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Agricultural Irrigation Initiative: Overview

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) is an alliance funded by more than 140 Northwest utilities and energy efficiency organizations in Idaho, Oregon, Montana, and Washington working to accelerate the innovation and adoption of energy-efficient products, services, and practices in the Northwest. In 2011, NEEA launched the Agricultural Irrigation Initiative with the goal of reducing agricultural irrigation energy use by twenty percent by 2020, through a series of market activities to test and promote a product solution for center pivots that enabled integrated precision irrigation technology. The main activities that NEEA undertook between 2011 and 2014 included field demonstrations to test the product, some specific technology field tests, infrastructure support (data standards work), the development of a business case and economic modeling, and marketing and outreach.

NEEA discontinued funding this Initiative in 2014 with the hope that the market will continue to develop and refine the solutions identified through field demonstrations, data standards work, and collaborative work with industry stakeholders. NEEA will continue to monitor and scan the market and will engage if opportunities arise with which it can help on behalf of the region.

Mother Nature can trump the best planning. Circumstances such as frozen ground, hail, and heavy wind affected the results of the demonstrations in this Initiative, as did technology challenges (such as lack of communication standards, incompatibility of equipment, installation delays, and limited access to communication links). With such rich learning as a resource, this overview report and a series of eleven detailed reports addressing specific elements of the Agricultural Irrigation Initiative document NEEA's program context, design, and lessons learned, targeted to growers, vendors, and utilities. Together, these reports document the technical details and nuanced findings from three years of large-scale field demonstrations on seventy-four fields with twenty-two growers. These reports are rich in technical and market knowledge and can accelerate the agricultural industry's adoption of more efficient uses of water and resources. All of these reports are available at http://neea.org/reports.

1. Introduction

1.1. Agricultural Irrigation Initiative Purpose

The Northwest Energy Efficiency Alliance's (NEEA's) Agricultural Irrigation Initiative proposed to accelerate agricultural energy efficiency savings opportunities in the Northwest as identified in the Northwest Power and Planning Council's (NPPC's) Sixth Power Plan (NPPC 2010). NEEA set an external goal, developed by and supported across the regional grower community, of reducing agricultural irrigation energy use by twenty percent by 2020. The objective of the Initiative was to deliver easy-to-use, integrated agricultural irrigation energy efficiency solutions. NEEA established an internal energy savings target for this Initiative of forty-two aMW.

Given the industry-specific and scientific natures of some terms used in this report, please refer to the AgGateway AgGlossary (http://agglossary.org/wiki/index.php/main_page) for definitions.

1.1.1. NEEA Overview

NEEA works to accelerate the innovation and adoption of energy-efficient products, services, and practices in the Northwest. Market transformation is the strategic process of intervening in a market to create lasting change in market behavior by removing identified barriers and exploiting opportunities to accelerate the adoption of all cost-effective energy efficiency as a matter of standard practice.

NEEA's unique role in this process is to look to the future to find emerging opportunities and to create a path forward to make those opportunities a reality in the region. As NEEA tests and vets those emerging opportunities, it creates conditions for sustained market adoption, successful utility programs, and accelerated benefits for the end-use customer.

1.1.2. Agricultural Irrigation Initiative Overview

According to the Sixth Power Plan (NPCC 2010), agricultural irrigation uses eighty-five percent of the Northwest's agricultural electrical energy and five percent of the region's total electrical energy, which represents a $335 million annual electricity load. Reducing that load by twenty percent would result in an annual savings of $67 million.

NEEA has directly invested $2.6 million in this Initiative and leveraged more than $300,000 in donated equipment and resources through the four major activities[1] outlined below.

[1] The findings and conclusions in this report are based upon the results of these activities. Readers should consider the conclusions in this and all reports in this series advisory/directional rather than generalizable.

1. Demonstrations: Conducted field demonstrations for each product tier using the scientific method in order to identify energy savings and non-energy benefits such as increased yield and water savings. The Initiative focused on demonstrating integrated solutions with three main irrigation delivery systems:
    - Precision Flat Rate irrigation (PFR) – Uniform application of water across a field
    - Variable Speed Irrigation (VSI) – Varies water application by varying pivot speed
    - Variable Rate Irrigation (VRI) – Varies water application through pivot speed and individual sprinkler nozzle control
2. Data standards: Provided a common set of data standards through the Precision Ag Irrigation Leadership (PAIL) project to convert weather, soil moisture, and other relevant data from a variety of original equipment manufacturer (OEM) hardware and software programs into an industry-wide format for download and use by an irrigation data analysis and prescription program
3. Business cases: Developed a preliminary business case for growers to adopt the products, and a preliminary business case for vendors to sell and promote the products
4. Outreach and marketing: Developed awareness among industry stakeholders through presentation of results at industry meetings and conferences

The original target market for this Initiative focused on corporate and family growers farming one hundred or more acres, equipped with pressurized irrigation systems and characterized by center pivot systems. In addition, the Initiative demonstrations targeted growers with progressive relationships to technology, most likely "pioneers" or "early adopters," with the assumption that the technology would diffuse and find relevant application over time to a much broader spectrum of the market, including smaller farms and growers further down the technology adoption curve. Table 1 below provides information on acreage in the Northwest region under center pivot irrigation and potential energy savings.

Table 1. Center Pivot Irrigated Acreage with Estimated Energy Savings

Region 17 Pacific Northwest	
Total center pivot irrigated acreage (factoring out <100 acre farms)*	2,848,470
Estimated farms based on total acreage	5,038
Average # farms or managers	814
Average # acres/manager (or farm)	3,500
Total energy load for irrigation in aMW (per the Sixth Power Plan)	645
Total energy load for center pivot irrigation (≥100 acres) in aMW (per the Sixth Power Plan)	268
Savings estimate	20%
Energy savings estimate in aMW	54[2]

[2] NEEA further discounted this early savings estimate to 42 aMW for its internal savings estimate.

Figure 1 shows an example of the primary technology upon which NEEA based the goals of this Initiative: a typical center pivot used for irrigation. Figure 2 shows an aerial image of fields irrigated by center pivots. The *Overview of Center Pivot Irrigation Systems* report provides information on how center pivots work.

Figure 1. Center Pivot Used for Irrigation

Figure 2. Center Pivot Irrigated Crop Circles

1.1.3. Context

New techniques and data are available to assist growers in making precise decisions about irrigating a given field. NEEA believes that the integration of data from current weather systems, moisture sensors, and soil mapping techniques, in conjunction with optimal irrigation management, will yield both higher profitability and lower energy costs for growers. The integrated use of these technologies would provide an exact analysis and facilitate recommendations for when, where, and how much water to apply, defined as "precision irrigation."

Additional benefits of precision irrigation include reduced labor, lower fertilizer and chemical intensity usage, improved crop uniformity and quality, and potentially increased yield.

NEEA's hypothesis for market transformation was that an integration of current and new irrigation efficiency technologies would provide an attractive value proposition to large growers worried about water availability, under pressure to reduce inputs (labor, fertilizers), and with the time demands of managing larger enterprise operations. Once these large growers demonstrated the benefits of water and energy reductions and the technologies dropped in price, growers with smaller farms would be attracted to the increased profit potential and would adopt the products, thus accelerating market adoption.

1.2. Initiative Background and History

NEEA conducted an industry stakeholder collaboration, visioning, and planning workshop on improving energy efficiencies in agriculture in Walla Walla, Washington on November 16-17, 2011. Twenty-two participants from NEEA's stakeholder community attended, including utilities, growers, manufacturers, universities, and vendors. The group identified barriers and opportunities and adopted the goal of reducing agricultural irrigation energy use by twenty percent by 2020.

1.2.1. Theory of Market Transformation

Starting with input received at the 2011 Walla Walla meeting, NEEA identified key market barriers as well as interventions that could encourage market adoption of precision irrigation solutions, summarized in Table 2.

Table 2. Overcoming Market Barriers

MARKET BARRIERS	INTERVENTIONS	OUTCOMES
▪ Lack of cost-effective, easy to use, integrated products ▪ Perceived lack of value for cost ▪ Lack of awareness and knowledge among growers and vendors of energy-efficient irrigation practices ▪ Cultural resistance to change	▪ Develop an easy-to-use, integrated solution ▪ Standardize definitions, tools and methodologies ▪ Prove the business case through accepted proof points ▪ Educate, train and/or certify growers and market actors to use integrated irrigation management systems	▪ Growers and market partners aware of and value integrated irrigation management products ▪ Products/services available and broadly adopted ▪ Agreed upon standards in use ▪ Growers and market partners have technical skills and expertise to use, sell, and support the product effectively

2. Overview of Report Series

A series of twelve reports thoroughly documents NEEA's experience gained through three years of market research, market activity, and demonstrations associated with its Agricultural Irrigation Initiative. The eleven reports in addition to this Overview report are briefly summarized below and are available at http://neea.org/reports.

1. The Future of Agricultural Irrigation
Demands for food for a growing population, climate change, and limited fresh water resources drive an increasing need for efficient use of agricultural water. What does the future hold for irrigation? This report provides an overview of the key technology and agronomic trends impacting irrigation in the Pacific Northwest. It outlines the regional and global forces that will drive changes in the region's irrigation practices and address the impact of precision agriculture. It provides a road map of current and emerging irrigation technologies, including next-generation technologies and irrigation management practices focused on economic optimization. Finally, it recommends strategies for guiding and accelerating development and adoption of precision irrigation technologies.

2. Overview of Center Pivot Irrigation Systems
Center pivots are an important method of irrigating farmland. They provide the largest amount of pressurized irrigation of acreage in the Pacific Northwest. This report provides a basic introduction and overview to center pivot systems, how they work, some of the basic interconnected elements, and their key components.

3. Soil Science and the Basics of Irrigation Management
Soil properties are critical to understanding how much water should be applied to a field of crops. However, soil science terminology and principles can be complex and a bit overwhelming to understand at first glance. For those who are not soil scientists, this report provides foundational concepts and definitions.

4. Irrigation Delivery Systems
Center pivot systems provide multiple means of delivering water to fields. This report describes the technologies and details the findings from demonstrations on three major precision irrigation delivery systems: Precision Flat Rate (PFR), Variable Speed Irrigation (VSI), and Variable Rate Irrigation (VRI). This report does not cover other irrigation delivery systems such as Low Energy Precision Application (LEPA) and Low Elevation Spray Application (LESA), drip, wheel line, or fixed.

5. Using Soil Electrical Conductivity Mapping for Precision Irrigation in the Columbia Basin
The more complex irrigation delivery systems, such as VSI and VRI, require accurate mapping of soil water-holding capacity as a critical input for determining an optimal irrigation schedule and approach. As NEEA conducted its demonstrations, it found inconsistent levels of performance and results. This report uncovers the mystery of why soil mapping performed well in some fields and not in others.

6. Instrumentation and Hardware Best Practices in Precision Agriculture
NEEA discovered a number of unanticipated challenges associated with efforts to integrate irrigation equipment into usable systems. This report offers actionable suggestions to irrigation dealers and manufacturers that can improve customer experiences, as well as suggestions to growers for successfully incorporating modern sensor and telemetry technologies into farm operations.

7. Pivot Evaluation Best Practices
NEEA assembled a team of experts to review existing center pivot evaluation methods and to organize a systematic process for evaluating pivot performance. This report introduces a range of evaluation methods for validating pivot performance and for diagnosing performance issues and defective components. It also provides suggestions to growers for cost-effective improvements based on subjective assessments of measured data.

8. Precision Water Application Test
A test of precision water application under field conditions, commonly known as a "catch-can test," can help the grower to determine how evenly water is being applied on a given field. The results of such tests have real implications for the efficiency of precision irrigation approaches such as VRI, which manages application of water by zones. This report describes the tests performed on the fields in NEEA's VRI demonstrations. Based on the results, the research team determined the smallest practical management zone size; this information will enable practical VRI designs and will define the limits of the VRI systems' precision.

9. Grower Experience
Market adoption of precision irrigation practices and technologies requires acceptance of and use by growers within the contexts of their farm operations and agronomic practices. While these technologies offer the promise of improved yield, with corresponding savings in energy and water costs, they also come with the burden of time and effort for the growers to implement. This report describes some qualitative findings that could inform future product and program design.

10. Data Exchange Standards
Precision irrigation is an information-intensive undertaking. Technology has come a long way in helping growers use data to irrigate their land more efficiently. Growers can invest in technologies such as soil mapping, installation of pumping plants and flow meters, soil sensors, and irrigation delivery strategies. However, few of these tools communicate effectively or efficiently with one another, especially between brands. This report describes work led by NEEA, with extensive assistance from the ag equipment manufacturers, in developing a set of data standards within the Precision Ag Irrigation Leadership (PAIL) project. The PAIL project enables data sharing among different components of an irrigation system by providing a common set of data standards. Of all the activities that NEEA commissioned during this Initiative, data standards have the greatest potential to increase energy efficiency because they promote adoption of all types of technology. Data standards will enable a large and lasting impact on energy efficiency in the irrigation industry efficiency.

11. Business Case, Economic Modeling, and Market Channel Improvements
Market adoption requires more than technology development. The industry must carefully analyze whether a market exists for the new solutions, and whether industry stakeholders (such as equipment manufacturers, irrigation consultants, and software service providers) see economic or other value in providing the solution. This report articulates the case for adoption of NEEA's Agricultural Irrigation Initiative solution by both growers and vendors. It identifies areas in the market channel that must be enhanced before integrated precision irrigation solutions can be successful in the market. It also examines whether using the precision irrigation solutions can reduce costs and lower energy usage, while providing higher profitability for growers. It provides an economic model specific to eastern Washington and Oregon, analyzing the dollar impact of investing in, and using, precision irrigation technologies.

3. Key Lessons Learned, Next Steps, Value of Findings

3.1. Lessons Learned

The findings from each of the topics covered in the reports summarized in the preceding section resulted in numerous detailed lessons learned. The key lessons learned across all reports are listed below by audience or market type.

3.1.1. For Growers

Regular pivot evaluation and maintenance is crucial

NEEA learned that few growers have a regular cadence for pivot and sensor calibration. This maintenance is a precursor for deeper efficiency and supports long equipment life and any upgrades. For more information, please see the *Pivot Evaluation Best Practices* report.

Not all soils are created equal, and one solution doesn't always meet the conditions of a particular field – Apparent electrical conductivity (EC_a) soil mapping isn't effective for all soils

EC_a soil mapping can be incredibly valuable as an input for precision irrigation; on the other hand, it is costly and can be inaccurate. NEEA discovered a simple and low-cost test to determine whether EC_a mapping is likely to work on a given field for specific soil types found in the Pacific Northwest. For more information, please see the *Using Soil Electrical Conductivity Mapping for Precision Irrigation in the Columbia Basin* report.

Solve connectivity issues first

All precision irrigation is reliant on good data connections, whether Internet, satellite, or line of sight radio communication. NEEA ran into all kinds of challenges implementing fully functional on-farm wireless networks, courtesy of both the natural world (extra tall-corn plants, birds, and so forth) and of technical issues related to wiring connections, signal strength, and other challenges around communication protocols. The presence or absence of a solid data connection at the start of the season can make or break a demonstration. For more information, please see the *Instrumentation and Hardware Best Practices in Precision Agriculture* report.

Precision irrigation requires IT proficiency

NEEA observed that the farming operations with in-house IT skillsets and aptitudes are able to troubleshoot, implement continuous improvements, and maximize the capabilities of precision irrigation technology. For more information, please see the *Business Case, Economic Modeling, and Market Channel Improvements* report.

3.1.2. For Vendors

Improve installation of new technologies

The occasions of technology installations offer vendors a critical point of contact with growers for building trust in their products or services and with the vendors themselves. NEEA identified many areas for improvement in the installation processes for many technologies, including the need to develop a shorter, easier process and to provide good documentation and support (know the audience, language, and their levels of IT expertise). For more information, please see the *Grower Experience* report and the *Instrumentation and Hardware Best Practices in Precision Agriculture* report.

Integrated solutions are the holy grail

While individual irrigation-related technologies can themselves substantially improve energy efficiency, the holistic approach of integrating all the various irrigation-related technologies holds the most promise for maximizing performance, profits, and impacts for growers and vendors alike. Integrated solutions include technologies from the pumps at the river to the emitters on the pivots, as well as all the instrumentation that monitors all the variables.

Vendors' continued collaborations to design and market integrated, easy-to-use solutions will improve the grower experience and help to accelerate market adoption. This developing vertical integration of the supply chain can be attributed to the creation of industry-wide data standards and their widespread adoption by the manufacturers. NEEA needs strong technical and business representation to make the standards widely applicable; its relationship with the PAIL project will be a key element in ensuring the successful integration of all the different technologies found in a precision ag operation. For more information, please see the *Data Exchange Standards* report.

Design controls so growers feel empowered

NEEA found that growers need to be empowered to maintain control over their irrigation systems and decisions. Technologies, solutions, and demonstrations must be tailored to ensure that the grower is in command. For more information, please see the *Grower Experience* report.

Right-size the management zone for "precise" precision irrigation

Designing irrigation prescriptions to accurately apply water in a field using Variable Rate Irrigation requires dividing the field into reasonable management zones. The NEEA research team led by OSU performed an extensive catch-can test, also called a precision water application test, to determine the realistic size and threshold for a management zone, which will facilitate the generation of more effective irrigation prescriptions. For more information, please see the *Precision Water Application Test* report.

3.1.3. For Utilities (and Other Organizations that Run Demonstrations)

Understand that available technology may still necessitate special considerations in implementation

NEEA's integrated solution relied on more than ten hardware and software applications that needed to interface effectively. Not all technologies performed as advertised, and sometimes they required field adjustments. Researchers can mitigate these challenges through actions such as using multiple brands of equipment for a given function, isolating demonstrations of individual technologies, and conducting demonstrations on smaller pivots. Detailed information on demonstration findings that unveiled these challenges is available in the *Irrigation Delivery Systems* report.

Adjust timeline to begin demonstration sooner

Through this Initiative, NEEA learned how to schedule planning, contracts, and decisions to work within the natural cycles that drive all agricultural work, including planting, harvest, and preparation. Ideally, NEEA would develop contracts or agreements in the summer prior to the following growing season, then recruit growers with the assistance of utilities for demonstrations in the fall, incorporating appropriate contractual agreements and relationship-building. This would allow the demonstrations to run for the entire next growing season(s) with all systems working properly from the beginning of the season.

Earning grower trust differs from other markets

Growers have unique motivations and barriers to adopting energy-efficient technology. NEEA learned first-hand the importance of building personal trust within grower communities when working to accelerate the adoption of a new product. Developing this trust is key to working effectively within the grower culture. Regional utilities with strong local customer relationships can be NEEA's biggest ally in building this trust.

Determine plan to measure energy savings at the outset

NEEA has not yet demonstrated a cost-effective, reliable way of measuring water and energy savings in complex, variable agricultural systems such as a large center pivot operation. Recommendations for future work include development of a vetted, pre-season plan with both primary and backup savings measurement processes. This is challenging work for which solutions must be developed and deployed.

Grower technology adoption is slower than that in other industries

NEEA learned that growers (even early adopters and pioneers) take a minimum of three years to adopt a new technology – the first year for watching other case studies, the second for trying a small demonstration, and the third for scaling to include multiple pivots. This duration affects the length of time necessary to conduct a demonstration, the realistic objectives for one growing season, and the time span for scaling a utility incentive program. If demonstrations don't go as planned, the length of time until adoption can stretch out even further.

Precision agriculture requires innovative incentives

NEEA observed that growers (as customers) are not price-sensitive in the same way that a residential customer would respond to an incentive for an energy efficient refrigerator. While cost is a consideration, complexity, ease of use, and yield are big drivers for growers' considerations of a complex pivot system upgrade. The role and impact of long-term prescriptive utility incentives is unclear. Some early findings and anecdotal information point to possible upstream incentives through retailers, and potential deep impacts through training and rewards offered by vendors.

3.2. Accomplishments and Next Steps

3.2.1. Data Standards

NEEA brought together industry stakeholders to develop an agreed-upon set of data standards for the transmission of data necessary to develop, execute, and record a precision irrigation plan. Together with NEEA, the industry stakeholders initiated a data standards development project called Precision Ag Irrigation Leadership (PAIL) within AgGateway, a national organization devoted to e-business in agriculture. Highlights of accomplishments include:

- Recruiting the two pivot manufacturers that represent more than sixty-five percent of the market
- Achieving broad participation in PAIL from pivot manufacturers, instrumentation (such as that used for soil, weather, and data logging), data warehousing, decision support systems and numerous ag industry leaders
- Transitioning Phase One of the data standards work to the American Society of Agricultural and Biological Engineers (ASABE), the organization that will house, maintain, and promote the standards while maintaining the development and promotion activities of the AgGateway organization
- Proving the efficacy and completeness of the data standards through industry-supported field trials
- Inspiring new products and partnerships within the precision irrigation industry

This work will continue through funding from NEEA Codes and Standards. NEEA will evaluate it for impact and results on a regular basis.

3.2.2. Pivot Evaluation

NEEA's team has identified potential opportunities for creating savings by improving the state of the art for pivot evaluations. Pivot evaluation is the practice of performing quality control on all of the components of a pivot system to ensure that the system is running to manufacturer specifications and that the components are working properly together.

- Not all pivot systems perform as specified or designed, which leads growers to overwater (potential opportunity)
- The use of pivot evaluations could potentially drive significant energy savings in the region (possible intervention)
- Utilities could use pivot evaluations as a way to obtain deeper energy savings; they could leverage their existing programs with the inclusion of a method such as this

This research will continue at NEEA in the Emerging Technology group, with the scope yet to be defined.

3.3. Value of Findings

NEEA's 2012-2014 demonstrations did not provide enough specific, quantifiable energy reduction data to create a proven product for a utility incentive program. Challenges included problems isolating the energy usage impact to a single pivot or field, and difficulties obtaining confidential energy usage data for specific farms. However, noting actions such as reducing the number of pivot turns allowed NEEA to estimate the potential energy savings of each of the three precision irrigation delivery systems.

NEEA has demonstrated the existence of an opportunity to save energy and water in the agricultural irrigation sector through more precise irrigation practices. However, many of the technologies are not yet mature enough for market introduction of a fully-integrated system. NEEA's support of the data standards development work will help to provide the necessary infrastructure for future market intervention opportunities. For the near term, NEEA has discovered some potential interventions, such as regular evaluations of pivot systems, that may present solid opportunities for utilities to engage with growers and to help them achieve higher levels of energy efficiency.

4. Conclusions

The climate for precision irrigation is rapidly changing, and industry is responding to the new needs and demands. NEEA believes that the need for continued innovation and efficiency improvements will remain. Frequently drought-stricken markets such as California and Australia can be prime exemplars to the Northwest in demonstrating precision irrigation solutions.

NEEA established that growers require at least three years to test and adopt new technologies. The Northwest has the opportunity to invest in testing, refining, and promoting regionally-appropriate precision irrigation technologies many years prior to the actual need for the efficiency promised by the new technologies. This expanding industry requires collaboration among competitors, shared risk, shared learning, and experimentation. While the three-year NEEA Agricultural Irrigation Initiative has ended, NEEA will continue to scan, research, and fund agricultural energy efficiency opportunities.

NEEA welcomes ideas!
Unsolicited proposals can be sent to http://neea.org/get-involved/submit-your-idea

5. References

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