessments. These districts collectively serve 427,000 acres; estimated >60% of statewide acreage served by IDs
Irrigation districts have prioritized, actionable plans for modernization	System improvement plans (SIPs) completed	As of Q3 2021: 19 districts had completed or substantially completed SIPs; serving >300,000 acres
	District staff understand priorities and next steps.	All interviewed district managers (17) reported they understood their priorities and next steps
Irrigation districts have necessary materials and information to apply for outside funding	Number of funding applications completed and dollar amount of funding requested	Not fully tracked in program documentation shared with Apex. As of January 2021, program listed $168M of funding as secured and $39M as pending, excluding Energy Trust investment.[1]
	District staff ability to provide information needed for funding	Interviewed district staff reported Watershed Plans and other documents produced with program support contained information needed for funding applications.
Potential partners and funding organizations see potential benefits of modernization	Number of organizations aware of benefits modernization and considering developing or expanding support	• As of January 2021, FCA reporting listed 12 organizations providing funding for modernization and two additional organizations with pending funding, excluding Energy Trust and participating irrigation districts. • Interviewed irrigation districts listed nine organizations supporting their modernization efforts

[1] Figures cited are aggregated across all participating irrigation districts, regardless of utility provider. Districts not served by investor-owned utilities (IOUs) are eligible for program support in anticipation that hydroelectric power generated in these districts would nonetheless be delivered to the IOUs.

Indicators Associated with Medium-Term Outcomes

The IMP has made substantial progress against its medium-term indicators as well as its short-term indicators (Table 9**Error! Reference source not found.**).

Table 9: Assessment of Medium-Term MPIs

Outcome	MPI	Finding
Irrigation districts make modernization improvements	Number of districts making improvements, length of canal piped or otherwise modernized, irrigated acreage affected by modernization improvements	10 districts, serving 162,866 acres (>20% of acreage served by Oregon irrigation districts), have installed at least some improvements.[1]
Irrigation districts receive outside funding	Number of sources providing funding, amount of funding provided	As of January 2021, 13 outside funders had committed $70.7M for irrigation modernization projects in 2020 and 6 funders had committed $26.1M for projects planned for 2021
Additional outside support and funding becomes available for modernization	Number of organizations developing or expanding funding support for modernization and dollar amount of new funding available	As described in Section 2.3.2, the IMP contributed to reauthorization of NRCS PL 83-566 funding and allocation of that funding to Oregon.

[1] As noted above, figures cited include all participating irrigation district, regardless of utility provider, in anticipation that hydroelectric power generated would be delivered to IOUs.

Indicators Associated with Long-Term Outcomes

The IMP has made progress toward its long-term outcomes, but, as Table 10**Error! Reference source not found.** indicates, the program continues to work toward these objectives.

Table 10: Assessment of Long-Term MPIs

Outcome	MPI	Finding
Reduced need for pumping on farms and in water delivery	Amount (gallons or acre-feet) of pumped water reduced	Energy Trust is considering approaches for estimating energy savings. Section 5 of this report proposes one approach.
Small hydro equipment installed	Number of districts with hydro installations; number of hydro installations; MWh of hydro generation	Of the IMP districts interviewed: • 2 had hydro installations predating their modernization projects • 2 installed hydro as part of modernization projects with program support

		• 7 had potential to install hydro as part of modernization but had not yet done so

Appendix C: Energy Savings Calculation Example

This appendix uses the example of a hypothetical irrigation district to illustrate the approach to calculating energy savings from reduced on-farm pumping described in Section 5.1. This hypothetical district delivers 50,000 acre-feet of water per year to farmers growing a variety of crops using center pivots with relatively high pressure requirements. We assume Energy Trust conducts topographic analysis and surveys of local irrigation contractors and farmers to determine that:

- On average, there is 100 feet of head between the water source and the pumps used to pressurize the irrigation systems.
- The typical pump efficiency on the system is about 60%.
- The pumps currently deliver 140 feet of head.
- The piping system design will keep piping friction head losses to 10%.

We then use the equation described in Section 5.1 to calculate the expected energy savings in kWh:

> *Electric Energy Savings (kWh) = Mass of water (kg) * 9.8 m/s^2 * (Ditch elevation (head) (meters) – Pipe losses (in meters of head))/(Pump efficiency) * 1 kWh / 3,600,000 J*

The quantity *(Ditch elevation (head) (meters) – Pipe losses (in meters of head))* is calculated as (100 feet – 10% * 100 feet) * 0.3048 m / foot = 90 feet * 0.3048 m / foot = 27.4 meters of head delivered to the pump inlet.

The annual mass of water in kg is given by 50,000 acre-feet * 43,560 cubic feet / acre-foot * (0.3048 m/foot)^3 * 1000 L /m^3 * 1 kg/L = 61,674,091,877 kg.

Substituting these values into the savings equation, the resulting annual energy savings for converting the hypothetical irrigation district to piped water are then estimated as 61,674,091,877 kg * 9.8 m/s^2 * 27.4 meters / 60% * 1 kWh / 3,600,000 J = **7,667,000 kWh.**

Appendix D: Documents Reviewed

Title	Author	Date	Description
Energy Trust IMP Deliverables Check List	FCA	*Not listed*	Check-list of deliverables completed by participating irrigation district
Overview of the Irrigation Modernization Program	FCA	March 2020	Graphic showing progress of participating irrigation districts through IMP process
Repowered Hydro System Boosts Clean Energy Generation	Energy Trust	October 2015	2-page case study describing Farmers Irrigation District (Hood River) modernization project.
Farmers Conservation Alliance Irrigation Modernization Program 2019 Report	FCA	January 14, 2020	Report detailing IMP progress against six defined objectives, as of end of 2019
Farmers Conservation Alliance Irrigation Modernization Program 2020 Report	FCA	December 17, 2020	Report detailing IMP progress against six defined objectives, as of end of 2020
Irrigation Modernization Update for Energy Trust of Oregon's Board of Directors	FCA	*Not listed*	PowerPoint update to Energy Trust board
Memo on Irrigation Modernization Context and Framework for Selecting Case Studies	Julie O'Shea, FCA	January 18, 2019	2019 memo describing IMP process and impacts
Irrigation Modernization & Hydropower Contract Amendment	Energy Trust	*Not listed*	Presentation describing program and its benefits
Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study	Les Perkins, FCA	June 2013	Report describing hydropower opportunities related to irrigation modernization as well as barriers to uptake and providing a case study of two irrigation districts.
FCA Energy Trust Investment	FCA	January 2021	Series of infographics describing Energy Trust's investment in IMP and its outcomes
Irrigation Modernization Program: Overview Brief	*Not listed*	*Not listed*	2-page description of the IMP and benefits of irrigation modernization

Title	Author	Date	Description
Irrigation Modernization Update	*Not listed*	*Not listed*	PowerPoint presentation describing IMP and its progress
Making Water Work: Strategies for Advancing Water Conservation in Oregon Agriculture	Oregon Environmental Council	January 2012	Report on agricultural water usage and need for greater water conservation in the agricultural sector
Role of Hydropower in IMP	*Not listed*	*Not listed*	Short discussion of potential for irrigation modernization to incorporate hydropower and barriers to doing so.
Small Hydropower Technology and Market Assessment	Summit Blue Consulting	January 26, 2009	Report assessing potential and opportunities for small hydropower in Oregon, identifies irrigation districts as an area of opportunity
Capturing Untapped Potential: Small Hydro in Irrigation Canals	Jessica Andrews and Mike Britton	10/1/2017	Hydropower trade magazine article about generation in the North Unit Irrigation District, North of Bend
Canal Plus: These Tiny Turbines Can Turn Man-Made Waterways Into Power Plants	Chris Noon	September 5, 2019	Article from GE about a company they partnered with that has developed turbines designed to be placed in existing irrigation canals (without additional modernization elements)
HydroSource	Oak Ridge National Laboratory	*Not listed*	Compilation of datasets and data sources related to hydropower in the US.
U.S. Hydropower Market Report	U.S. Department of Energy	January 2021	Report tracking hydro generation across the US and trends in hydro generation and pumped storage hydro.
2018 Irrigation and Water Management Survey	U.S. Department of Agriculture	November 2019	Survey providing state-level estimates of irrigation usage, including acreage, amount of water used, pump type, etc.

Appendix E: Data Collection Instruments

Staff Interview Guide

Introduction

Thank you for taking the time to speak with me today. As I mentioned in my email, we are working with Energy Trust to help understand and document the role Energy Trust and the

IMP have played in accelerating irrigation modernization projects and bringing about the hydroelectric generation and energy savings associated with those projects. We wanted to speak with you so we could get a better understanding of the program and hear about your experience with irrigation modernization. Do you have any questions before we begin?

I will be taking notes as we talk. Do you mind if I also record our conversation, just to help with my notetaking? We won't share the recording with anyone, and we won't report anything in a way that would identify individual respondents.

Program Operations

Q1. What is your role with regard to the IMP?

a. How long have you been in that role?

b. Were you involved with the program before you came into that role? If so, how?

Q2. I understand that Energy Trust had been working with irrigation districts before the current iteration of the IMP launched in 2015. How is the current program different from those earlier efforts?

a. [*If not addressed:*] I understand the current program grew out of a study the FCA did for Energy Trust in 2013. What were the key lessons from that study that informed the current IMP?

Q3. How, if at all, has the program changed since it launched in 2015?

a. What motivated those changes?

Q4. I understand irrigation modernization projects can take different forms, depending on the conditions and needs of the district. From your perspective, what are the key elements that define irrigation modernization?

Q5. Please take me through the process of working with an irrigation district. What are the steps to modernization, and how does the program help?

a. What parts of the process do participants have to do on their own?

b. Which steps are the most challenging for participants?

c. What are the main indicators along the way that a participant is making progress?

d. How, if at all, does the program track those indicators?

Q6. I understand the program leverages a variety of different funding sources. Which funders are involved in each step of the process?

a. How important are each of those funding sources in irrigation modernization projects' ability to move forward?

b. What requirements do irrigation districts have to meet to receive funding from each of those sources?

c. How easy or hard is it for irrigation districts to meet those requirements? Why do you say that?

d. How does irrigation modernization contribute to the missions of the organizations providing that funding? [*If needed:*] What benefits of modernization are they most interested in?

e. How, if at all, has Energy Trust or FCA worked with those organizations, beyond leveraging their funding for individual projects? [*If needed:*] What efforts, if any, have there been to coordinate offerings between the IMP and these organizations?

Motivations and Barriers

Q7. I understand about 30 districts are working with the program at various stages in the modernization process. How do the ways different districts approach modernization and work with the program differ?

a. [*If not addressed:*] How, if at all, did the districts' motivations differ? How were they similar?

b. [*If not addressed:*] How, if at all, did the challenges each district faced along the way differ? How were they similar?

Q8. Thinking about the irrigation districts that the program has worked with, what characteristics have been important in allowing districts to successfully modernize?

Q9. What do you see as the greatest barriers preventing irrigation modernization?

Q10. How does the IMP address those barriers?

Market Transformation

Q11. What would need to change for more districts to modernize without IMP's help?

a. How could those changes come about?

b. [If not addressed:] Do you see potential for the program to bring about those changes?

c. [If so:] How do you anticipate program activities will lead to those changes?

Q12. Have you seen any shifts in awareness of, or interest in, modernization among irrigation districts?

a. [If so:] What do you think is leading to those shifts?

Q13. How did FCA work with Energy Trust before the launch of the IMP?

a. What, if anything, was FCA doing to promote irrigation modernization independent of Energy Trust before the launch of the IMP?

b. What other partners, if any, were involved in that work?

Q14. What has Energy Trust funding allowed FCA to do through the IMP that it wasn't able to do previously? [*If needed, probe:* Did Energy Trust funding allow FCA to offer support it had not previously offered? Did Energy Trust funding allow FCA to offer support to more irrigation districts?]

a. Are those changes something FCA would have pursued if it had not been involved with Energy Trust?

b. [*If so:*] How might those activities have been different if Energy Trust funding had not been available? [*If needed:* For example, would their scale have been different? Would their focus have been different?]

c. Are there other potential funders that would be likely to support those changes? If so, who are they?

d. [*If other funders:*] How likely is it that FCA would have been able to access funding from those sources?

e. [*If other funders:*] What priorities or requirements do those funders have that might lead FCA to approach irrigation modernization differently?

Q15. [*If not addressed:*] To what extent would FCA be able to help irrigation districts access outside funding sources without Energy Trust's support?

a. How might the support FCA provides be different if Energy Trust funding were not available?

b. How likely is it that irrigation districts would be able to able to access that funding with that level of support?

Q16. What other organizations promote irrigation modernization?

a. How do their offerings differ from the IMP?

b. How does the IMP coordinate with those organizations?

Q17. I have seen estimates of energy savings associated with irrigation modernization projects in some of the documents Energy Trust shared with us. Can you tell me more about the source of those estimates?

a. [*If not addressed:*] Are those estimates of savings from eliminating or reducing the need for pumping on farms? Do they include any other sources of energy savings? If so, what?

b. [*If not addressed:*] Are those estimates based on a per-acre energy usage estimate? A per gallon pumped estimate? Something else? What is the source of those estimates?

Q18. What other organizations or experts should we talk with that can provide further insights into irrigation modernization?

a. Are there any specific market research or reports that you view as essential to understanding irrigation modernization, it's current state in the market and its market potential?

Q19. Those are all the questions I have prepared. Is there anything we haven't discussed that you think I should know as we move forward with our research? Are there any other questions I should be asking people?

Irrigation District Interview Guide

Introduction

Thank you for taking the time to speak with me today. As I mentioned in my email, we are working with Energy Trust of Oregon, which is one of the funders of FCA's Irrigation Modernization Program. Our research will help Energy Trust understand the role the program has played in bringing about irrigation modernization projects. We wanted to hear from irrigation districts to understand how you think about irrigation modernization opportunities and hear any feedback you have about Energy Trust and FCA's efforts. Do you have any questions for me before we get started?

I'll be taking notes as we talk. Would it be OK if I also record our conversation? The recording is just to help with my notetaking. We won't share it with anyone or report anything in a way that would identify individual respondents.

Background

Q1. First, as background, what are the most important things I should understand about your irrigation district? [*If needed, probe:*] How big is it (irrigated acres)? How many water users does it serve? What types of users (large farms or small, ranches or row crops, etc.)? What is the typical irrigation season?

Q2. And what is your role in the district?

a. How long have you been in that role?

Modernization Support

Now I'd like to talk about any irrigation modernization improvements that your district has made or considered. When we talk about irrigation modernization, we are talking, broadly, about proactively making improvements that will improve the irrigation system's performance and efficiency to meet the goals of the district and its community. Modernization improvements might include moving from open canals to pressurized pipes, improving monitoring and control capabilities, adding hydroelectric generation, or other things.

Q3. [*Participants:*] When did your district start working with FCA to explore opportunities to modernize your system?

Q4. [*Participants:*] What motivated you to start working with FCA at that time?

Q5. [*Participants:*] Were you aware of the opportunities to modernize your system before you started working with FCA?

a. How did you learn about them?

b. Had you taken any steps to make modernization improvements before you started working with FCA?

c. [*If not:*] Why hadn't you pursued those opportunities?

Q6. [*Non-Participants:*] What opportunities, if any, are you aware of to modernize your system?

a. How did you learn about them?

b. What steps, if any, have you taken to plan for or make those improvements?

c. [*If none:*] Why haven't you taken steps to make those improvements?

Q7. [*All:*] When you think about modernization improvements, what are the most important benefits your district would hope to gain from those improvements?

a. Are those benefits something that you can/would be able to measure?

b. What metrics would you use to measure those benefits?

Q8. [*Participants, non-participants if they have taken steps to modernize:*] At what stage in the process of identifying, planning, and implementing modernization improvements is your district?

a. When did you begin the process?

b. How easy or difficult has it been to work through the modernization process so far, [*Participants:*] with FCA's support?

c. What has been the most challenging aspect of the modernization process?

Q9. [*All:*] What are the next steps for you to continue the process of modernizing your system?

a. How well do you understand what you need to do next to move your project forward?

b. What resources do you need to complete the next stage in your project?

c. Do you have those resources? [*If not:*] How confident are you that you will be able access them? Why do you say that?

d. What do you anticipate will be the biggest challenges with those next steps?

Q10. [*All:*] What internal stakeholders' support did/would you need to gain in order to pursue modernization improvements?

a. How easy or difficult was it/would it be to gain their support?

b. What were/would be their main concerns about pursuing a modernization project?

c. How would you/were you able to overcome those concerns?

Q11. [*All:*] What external stakeholders' support did/would you need to make modernization improvements?

a. How easy or difficult was it/would it be to gain their support?

b. What were/would be their main concerns about a modernization project?

c. How would/were you able to overcome their concerns?

Q12. [*Non-participants:*] What organizations have you worked with, or considered working with, on irrigation modernization projects?

Q13. [*Non-participants:*] Are you familiar with the Farmers' Conservation Alliance and the support they offer for irrigation modernization?

a. [*If yes:*] Have you considered working with FCA to modernize your system?

b. [*If familiar with FCA:*] Why aren't you working with FCA to modernize your district?

c. [*If familiar with FCA:*] Under what circumstances might you consider working with FCA?

Q14. [*Participants:*] What aspects of the support you received from FCA have been most important in allowing you to move forward with you modernization project? Why do you say that?

Q15. [*Participants, non-participants if they have taken steps to modernize:*] Other than FCA, what funding or support have you applied for or used to modernize your system since 2015? [*For each source, probe:*]

a. What part of the modernization process did that funding support?

b. What requirements did you have to meet to access that funding or support?

c. How easy or difficult was it to meet those requirements?

d. [*Participants:*] How important was FCA's support in enabling you to meet those requirements?

Hydro Generation

Q16. [*Participants, non-participants if they have taken steps to modernize:*] Have you installed, or are you planning to install, any hydroelectric generation as part of your current/recent modernization project? [*Note: We are interested in generation installed recently (e.g. since 2000), not long-standing equipment.*]

a. [*If not:*] Why not?

b. [*If so:*] What do you see as the greatest benefits of hydro generation for your district?

c. [*If so:*] At what stage in the project did you/do you plan to install hydro generation? Why?

d. [*If so:*] What were the greatest challenges around installing the hydroelectric generation?

Q17. [*Non-participants:*] Were you aware that there can be an opportunity to install hydro electric generation when you pipe and pressurize an irrigation system?

a. [*If yes:*] From your perspective, what would be the most important benefits from installing hydro generation on your system?

b. How important are those benefits when you think about potentially undertaking a modernization project?

Closing

Q18. [*Participating:*] Based on your experience with irrigation modernization projects, what advice would you give to other irrigation districts considering modernization projects?

a. Are there any characteristics or resources that your district has that have been particularly important in allowing you to complete your modernization project? What are they?

Q19. Those are all the questions I have prepared. Is there anything we haven't discussed that you think it is important for me to know about irrigation modernization or Energy Trust and FCA's role in supporting it?

Funder & Stakeholder Interview Guide

Introduction

Thank you for taking the time to speak with me today. As I mentioned in my email, we are working with Energy Trust of Oregon to help document the Irrigation Modernization Program. Energy Trust provides FCA with funding to support the program, and our research hopes to understand the role the program has played in bringing about irrigation modernization projects. We wanted to hear from people like you who [also support irrigation modernization projects/have expertise in irrigation modernization] to get a better understanding of the irrigation modernization landscape and hear any feedback you have about Energy Trust and FCA's efforts. Do you have any questions for me before we get started?

I'll be taking notes as we talk. Would it be OK if I also record our conversation? The recording is just to help with my notetaking. We won't share it with anyone or report anything in a way that would identify individual respondents.

Background

Q1. To start with, I want to make sure we're clear about what we mean by irrigation modernization. When we talk about irrigation modernization, we are talking, broadly, about proactively making improvements that will improve an irrigation system's performance and efficiency to meet the goals of an irrigation district and its community. Modernization improvements might include moving from open canals to pressurized pipes, improving monitoring and control capabilities, adding hydroelectric

generation, or other things. Is that consistent with the way you think about irrigation modernization?

   a. [*If not:*] How is the way you approach irrigation modernization different?

Q2. [*If not already clear:*] First, please tell me a little bit about your organization and how irrigation modernization fits into your larger mission.

Q3. And what is your role, both in the organization and with regard to its irrigation modernization work?

   a. How long have you been in that role?

   b. Were you involved in irrigation modernization before you came into that role? If so, how?

Modernization Support

Q4. What does your organization do to support irrigation modernization projects? [*Probe to understand what phase of the project support targets.*]

   a. When did your organization begin offering that type of support?

   b. What motivated your organization to start supporting irrigation modernization projects at that time?

Q5. From your organization's perspective, what are the most important benefits of irrigation modernization upgrades?

   a. What metrics, if any, do you track to measure those benefits?

   b. How do you get the data to assess those metrics?

Q6. What requirements do irrigation districts need to meet to receive the support that your organization offers?

   a. How easy or difficult is it for them to meet those requirements? Why do you say that?

   b. Which requirements are most difficult to meet? Why?

Q7. What additional support, beyond what your organization provides, do irrigation districts typically need to complete irrigation modernization projects?

   a. [*If not addressed:*] What support do they typically need to meet your organization's requirements for funding or support?

   b. [*If not addressed:*] What support do they typically need to complete modernization projects after receiving the support your organization provides?

   c. Where do irrigation districts typically find that type of support?

Awareness and Barriers

Q8. What are the most important barriers and reasons that prevent more irrigation districts from modernizing their systems?

a. What type of support do districts need to overcome those barriers?

b. Do you see a scenario in which irrigation districts would undertake modernization projects without significant outside support? If not, why not? If so, what would need to change for that to happen?

Q9. To what extent are irrigation districts aware of the opportunities and benefits of modernizing their systems?

Q10. What are the most important motivators for irrigation districts to complete modernization projects?

a. What might trigger an irrigation district to consider a modernization project? What are the consequences if they don't modernize?

b. What benefits would be most important in leading them to move forward with that project?

Q11. Based on your experience with irrigation modernization projects, what characteristics or resources that a district might have are most important in allowing them to successfully complete modernization projects?

Q12. How has uptake of irrigation modernization projects changed over time? [*If needed:*] Are you seeing more interest in irrigation modernization now than you did in the past?

a. Why do you think that is?

Q13. How do you anticipate uptake of irrigation modernization projects will change going forward? Why do you say that?

a. What market trends or events might impact investment in irrigation modernization projects, either bringing about more projects or making projects more difficult? [*Probe to distinguish between short term trends (next 2 years) and longer-term trends (3 years or longer)*]

b. How could organizations that promote irrigation modernization respond to those trends to take advantage of positive trends and/or mitigate the effects of negative trends?

Role of IMP

Q14. Are you familiar with the project development support that Energy Trust provides through the Irrigation Modernization Program, which FCA delivers?

Q15. From your perspective, how important is that support in allowing irrigation modernization projects to move forward? Why do you say that?

Q16. How, if at all, has your organization coordinated with FCA and Energy Trust on irrigation modernization?

Q17. How, if at all, has your organization adapted the support you provide for irrigation modernization as a result of the Energy Trust and FCA program?

Q18. What impact do you think the Energy Trust and FCA program have had on the number of projects you have been able to support?

a. What about the size of those projects – how, if at all, has Energy Trust's program influenced the dollar amount of support you have provided?

Measurement of Energy Savings

Q19. What metrics does your organization track about the outcomes of the irrigation modernization projects you support?

a. What data do you use to track those metrics? How do you obtain it?

Q20. Does your organization estimate energy savings or any other social, economic, or environmental benefits resulting from reduced on-farm pumping due to irrigation modernization?

a. [*If so:*] How do you generate those estimates? [*Probe for key inputs and their sources as well as methodologies; ask if any documentation of approach is available*]

Closing

Q21. Those are all the questions I have prepared. Is there anything we haven't discussed that you think it is important for me to know about irrigation modernization or Energy Trust and FCA's role in supporting it?