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Explaining the Dynamics of Transition to an Integrated WEF System: Two Cases of Irrigated Agriculture in Oregon, USA

Patricia Fernandez-Guajardo[1] & Edward P. Weber[2]

[1] University of Monterrey, Nuevo Leon, Mexico

[2] Oregon State University, Oregon, USA

Correspondence: Edward P. Weber, Oregon State University, Oregon, USA. E-mail: Edward.weber@oregonstate.edu

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Abstract

In recent years, the integrated Water-Energy-Food (WEF) Nexus approach has gained traction as a more effective way to manage these interdependent and essential resources. A growing number of traditional food and water irrigation systems in Oregon, USA are transitioning to modernized, holistic, and sustainable Hydro-Irrigation-Restoration Systems that embrace the WEF Nexus approach (Weber 2017). The question is: what factors explain the successful transition? Two cases of irrigation modernization in Hood River, Oregon demonstrate that system transitions follow a pattern of socio-technical change wherein four structural factors are key: economic incentives, changing values expressed in regulations**,** technological innovation, and external shocks (*e.g.*, major disasters). Yet, while the structural variables associated with the social-technical change approach are necessary for explaining the transitions to new WEF systems in Hood River, they are not sufficient. The case studies display the crucial importance of individual agency, or the actor dynamics capable of enabling or hindering system transformations (see Van Driel and Schot 2005, 54). Chief among these "agency" factors are (1) facilitative, visionary, trust-worthy leadership, (2) the cultivation of trust and collaborative problem-solving capacity, (3) the willingness to embrace risk and trade short-term costs for the potential of long term gains (e.g., low discount rates), and (4) the adoption of a new set of ideas, or shared norms, governing decision-making which embraced the idea that an integrated, modernized system could simultaneously promote economic, environmental, and energy sustainability.

Keywords: socio-technical transition, irrigation modernization, water-energy-food nexus, sustainability, system change

1. Introduction

In recent years, especially since the World Economic Forum of 2011, the Water-Energy-Food Nexus (WEF) approach has gained recognition as a more sustainable way of managing these resources that are essential for human life. The nexus approach acknowledges that each element is needed for generating or providing the others, thus integrated management is required in order to increase efficiency, reduce trade-offs across sectors, and promote long-term sustainability (Bazilian, et al., 2011; Endo, Tsurita, Burnett, & Orencio, 2017; Ernst & Preston, 2017; Fernandez-Guardado, Weber & Seales, 2023 ; Hellegers et al., 2008; Hoff, 2011).

Traditional irrigated agriculture in the US West is a good example of water and food systems that fail the WEF Nexus test. Designed with food and water as the primary foci; energy was an afterthought and technologies limited—open canals and gravity flow irrigation schemes--given the systems were first employed in the late 1800s and early 1900s. The end result is large, often massive, water losses (22% on average in the US West), low stream flows with warm temperatures harmful to fish and riparian zones, high energy costs from pumping water, and water reliability issues, especially in dry years when junior water rights holders risk not getting their water share. In addition, irrigation system management has become more complicated in recent decades due to regulatory restrictions on water flows stemming from the federal Endangered Species Act (ESA, 1973) and the Clean Water Act (CWA, 1972), while climate change threatens more water scarcity as well as changing precipitation patterns challenging effective irrigation system operations.

In response to this multi-faceted wicked problem, and in an attempt to integrate the water, energy and food functions into an integrated, more efficient and sustainable whole, some farming communities in Oregon, USA have started modernizing their infrastructure into Hydro-Irrigation-Restoration Systems (Weber 2017). And while Oregon is the undisputed leader in these endeavors, only seven such integrated systems have been, or are being, built, and 43 more are in various phases of the planning process as of 2023 (FCA 2023).

It is clear that the promise of successfully integrating traditional irrigation systems such that long-term, more efficient/productive, and sustainable economic and environmental systems result is exciting. Yet it is also arguably an order of magnitude more difficult than managing water, energy and food sectors in isolation. This is because the transition to an integrated system requires massive change, or what Geels and Schot (2010) call a "radical shift" in the existing resource management regime. The shift includes not only technical innovations and their adoption, but also changes in institutions, perceptions, culture and, in general, the way we think about and utilize resources (Geels & Schot, 2010; Markard, Raven & Truffer, 2012). The problem is that institutions, perceptions and culture are "sticky/slow to change" given they are grounded in "shared beliefs and discourses, power relations, and political lobbying by incumbents" that are vested in, and favor, the status quo. At the same time, existing systems are often dominated by "lock-in mechanisms" that create stability and inertia in the system (*e.g.* sunk investments in technology or infrastructure) (Geels, 2011, p. 25).

How can such a transition be managed? What factors might drive stakeholders in an existing food-and-water-only system to take the necessary decisions to radically transform their system into an integrated whole capable of delivering on the promise of long-term environmental and economic sustainability? To study this puzzle we focus on two cases of irrigation modernization in the Hood River Valley of Oregon (USA). Starting in the 1980s, the FID and MFID started transitioning their traditional 100+ year old water and food-based irrigation systems into integrated Hydro-Irrigation-Restoration Systems (Weber 2017). These new integrated WEF Systems, largely completed by 2019**,** replaced open, leaky canals with closed conduits, incorporated small, low impact run-of-river hydropower plants, designed and implemented innovative fish screens, increased water efficiency by almost 100%, dedicated significant new instream water rights for the sake of fish and ecosystems, created large and ongoing greenhouse gas reductions, and increased farms' economic viability by significantly reducing production and energy costs, while also increasing crop yields and water reliability (Fernandez-Guardado, Weber & Seales 2023).

Explaining why and how farmers adopted these successful new sustainable WEF systems in Hood River entails reliance on both structural and agency-based factors. In the first case, our empirical findings support studies on socio-technical change, wherein these two system transitions occurred due to the interactions among four structural factors are key: economic incentives, changing values expressed in regulations**,** technological innovation, and external shocks (*e.g.*, major disasters) (*e.g.* external shocks, such as macroeconomic crisis or major accidents) (Geels, 2002; Geels, Sovacool, Schwanen, & Sorrel, 2017; Van Driel & Schot, 2005).

Yet, while the structural variables associated with the social-technical change approach are necessary for explaining the transitions to new WEF systems in Hood River, they are not sufficient. The case studies display the crucial importance of individual agency, or the actor dynamics capable of enabling or hindering system transformations (see Van Driel & Schot 2005, 54). Our findings show that chief among these "agency" factors are facilitative, visionary, trust-worthy leadership (Rotmans & Loorbach 2009; Emerson & Nabatchi 2015), the cultivation of trust and collaborative problem-solving capacity (Weber, Lovrich & Gaffney 2007), the willingness to embrace risk and trade short-term costs for the potential of long term gains (e.g., low discount rates) (Sabatier et al. 2005, 182), and the adoption of a new set of ideas, or shared norms, governing decision-making that gradually expanded to a more holistic framing of "sustainability" that embraced the idea that an integrated, modernized system could simultaneously promote economic, environmental and energy sustainability (Weber 2003; Weber 2009).

2. Understanding Socio-Technical Transitions

In the field of transitions studies, a transition is defined as "a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms" (Rotmans, Kemp, & Van Asselt, 2001, p. 16). Such transition processes generally include changes and developments in different areas of a society (*e.g.* technology, economy and institutions) that mutually reinforce each other. That is why it is described as a "co-evolution" process (Geels & Schot, 2007). This transformation occurs over long periods, typically spanning one generation or more. Essentially, transitions involve a destabilization of the *status quo* (otherwise characterized by inertia and stability), a period of disruption (generally accompanied by the emergence of new technologies or "novelties") and the emergence of a new equilibrium (which includes the development of new social practices and norms) (Rotmans, Kemp, & Van Asselt, 2001).

The interest in how a new regime or new stabilization point emerges through technological change appeared first in the field of energy-related transitions. The earliest works in this field focused on understanding the technological changes that were making industries such as the automobile industry “greener” by moving away from hydrocarbon-based technologies (Kemp, 1994; Schot, 1992; Schot, Hoogma, & Elzen, 1994). The mutual influence between technological and societal change, which was already acknowledged in the earliest works, received even greater attention in subsequent studies, highlighting a “socio-technical” approach (see Markard, Raven & Truffer, 2012). Such “socio-technical transitions” frameworks are now applied to help understand changes in different fields such as energy, transportation, food industry, and the water sector. These transitions are generally oriented towards more sustainable ways of production and consumption as a response to current environmental pressures such as climate change (Markard, Raven, & Truffer, 2012).

Geels (2011) points to three characteristics of such “sustainability” transitions that differentiate them from other historical transitions. First, they aim to address relentless environmental problems. As has been widely noted, environmental problems are subject to “the tragedy of the commons” (Hardin, 1968), thus, private actors have little incentives to change. Second, in sustainability transitions, the best solution may not offer enough incentives for adoption under normal market conditions. Its implementation requires policy and institutional changes that create incentives for actors to change (like subsidies or regulations). Third, many of the existing systems in which such transitions are needed are dominated by “lock-in mechanisms” that create stability and inertia in the system (*e.g.* sunk investments in technology or infrastructure). There are also social elements that contribute to the stabilization of the system such as “shared beliefs and discourses, power relations, and political lobbying by incumbents” (Geels, 2011, p. 25). These mechanisms, coupled with the preferences and practices of established users and consumers, reinforce each other and make change difficult.

“Sustainability transitions” has become an umbrella concept that includes different analytical frameworks for studying how socio-technical transitions occur. Three of the main frameworks are: Strategic Niche Management (SNM), Multi-level perspective (MLP) and Transitions Management (TM) (Markard, Raven & Truffer, 2012). All these frameworks adopt a systemic approach; all consider transitions as a multi-level, multi-phase, long-term process; and all contend that technological innovations (which take place in *niches*) are essential, yet linked to broader social and institutional processes.

We could say, then, that at the base of the systems in which transitions happen there are resources (such as water resources), actors that use the resources (e.g. farmers), technology and knowledge to utilize the resource (material artifacts, for example, irrigation infrastructure), and the ways society uses that technology and resources (social practices linked with perceptions about the resource and technology), as well as rules and institutions created to provide a social function such as supplying water for irrigating agricultural crops (see Geels, 2004). In short, an effective socio-technical transition produces a “radical shift” in the regime (Geels & Schot, 2010), which includes not only technical innovations and their adoption, but also changes in institutions, perceptions, culture and, in general, the way we think about and utilize resources (Geels & Schot, 2010; Markard, Raven & Truffer, 2012).

Within the traditional western US irrigation system, the type of transition needed to advance a WEF nexus approach would be an example of a sustainability transition. It requires not only special technologies in water delivery and energy generation to capture the efficiencies and synergies and minimize the trade-offs among sectors, but also a shift from the dominant values and practices associated with the 100+ year-old segmented “water and food only” approach to irrigated agriculture to a new, more holistic worldview incorporating water, food *and* energy.

Yet, the heavy reliance on structural factors as the key to understanding socio-technical transitions may be necessary, but not sufficient to crafting a full explanation of why and how transitions occur. Within the larger literature there have been calls to increase the attention paid to the role of actors in influencing transitions pathways (see for example Markard, Raven & Truffer, 2012) and clarifying dynamics “between actors and institutional change” (Brown, Farrely & Loorbach, 2013, p. 701). Put differently, to fully understand the socio-technical transition process, “we need to follow the actors at the micro level and study how they carved out and negotiated a particular course” (Van Driel and Schot 2005, 54).

3. Research Methods

This is a comparative case study of two irrigation districts–Farmers (FID) and Middle Fork (MFID)--in Oregon’s Hood River Valley that are at different phases of the modernization process. The two cases, FID and MFID are instances of critical cases (Yin, 2014), as they are completed transitions.

Qualitative methods are employed to investigate the conditions under which transitions toward integrated hydro-irrigation-restoration systems occur. Primary data consisted of 33 semi-structured, in-person interviews conducted between April 11, 2018 and June 5, 2019, along with the review of primary documents associated with the irrigation district operations up through year 2021. Interviewees included members of the irrigation districts (current or former members of the Board of directors or managers) or from different stakeholders groups (*e.g.*, federal, state or local government agencies, the Native American Tribes present in the area, or water, environmental or energy-related organizations). This information was complemented with secondary data. Examples of these documents include irrigation districts' water management and conservation plans; documented histories of the districts; external evaluations of the hydropower projects; watershed assessments and action plans; conservation strategies; meeting minutes of the irrigation district, and reports on fisheries projects.

4. Background: Two Cases of Irrigation Modernization in the Hood River Basin

The Hood River basin, in north central Oregon, extends over an area of 482 square miles (U.S. Bureau of Reclamation, 2015). The basin's highest point is Mount Hood, where the three main tributaries of the Hood River are born, the East, the West and the Middle Fork. These tributaries are fed primarily by glaciers and are subject to recurrent damage such as landslides, debris flows and flooding (Coccoli, 2004).

Agriculture is the main economic activity in Hood River County. The main crop is pears, followed by "apples, cherries, peaches, blueberries, wine grapes, and grass hay" (Perkins, 2013, p. 6). There are five irrigation districts in the Hood River basin: Farmers Irrigation District (FID), Middle Fork Irrigation District (MFID), East Fork Irrigation District (EFID), Dee Irrigation District (DID), and Mount Hood Irrigation District (MHID).

Initial development of the FID and MFID irrigation systems occurred in the latter part of the 19th Century. The conveyance and distribution systems featured a combination of hand-dug ditches and open wooden canals. These systems were highly inefficient, with major water loss of roughly 50% due to evaporation and seepage, as well as regular overflows and interruption of water deliveries due to glacier-based debris flow (FID General Manager, personal communication). Further, farmers experienced significant energy-related operating costs given their need for electric pumps to move water within their orchards, while system vulnerability to yearly problems from land/mudslides, debris flows and flooding generate hundreds of thousands of dollars in annual maintenance and repair costs. By the early 1980s, the inefficient irrigation system, combined with price competition from expanding globalization that lowered agricultural prices, made Hood River farming less economically sustainable.

In response, FID and MFID decided to start transitioning their segmented "water and food" irrigation systems into integrated water, energy and food systems (see Table 1). They started by replacing their open canal systems with enclosed conduit pipes, using the natural fall in elevation to pressurize the water delivery system. Also included in these initial phases of modernization were the construction of new, small hydropower generating plants, which do not have dams or impoundments, and where water is returned to streams after passing through the plants or is otherwise used to irrigate crops, both made possible by the new enclosed pipelines that also resulted in pressurized water deliveries and water savings.

Modernization continued in the 1990s with the installation of innovative horizontal fish screens to replace ineffective vertical screens that had created compliance issues with Oregon's 1986 legislative rule designed to prevent harm to salmon and steelhead. The importance of the state-based fish protection rules, and the absolute need for approved fish screens, was strengthened further by federal ESA listings for salmon, steelhead and bullhead trout in the late 1990s.

The final element of irrigation modernization involved technological advances made possible by the digital revolution in the 2000s. Both FID and MFID took advantage by installing system-wide highly accurate digital measurement telemetry capable of monitoring flows from a computer (or smart phone), rather than moving from diversion to diversion to manually read flows. The new telemetry system included an alarm feature that would trigger and send warnings to FID managers when anomalies occurred, meaning system problems could be targeted and attended to promptly, ensuring restored flows much sooner than with the old system. And just like the new horizontal self-cleaning fish screens, telemetry reduced O&M costs, thus increasing available capital for system improvements (Bryan 2008; Fernandez-Guardado, Weber & Seales 2023).

The transition process toward modernized, integrated Hydro-Irrigation-Restoration Systems for both districts took roughly 30 years, with modernization almost 100% completed by 2019.

Table 1. System characteristics and components of modernization

	FID	**MFID**
Conveyance system size and characteristics	Over 60 miles. Over 99% in closed conduits. - Pressurized by gravity.	Over 60 miles. 100% in closed conduits. - Pressurized by gravity.
Hydropower generation	3 hydro generators - Combined capacity 4.8 MW - Uses water rights year-round	3 hydro generators - Combined capacity 3.3 MW - Uses water rights year-round.
Environment and Ecology	Reserved instream flows from water savings - Fish-friendly horizontal screens on all diversions - Meeting CWA temperature standards - Significant riparian zone restoration - Significant greenhouse gas emissions reductions	Reserved instream flows from water savings - Fish-friendly horizontal screens on all diversions - Meeting CWA temperature standards - Significant riparian zone restoration - Significant greenhouse gas emissions reductions
Digital Telemetry	Easier management, faster response times, high accuracy, improved water reliability	Easier management, faster response times, high accuracy, improved water reliability
Economics	Reduced energy costs - Increased revenues from (saved) water & hydropower sales - Reduced O&M costs - Increased crop productivity tied to pressurized delivery & higher water reliability	Reduced energy costs - Increased revenues from (saved) water & hydropower sales - Reduced O&M costs - Increased crop productivity tied to pressurized delivery & higher water reliability
Water Reliability	High certainty of delivery to *all* users even in dry years	High certainty of delivery to *all* users even in dry years

5. Results: Explaining the Transitions toward Integrated WEF Systems

The socio-technical transitions literature primary focus is on structural factors such as external shocks to a system (e.g., macroeconomic crisis, major accidents, natural disasters). More recently, however, scholars have called into question the ability of structural-based socio-technical explanations to fully explain system transitions. This more recent scholarship recognizes the necessity of "structure," yet argues that individual actors and their choices are also critical factors in explaining change.

5.1 The Importance of Structure

In the cases of FID and MFID irrigation modernization, the first part of the explanatory puzzle is comprised of four structural factors: 1) economic incentives; the search for efficiency, 2) the regulatory framework, 3) weather-related disasters, and 4) technological innovations.

5.1.1 Economic Incentives to Change

Unsurprisingly, economics were central to the Hood River Districts' decision to modernize their water delivery systems. First, the existing systems were highly inefficient open canals and laterals close to 100 years old, with roughly 50% of conveyed water lost through evaporation, seepage, and operational spills, which result from the need to "push" more water through the system than is actually needed due to the physics associated with delivering water through open canals to water users at the end of each ditch. Enclosing canals in pipes meant massive water savings. As a key actor involved in FID modernization stated:

> *The key factor [for modernization] was survival. The inefficient delivery of water to the irrigators really eroded security and reliability. [FID's] system was falling apart and being able to modernize that system ensured that they would be able to provide reliable water [deliveries]* (personal interview, 05/24/2018).

Second, the increasingly stiff price competition in the 1970s through 1990s from expanding globalization lowered agricultural prices for Hood River growers, making farming less sustainable. Third, the cost per kWh of electricity had more than doubled between 1980 and 1996, and predictions in the mid-1990s were for more of the same going forward (EIA 2023). Finally, adding small hydro generating plants to each water delivery system, while entailing significant investment and debt in the short-term, promised a new source of steady, long-term revenue that would keep growers' overall expenses down (interviews MFID1, MFID3). In the Middle Fork case, a stakeholder emphasizes that

> *The Middle Fork [Irrigation District] is trying to provide an adequate quality water supply to the growers at affordable costs. Which partly is the reason for the hydro. The district at the time needed quite a bit of updating its systems. And the cost would have been extremely prohibitive without the additional source of income that the hydro provided (interview MFID3).*

5.1.2 Regulatory Framework

Three parts of the overarching regulatory framework played important roles in pushing irrigation modernization in the Hood River forward. First, the 1978 Public Utility Regulatory Policy Act (PURPA) required utilities across the US to purchase energy at market prices from renewable generators smaller than 80 megawatts. This opened the door to the small hydropower plants in the FID and MFID since no plant generated more than 10 megawatts of hydropower.

> *If [PURPA] wasn't there, then the need to modernize wouldn't go away, but the ability to modernize would be hindered, because of the high cost of bringing these projects up to date, and putting that [cost] burden on the farmer is not feasible (interview MFID1).*

The small hydro plants for FID not only reduced irrigation district energy costs by more than 80%, the sale of excess electricity back to PacificCorp produces average annual revenue of almost $2M, which was used to retire the $12M debt from the initial modernization (through 1996) and is now used to pay down the more than $35M debt due to system modernization since 1996 (Perkins 2013; Fernandez-Guajardo, Weber & Seales 2023). In addition, once the debt is fully retired, the annual energy revenues become income for the Districts.

The second regulatory driver in the Hood River cases involved the 1973 federal Endangered Species Act (ESA). Massive declines, often 90% or more, of Columbia River Basin fisheries in the 20th Century eventually led to ESA listings for 13 salmon, trout, and steelhead stocks, including the Lower Columbia Steelhead (1998), Chinook (salmon, 1999), and Coho (salmon, 2005). Bull trout, also present in the Hood River, was listed as threatened in 1998 (Coccoli, 1999, p. 1). An ESA listing means that irrigation systems cannot allow fish into their canals or they will be subject to daily $25,000 fines for each count of "taking" or otherwise "harming" a fish. The problem for irrigators in such a situation is that traditional river diversions are just that; they are designed to divert the required amount of water without regard for what happens to fish. The strict liability of the ESA was central to the experimentation and development of the new fish-friendly Farmer's Screen for river diversion points (Perkins 2013; see Technology section). The late 1990s listings were also responsible for "bring[ing] people together…. [T]he folks up in Hood River were really already working together and trying to find solutions for how to support each other…. [T]he Endangered Species Act for sure [was a driver]. (interview FID12).

The final regulatory driver was the federal Clean Water Act (CWA), which sets water quality standards, including appropriate water temperatures for cold water species such as salmon, steelhead and trout. Using this authority, in 1998 the Oregon Department of Environmental Quality (ODEQ) listed several sections of the Hood River as being too warm and therefore out of compliance with the CWA (Hood River Watershed Group, 2002). Together with the ESA, it now became an imperative for irrigators to operate their systems with due care for protecting fish and wildlife habitat, thus adding to the pressure to transform their existing non-fish-friendly systems.

5.1.3 Opportunity from Crisis: Weather-related Disasters

"[D]ramatic triggering events" can provide powerful incentive for change (Emerson & Nabatchi, 2015, p. 47). Such external events typically involve extreme weather events such as droughts, floods, and landslides that disrupt and/or damage system operability (Emerson & Nabatchi, 2015; Jenkins-Smith, Nohrstedt, Weible, & Sabatier, 2014). In the FID case, the 1996 flood and mudslides that destroyed and/or severely damaged key parts of the water delivery system made clear the risks to water availability for growers and high maintenance costs associated with open canals. It also exposed the vulnerability of the small hydropower stations, and their ability to produce steady power and revenue, because the damage stopped the flow of water to the hydro stations.

Faced with the need to reconstruct the system, and coupled with pressure from state and federal agencies to incorporate fish friendly adaptations (see Regulatory Framework section), FID farmers and leaders seized the opportunity to convert the remaining 70% (52 of 73 miles) of their system to closed, pressurized pipes. Despite being expensive in the short-term, a full conversion would be the more cost-effective option over the long-term because buried pipes would alleviate, and even eliminate the grave risks and costs from extreme weather events, while also increasing hydropower, hydro revenues, and water reliability for growers (FID Meeting Minutes March 1996).

A weather-related event similar to the one that affected FID struck the MFID system in 2006. A major flood with debris and silt flow caused severe damage in numerous places. The event created an opportunity to rebuild the infrastructure, while also addressing critical issues related to fish and water quality (Perkins, 2013). MFID leadership took the same course as FID had 10 years earlier, find and commit the resources to enclosing the rest of the open canal system as soon as possible in order to create a foundation for long-term economic sustainability.

Further, the reconstruction works and the environmental concerns also created an opportunity for new collaborative efforts with USFS, USFWS and NMFS to create a long-term plan for environmental stewardship. The meetings with these federal agencies soon extended to state agencies ODFW and ODEQ, as well as the Confederated Tribes of Warm Springs (MFID, 2010). The coordinated work of this group resulted in the development of a Fisheries Management Plan, completed by 2010. It addressed issues of water quality, riparian zone health, minimum instream flows, and included measures for MFID to advance "improved, 'fish-friendly'… facilities" (MFID, 2010, p. 3). The Plan provided a guide for MFID to comply with federal ESA and CWA, while continuing to meet growers' water irrigation demands.

5.1.4 Technological Innovation

The role of technology is at the core of socio-technical transitions. Transitions typically involve a major development in the existing technology in a given sector or regime, which creates opportunities for change (Geels, 2002; Loorbach, 2010). In the FID and MFID cases, transformation into an integrated Hydro-Irrigation-Restoration System required new technology created through a years-long process of in-house innovation at FID.

The initial efforts to modernize irrigation diversions from Hood River in the 1980s and early 1990s involved the installation of conventional vertical fish screens to allow irrigation water to flow while keeping fish and debris out. The vertical screens, however, were plagued with problems, proving to be ineffective at protecting fish (they tended to suck in and harm fish) and unable to stop sediment and debris from entering the water delivery system, thus damaging both water flows and the fish screens. This led to additional labor for cleaning and maintenance, which meant economic losses to the districts and lower water reliability as water flows to crops and power generation had to be constantly interrupted for fish screen maintenance.

The 1996 flood in the FID system literally swept away all of their vertical fish screens, and with everyone knowing that several ESA listings for fish were imminent, FID embarked on a quest to create a new, more durable fish-friendly screen that protected fish, increased the reliability of water flows, kept out debris, and reduced maintenance costs. The result was the Farmers Screen, an innovative, horizontal fish screen technology with no moving parts that allows farmers to divert water from rivers without harming fish or trapping debris, while also reducing O&M costs by 95% (FCA 2018). Approved by NMFS and patented in 2006, the Farmers Screen technology has been installed at more than 50 locations in the US West as of 2023.

The MFID case is simpler. The proven success of the Farmers Screen, together with a well established trust-based relationship with FID leaders and growers in the Hood River Valley, convinced them to adopt and apply the new technology to their own diversions. In sum, without the horizontal fish screens, neither irrigation district would have completed the transition to the integrated hydro+irrigation+restoration system of today.

The final piece of technological innovation in irrigation system modernization capitalized on the digital revolution. This involved the system-wide installation of highly accurate digital measurement telemetry capable of monitoring flows from a computer (or smart phone), rather than moving from diversion to diversion to manually read flows. The new telemetry system included an alarm feature that would trigger and send warnings to FID managers when anomalies occurred, meaning system problems could be targeted and attended to promptly, ensuring restored flows much sooner than with the old system. And just like the new horizontal self-cleaning fish screens, telemetry reduced O&M costs, thus increasing available capital for system improvements (Fernandez-Guardado, Weber & Seals 2023; Bryan 2008).

5.2 The Role of Choices in System Transitions

Many irrigation districts in the State of Oregon encountered the same incentives for change and, as early as 1981, several other districts were considering adding small hydropower (FID Meeting Minutes, January & February 1981). Yet, all but one of the other districts rejected adding hydropower, along with the other key steps toward the modernized integrated Hydro-Irrigation-Restoration Model (see Weber 2017). Understanding this discrepancy in outcomes requires that we focus on the actors' behavior in the FID and MFID cases, because it is their choices that mediated between the incentives and the pressures for change described above. In short, the variables described below facilitated and sustained the socio-technical transition to modernized, integrated WEF system.

5.2.1 Facilitative, Visionary, Trust-worthy Leadership

Rotmans & Loorbach (2009) show that successful Socio-Technical Transitions require the presence of leaders with particular leadership traits—creative, visionary, and trust-worthy so that constructive problem-solving relationships can be built (see also Loorbach 2007; Taylor 2011). Weber and Khademian (2008) find that whenever complex problems cut across policy jurisdictions, thus requiring the engagement of multiple stakeholders, successful Collaborative Capacity Builders (CCBs) need good conflict resolution skills, a reputation as fair and honest, and the ability to build relationships and trust as well as champion the collective, positive sum, "common good" benefits for all involved (see also Emerson & Nabatchi, 2015). More than half the interviews show that FID and MFID managers and Boards of Directors displayed these characteristics throughout the process, starting in the 1980s with FID Manager Jerry Bryan.

> *Leadership within FID was very strong…. [Jerry] had some visionary thoughts on irrigation and conservation that are relatively unique not only in the Hood River Basin, but throughout the irrigation community in Oregon (interview FID15).*

Bryan's vision involved an overarching strategy designed to build relationships and trust with other stakeholders and focus FID on a new mission that believed that a positive sum environment *and* economy approach was best for the irrigators and the community writ large.

> *[Starting in the mid-80s] FID was openly, transparently working with the natural resource agencies. If not respected, we were at least granted a little bit more wiggle room [because] we were trying. A lot of people didn't trust us regardless because what irrigator invites fish agency people into a board meeting and swears to work together? … So there was a lot of mistrust, but … over time a lot of trust grew out of the fact that people found out we were sincere in wanting to save farmers and fish, and things started to grow from there…. [In fact,] [w]e used to have florescent green sticky notes all around the office that said, 'Think fish.' …[W]e wanted our crew, when they made their decision to get more water to an irrigator, we wanted them to be thinking about the implications for the fish… 'What does a fish need?' Isn't it fascinating that that provided insights that led to developing technologies like the [horizontal] fish screen and conserving water by piping. By striving to save the fish, protect the fish, enhance the fish, we also protected and enhanced irrigated agriculture (interview FID2).*

MFID experienced similar creative, constructive, and positive-sum-focused leadership. Crucial to their successful modernization process was "having a manager who has that vision and … getting all those stakeholders together. We [had] somebody [in Craig (manager)] who can communicate well, get the stakeholders together, find out what all the hurdles are and then … had a lot of patience and is willing to work through all of those different processes [with the many regulatory and natural resource agencies]" (MFID7). The MFID "engaged the broader community … [because] it's beneficial and it brings more value to both us and the watershed as a whole" (interview MFID1). In this way, "the [MFID] manager's "ability to network … [with] affected agencies, tribes and others has been critical in their success… [because] it helped them design projects, which not only could meet regulatory needs, but irrigation needs as well" (interview MFID9).

5.2.2 Risk and Low Discount Rates

A corollary to the facilitative leadership component involves the willingness of farmers and their leaders to embrace risk and trade short-term costs for the potential of long term gains (Sabatier et al. 2005, 182). This is the idea of low discount rates, wherein present benefits are considered only slightly more valuable than those obtained in the future, thus a low discount rate leads to a higher present value and an increased willingness to take on risk. In both cases, the decision to modernize—to add closed conduit pipes, new hydroelectric plants and fish screens, while also removing old diversion infrastructure—was risky. Moving ahead necessitated immediate increases in growers, or patrons, irrigation district fees and massive new debt totalling in the tens of millions of dollars for projects. In return, there was only the promise of a (1) medium-term (years later) positive impact on farmers' bottom lines—improved, more reliable water delivery, lower O&M costs, new energy generation revenues, and reduced energy costs, and (2) longer term (2+ decades) returns from retiring the debt and realizing millions of dollars of positive annual cash flow from hydropower production. In short, successful transitions toward sustainable management of the WEF nexus are more likely to occur when organizations and leaders are willing to take financial risk and trade short-term costs for long term gains (Rotmans & Loorbach, 2009).

5.2.3 The Cultivation of Trust and Collaborative Problem Solving Capacity

As both irrigation districts wrestled with the transition to modernization, they made it a point to engage frequently with major stakeholders, to practice transparency in decisions and communications, and to exemplify "good faith" in their bargaining and implementation efforts (Weber, Lovrich & Gaffney 2007). These actions were critical in transforming FID and MFID relationships with other stakeholders from one of distrust to trust by showing they had no hidden agendas and were full committed to problem solving strategies that were good for more than just farmers. In one key example, FID's process for securing hydropower rights during the 1980s was predicated on establishing cooperative relationships with state and federal natural resource and fish/wildlife agencies.

> *[In the 1980s] we, at Farmers Irrigation District were openly, transparently working with the natural resource agencies. So [at the beginning] there was a lot of mistrust, but over time a lot of trust grew out of the fact, when people found out that we were sincere in wanting to save farmers and fish, then things started to grow from there (interview FID2).*

Over at MFID, the same dynamic was occurring.

> *[MFID's] ability to network or get on board with affected agencies, tribes and others, has been critical in their success. ... It helped them design projects, which not only could meet regulatory needs or mechanisms, but it was also critically important for them to bring on the agencies' perspective (interview MFID9).*

Another example of how irrigators were willing to incorporate others' values involved the development of FID's Water Conservation and Management Plan in 1995. According to a member of FID, the plan displayed the kind of forward thinking not often associated with irrigated agriculture (interview FID9). In fact, "[FID's] plan fits perfectly with the goals, objectives and tasks outlined in the [broader, multi-stakeholder] 2008 Hood River Watershed Action Plan" (FID, 2011, p. Annex 2).

The fruits of trust-based relationships were also evident in the many projects carried out jointly with other stakeholders. Examples of these are minimum flows agreements and commitments to watershed restoration projects between the districts and Oregon's ODFW and ODEQ (Bryan, 2008, Perkins, 2013). As well, there was significant collaborative work between the Confederated Tribes of Warm Springs, both federal and state Fish and Wildlife agencies, and FID in the design, funding, development and testing of the innovative horizontal fish screen described earlier. Further, multi-sstakeholder. collaboration played a critical role in MFID's crafting of a Fisheries Management Plan, which proposed strategies that were decided using a consensus decision rule.

Finally, the collaborative forum provided by the Hood River Watershed Group brought stakeholders together to share information, to deliberate and discuss concerns, and to create awareness of just how entangled and connected the many economic, environmental and community issues were within the broader Hood River community. In short, the watershed group helped to forge new relationships that then were better able to find common ground (interviews FID6 & FID12).

5.2.4 Expanding the Core Ideas Underlying Irrigated Agriculture

Traditional irrigated agriculture in the US West built systems in which water quantity, or water as a commodity intimately connected to crop production, and hence farms' economic sustainability, was the core value. These core ideas, or shared norms, dominated decision-making (Wilkinson 1992). Yet, we find in the FID and MFID cases that the transition to a modernized system required the adoption of "new ideas or shared norms, for understanding public problems, the community itself, and the relationships among competing ideas, interests, actors, and sectors of society" (Weber 2009, p. 416). More specifically, the core ideas governing decision-making for FID and MFID gradually evolved, or expanded to a more holistic framing of "sustainability" that, while maintaining the focus on economics, also embraced the idea that an integrated, modernized system could simultaneously promote environmental and energy sustainability.

First, the synergies of the integrated, modernized system heightened attention to *efficient* water delivery resulting in water savings of over 50%. The "new" *system* surplus created room to address the key environmental protection goals of more water left instream, colder water more suitable to salmon, trout and steelhead, and improved habitat supportive of fish and other species. According to stakeholders, underlying this acceptance of environmentality "sustainability," or the willingness to share water with fish, was the belief that FID and MFID and their Boards of Directors were willing to be good stewards, "genuinely" concerned about water management that balanced concerns over quantity with those related to water quality and the idea of managing resources sustainably

In addition, and despite the overall politically conservative nature of the farmers involved, interviewees described them as having a 'progressive mind-set,' and as people who cared about the fish and wanted to protect their habitat. However, this 'fish-oriented' mindset seems to have evolved over time. According to a long time leader for FID, it took a long time for growers to realize that caring about fish might actually make good economic sense (Interview FID1). At the same time, as noted previously, interviewees also cited the pressure from federal and state regulations in shaping a pro-environmental ethic in the districts.

> *Over time [there] has developed [a] conservation ethic within the district, so now the revenues are important, but the conservation side is equally important. Some of that has to do with [environmental] regulations changing over time and the public perceptions changing over time. People are much more conscious now about water conservation, the importance of [leaving] water in streams,... So I would say, in the beginning, it was almost all about revenue and now it is pretty equal, the revenue side and the conservation side are kind of balanced now (interview FID3).*

Second, the addition of the small hydro generating plants gave irrigation district patrons new security via energy independence by lowering energy costs and producing new district revenues from electricity sales of almost $3M annually between the two districts. As well, since the 1980s, small hydro in the two districts has reduced greenhouse gas emissions by over 1 billion pounds, equivalent to the emissions from 95,000 cars (extrapolated from Fernandez-Guardado, Weber & Seals 2023).

Finally, the pressurization of the water delivery system resulting from piping and the fall in elevation created the conditions, together with the advent and application innovative digital water and system management technologies, for increased crop yields and enhanced profits from farming.

In sum, over the course of the 1980s through the 2000s, the FID and MFID slowly evolved and implemented their "idea" of what an irrigated agricultural system could and *should be* in pursuit of sustaining long-term a thriving small farm economy capable of promoting economic, environmental, and energy health.

6. Conclusion

The literature on the promise of the integrated WEF Nexus approach is large and growing and suggests that treating of these resources in a holistic, systems-based manner will increase efficiency, reduce trade-offs across sectors, and promote long-term sustainability across sectors. In the two irrigation modernization cases in Oregon examined here, the promise of the WEF Nexus has been turned into reality with the incorporation of low impact small hydro turbines, innovative new fish screens, and enclosed piping. Taken together, the new integrated systems have increased water efficiency by almost 100%, dedicated significant new instream water rights for the sake of fish and ecosystems, created large and ongoing greenhouse gas reductions, and increased farms' economic viability by significantly reducing production and energy costs, while also increasing crop yields and water reliability (Fernandez-Guardado, Weber & Seales 2023).

The successful achievement of enhanced sustainability for the environment, economy, and communities by these two Hydro-Irrigation-Restoration Systems (Weber 2017) highlights the importance of figuring out how and why such WEF system transitions can be accomplished. And while Weber (2017) found that collaborative governance arrangements were essential to understanding the successful transition from traditional food and water irrigation systems to the new integrated WEF systems, our findings show another way forward, namely that a focus on both the structural socio-technical transition dynamics and the individual agency, or actor, dynamics are crucial to understanding system transformations. These contrasting findings suggest that understanding how to more fully close complex system loops to achieve WEF Nexus success may well be context dependent, rather than amenable to the application of a single theoretical framework. Given the positive outcomes being produced with such irrigation modernizations, it is clear that more research into these transitions is warranted, since additional development of a framework to initiate, encourage and support the transition to Hydro-Irrigation-Restoration Systems increases the odds that greater efficiency and sustainability across the entire WEF Nexus is the likely result.

References

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., … Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy, 39*(12), 7896-7906. https://doi.org/10.1016/j.enpol.2011.09.039

Brown, R. R., Farrelly, M. A., & Loorbach, D. A. (2013). Actors working the institutions in sustainability transitions: The case of Melbourne's stormwater management. *Global Environmental Change, 23*(4), 701–718. https://doi.org/10.1016/j.gloenvcha.2013.02.013

Bryan, J. (2008). *The Story of the Farmers Screen.* Retrieved from http://farmerscreen.org/wp-content/uploads/2012/05/FID.Case_.Study_.2008.pdf

Coccoli, H. (1999, December). *Hood River Watershed Assessment.* Retrieved from https://nrimp.dfw.state.or.us/web%20stores/data%20libraries/files/Watershed%20Councils/Watershed%20Councils_300_DOC_HoodR_WSassess_1999.pdf

Coccoli, H. (2004). *Hood River Subbasin Plan.* Hood River Soil and Water Conservation District.

Emerson, K., & Nabatchi, T. (2015). *Collaborative Governance Regimes.* Washington, DC: Georgetown University Press. https://doi.org/10.1353/book44406

Endo, A., Tsurita, I., Burnett, K., & Orencio, P. (2017). A review of the current state of research on the water, energy, and food nexus. *Journal of Hydrology: Regional Studies, 11*, 20-30. https://doi.org/10.1016/j.ejrh.2015.11.010

Energy Information Administration. (2023). *State Electricity Profiles.* Retrieved from https://www.eia.gov/electricity/state/

Ernst, K. M., & Preston, B. L. (2017). Adaptation opportunities and constraints in coupled systems: Evidence from the US energy-water nexus. *Environmental Science & Policy, 70*, 38-45. https://doi.org/10.1016/j.envsci.2017.01.001

Farmers Irrigation District (FID). (2011). *Water Management and Conservation Plan v 9.0.* Hood River, OR. Retrieved from https://www.fidhr.org/images/policies/FID-WMCP-Version-9_FINAL_1-13-2011.pdf

FCA. (2018). *Farmers Irrigation District Case Study.* Retrieved from https://2pw3hv1eaczqwfliy22eqqvb-wpengine.netdna-ssl.com/wp-content/uploads/2018/07/Case-Study_FID.pdf

Fernandez-Guajardo, P., Weber, E. P., & Seales, L. (2023). Solving the Food-Water-Energy Nexus One Step at a Time: Modernizing Irrigated Agriculture in the US West. *Journal of Sustainable Development, 16*(2). https://doi.org/10.5539/jsd.v16n2p95

FID. (2021). *About us.* Retrieved from https://www.fidhr.org/index.php/about-us

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research policy, 31*(8-9), 1257-1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy, 33*(6), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Geels, F. W. (2011). The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions, 1*(1), 24–40. https://doi.org/10.1016/j.eist.2011.02.002

Geels, F. W., & Schot, J. (2007). Typology of sociotechnical transition pathways. *Research policy, 36*(3), 399-417. https://doi.org/10.1016/j.respol.2007.01.003

Geels, F. W., & Schot, J. (2010). The Dynamics of Transitions: A Socio-Technical Perspective. In J. Grin, J. Rotmans, & J. Schot (Eds.), *Transitions to Sustainable Development. New Directions in the Study of Long Term Transformative Change* (pp. 9-101). New York: Routledge.

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrel, S. (2017). The socio-technical dynamics of low-carbon transitions. *Joule, 1*(3), 463-479. https://doi.org/10.1016/j.joule.2017.09.018

Hardin, G. (1968). The tragedy of the commons. *Science, 162*(3859), 1243-1248. https://doi.org/10.1126/science.162.3859.1243

Hellegers, P., Zilberman, D., Steduto, P., & McCornick, P. (2008). Interactions between water, energy, food and environment: evolving perspectives and policy issues. *Water Policy, 10*(S1), 1-10. https://doi.org/10.2166/wp.2008.048

Hoff, H. (2011). *Understanding the nexus: Background paper for the Bonn2011 Nexus Conference: The Water, Energy and Food Security Nexus.* Stockholm: Stockholm Environment Institute.

Hood River Watershed Group. (2002, June). *Hood River Watershed Action Plan.* Retrieved from http://hoodriverswcd.org/

Hoogma, R., Kemp, R., Schot, J., & Truffer, B. (2002). *Experimenting for sustainable transport: the approach of strategic niche management.* London & New York: Routledge.

Jenkins-Smith, H. C., Nohrstedt, D., Weible, C. M., & Sabatier, P. A. (2014). The advocacy coalition framework: Foundations, evolution, and ongoing research. In P. A. Sabatier, & C. M. Weible (Eds.), *Theories of the Policy Process* (3rd ed., pp. 183–224). Oxford: Westview Press.

Kemp, R. (1994). Technology and the transition to environmental sustainability: the problem of technological regime shifts. *Futures, 26*(10), 1023-1046. https://doi.org/10.1016/0016-3287(94)90071-X

Kemp, R., Schot, J., & Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management. *Technology analysis & strategic management, 10*(2), 175-198. https://doi.org/10.1080/09537329808524310

Loorbach, D. (2007). *Transition management. New mode of governance for sustainable development.* Utrecht, the Netherlands: International Books.

Loorbach, D. (2010). Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance, 23*(1), 161–183. https://doi.org/10.1111/j.1468-0491.2009.01471.x

Markard, J., & Truffer, B. (2008). Actor-oriented analysis of innovation systems: exploring micro–meso level linkages in the case of stationary fuel cells. *Technology Analysis & Strategic Management, 20*(4), 443-464. https://doi.org/10.1080/09537320802141429

Markard, J., Raven, R., & Truffer, B. (2012). Sustainability transitions: An emerging field of research and its prospects. *Research policy, 41*(6), 955-967. https://doi.org/10.1016/j.respol.2012.02.013

Middle Fork Irrigation District (MFID). (2010). *Fisheries Management Plan.* Parkdale, OR.

Perkins, L. (2013, June). *Cumulative Watershed Impacts of Small-Scale Hydroelectric Projects in Irrigation Delivery Systems: A Case Study Prepared for Energy Trust of Oregon and Bonneville Environmental Foundation.* Hood River: Farmers Conservation Alliance. Retrieved from http://farmerscreen.org/wp-content/uploads/2013/09/FCA-Hydro-Case-Study-2013.pdf

Rotmans, J., & Loorbach, D. (2009). Complexity and transition management. *Journal of industrial ecology, 13*(2), 184-196. https://doi.org/10.1111/j.1530-9290.2009.00116.x

Rotmans, J., Kemp, R., & Van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *Foresight: The journal of future studies, strategic thinking and policy, 3*(1), 15-31. https://doi.org/10.1108/14636680110803003

Schot, J. W. (1992). Constructive technology assessment and technology dynamics: the case of clean technologies. *Science, Technology, & Human Values, 17*(1), 36-56. https://doi.org/10.1177/016224399201700103

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology analysis & strategic management, 20*(5), 537-554. https://doi.org/10.1080/09537320802292651

Schot, J., Hoogma, R., & Elzen, B. (1994). Strategies for shifting technological systems: the case of the automobile system. *Futures, 26*(10), 1060-1076. https://doi.org/10.1016/0016-3287(94)90073-6

Taylor, A., Cocklin, C., Brown, R., & Wilson-Evered, E. (2011). An investigation of champion-driven leadership processes. *The Leadership Quarterly, 22*(2), 412–433. https://doi.org/10.1016/j.leaqua.2011.02.014

U.S. Bureau of Reclamation. (2015). *Energy Assessment of Reclamation Owned Conduits Supplement to the "Hydropower Resource Assessment at Existing Reclamation Facilities Report.* Retrieved from https://www.usbr.gov/power/CanalReport/FinalReportMarch2012.pdf

Van Driel, H., & Schot, J. (2005). Radical Innovation as a Multilevel Process: Introducing Floating Grain Elevators in the Port of Rotterdam. *Technology and Culture, 46*(1), 51–76. https://doi.org/10.1353/tech.2005.0011

Weber, E. P. (2009). Explaining institutional change in tough cases of collaboration: "ideas" in the Blackfoot watershed. *Public administration review, 69*(2), 314-327. https://doi.org/10.1111/j.1540-6210.2008.01976.x

Weber, E. P. (2013). Building Capacity for Collaborative Water Governance in Auckland, Report for the Water Management Strategy and Policy Team, Auckland Council, a Regional Government in New Zealand (June).

Weber, E. P. (2017). Integrated Hydro-Irrigation-Restoration Systems: Resolving a Wicked Problem in the Whychus Creek Watershed (Oregon, USA). *Journal of Sustainable Development, 10*(2), 104-115. https://doi.org/10.5539/jsd.v10n2p104

Weber, E. P., & Khademian, A. M. (2008). Wicked Problems, Knowledge Challenges, and Collaborative Capacity Builders in Network Settings. *Public Adm. Rev., 68*, 334–349. https://doi.org/10.1111/j.1540-6210.2007.00866.x

Weber, E. P., Lach, D., & Steel, B. (2017). Wicked-Problem Settings. A New and Expanded Social Contract for Scientists and Policy Implementation? In E. P. Weber, D. Lach, & B. Steel (Eds.), *New Strategies for Wicked Problems* (pp. 207-215). Corvallis, OR: Oregon State University Press.

Weber, E. P., Lovrich, N., & Gaffney, M. (2007). Assessing Collaborative Capacity in a Multidimensional World. *Administration & Society, 39*(2), 194-220. https://doi.org/10.1177/0095399706297213

Wilkinson, C. F. (1992). *Crossing the next meridian: Land, water, and the future of the West.* New York: Island Press.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage Publications.

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