Sustainable Management of the Water-Energy-Food Nexus: From Traditional to Integrated Hydro-Irrigation-Restoration Systems

1. Problem statement and rationale

The need for integrated management of water, energy, and food production sectors is widely advocated in the literature regarding the water-energy-food nexus (WEF). This body of literature emphasizes the interactions and interdependencies among the management and use of water and energy resources and their relationship with food production (Hoff, 2011). These systems "are often coupled – they interact, overlap and have effects on the inputs, constraints, and outcomes of each other" (Ernst & Preston, 2017, p. 38). The nexus approach suggests that adaptation strategies that take into account such interdependencies are more likely to succeed and yield more sustainable outcomes (Hoff, 2011).

In the farming communities of the arid and semi-arid American West, challenges posed by the water-energy-food nexus are associated with water scarcity. This has become even more complicated since in many of these places the water rights for streams are fully assigned. This, coupled with the application of the Endangered Species Act of 1973 and the 1972 Clean Water Act, which often require that more water remains in the stream and for habitat restoration (and, therefore, less water for irrigation), further aggravates the situation. In addition, the structure of water rights ("first in time, first in right"), means that in years of drought, farmers with the most junior rights often do not obtain the water they need (Weber, 2017). To further complicate the situation, many farming communities face the problem of aging, inefficient irrigation infrastructure (FCA, 2013). This situation creates a complex problem, with multiple conflicting objectives involving water rights, environmental flows, ecosystem restoration, protection of endangered species, and water and energy for irrigation. Finally, water scarcity problems are likely to be exacerbated as seasonal stream flows become increasingly disrupted due to climate change. This will add stress to existing irrigation systems, especially in arid and semi-arid regions of the Western US.

A growing number of farmers, policymakers, and government officials are starting to make the case that existing, inefficient traditional irrigation systems are unlikely to be able to accommodate successfully all these competing demands, while at the same time recognizing the large untapped potential of carbon-free hydropower within these systems. Instead, these wicked problems are more likely to be amenable to the application of integrated systems and practices that capture and effectively deal with the interdependencies of such 'coupled systems.' What might an integrated irrigation system look like in this specific case of the WEF nexus? Clearly, greater efficiency in water delivery systems is required to find enough water make to meet the water demands both for irrigation (crops) and environmental protection needs. On the energy side of the equation, there would need to be small and micro run-of-river hydropower generating plants that avoid the negative environmental impacts of large, traditional dam and hydropower systems. Can it be done?

Irrigators, non-profits, legislators, government officials and communities across the US West are answering in the affirmative. They are building community hydro and agricultural hydro, or "ag hydro," systems in response to the water-energy-food nexus described above (NPCC, 2014; FCA, 2013). Key to both types of integrated systems are 'conduit projects.' These use already constructed water conveyance structures such as irrigation canals and add a generator to produce electricity. Projects like these in the Pacific Northwest have produced benefits related to water conservation and energy generation (NPCC, 2014; FCA, 2013). This has been possible, above all, through state and federal water conservation funds. The Northwest Power and Conservation Council (NPCC) estimates that installing a generator with a capacity of 1 MW to an existing irrigation system costs $2 million. This is a much more cost-effective alternative to "the pipeline necessary to pipe an open canal for 3-5 miles to use the water pressure for generation and to conserve water both for the irrigation district's patrons as well as providing water for instream benefits, [which] may cost in the range of $10 million" (NPCC, 2014, p.10).

The NPCC (2014) has identified 51 potential conduit projects in the Pacific Northwest that could be developed in the next 20 years and generate 295,645 MWh. A similar scoping study conducted only for Reclamation-owned canals estimated that 22.76 MW of potential installed capacity and 85,385 MWh of potential annual energy generation are available at 74 identified sites in the Pacific Northwest (USBR, 2012). Although these figures may seem modest,

according to the NPCC, the increase would be sufficient to meet the electricity needs of more than 24,860 homes, based on an average annual household consumption in Oregon of 11,892 kilowatt hours per year (FCA, 2013).

The practical relevance of the issue can be seen in the benefits that this type of projects has brought to the communities and in the recent legislation that favors their development as a way to promote renewable energy. These small-scale hydro projects, like any other hydropower project, have the advantage of producing carbon-free energy. But, unlike traditional large hydropower dams, they are considered to have low to zero negative impacts on the environment and communities (FCA, 2013). Even in some cases, they have had positive impacts when the "project developers have dedicated the conserved water instream to provide fish and wildlife, water quality and scenic values" (NPCC, 2014, p.10). Small-scale hydropower projects within irrigation systems may represent a significant advantage in small rural communities. In the communities where they have been carried out, these projects have provided a source of funding to improve the infrastructure for irrigation, watershed restoration, clean energy generation for the locality and "family wage jobs in an area where average incomes are below the state average" (p. 38).

Despite the positive results that these projects have generated and the fact that many other communities face similar problems, there are few projects of this nature. Oregon and Colorado are the two leaders in these endeavors; yet in Oregon, there are only 20 such integrated systems built or in the process of being built, while in Colorado there are fewer than ten (FCA, 2013). Herein lies the importance of investigating what factors are present in the communities that could explain the transition in the irrigation system, as well as to study cases in which this transition has not happened.

From a theoretical point of view, the way in which the WEF problem takes shape in the farming communities of the American West is an instance of a 'wicked problem'. The literature suggests that these kinds of problems are better addressed by collaborative, adaptive, and reflexive governance processes (Weber, Lach, and Steel, 2017). It also represents an instance of a transition process. The literature on transition management emphasizes that the technical infrastructure and the way in which actors behave and make decisions influence and stabilize

each other. This results in systems lock-in. For a resources management transition to take place, it is required not only to introduce new technologies, but also a collective process of learning and decision making (Bos *et al.*, 2013; Loorbach, 2010; Pahl, 2006). "It is argued that these so-called social learning processes overcome current system lock-in, *i.e.*, technical path dependency and enable the transformation of existing social-technical systems through the development of new relational capacities among actors" (Bos *et al.*, 2013, p. 1709).

Investigating the factors that make the transition possible in irrigation systems can help us understand how transitions occur in the context of the water-energy-food nexus. What role, if any, do collaboration and social learning play, two factors that the literature points to as key components for sustainable transitions and for addressing wicked problems? Are there other factors that matter more? Investigating and explaining the choice to change from a traditional irrigation system to an integrated model will offer important information for irrigators, farmers, policymakers, and other interested parties engaged in efforts to make farming and rural communities in the US West more economically and environmentally sustainable, especially in response to the challenges posed by climate change. The findings will also contribute to the literature on understanding the broader dynamics inherent within the WEF nexus.

2. Research goals and questions

2.1 Research goals

I am interested in understanding why some places undergo transitions towards more integrated water-energy-food systems while other places with similar problems do not. I want to understand the characteristics that are present in the context where collaborative efforts emerged and resulted in such transitions. I am also interested in understanding how this process developed; what characterizes the interactions among stakeholders in settings that transitions occurred and what characterizes multi-stakeholders interactions where these processes failed or did not arise. Following Maxwell (2013), I differentiate the intellectual and practical goals of this research:

Intellectual goals

i) To understand the institutional and social **context** within which community members interact and how the setting may influence their actions (cf. Maxwell, 2013).

ii) To understand the **processes** by which the transition from a traditional irrigation system to an "integrated hydro-irrigation-restoration system" (Weber, 2017) takes place.

iii) To understand the **structure** and **dynamics** in which organizations involved in water, energy, and agriculture are organized and interact with each other (cf. Lofland & Lofland, 2006) and how this may facilitate or hinder management transitions.

Practical goal

My goal is to provide insights that may help improving existing management practices in the water-energy-food nexus and help advance the development of sustainable food systems and the improve the rural communities that depend on such systems.

2.2. Research question

Through this research, I aim to answer this question: *Under what conditions do transitions toward integrated hydro-irrigation-restoration systems occur?* Table 1 (below) presents the links between my research question and the related theory that will inform this research.

3. Theoretical framework

Many studies that address the WEF focus on water/energy intensities and the technical solutions that would make more water- and energy-efficient systems (*e.g.*, AGU, 2012; Kenney & Wilkinson, 2011; USDOE, 2014). However, several authors have pointed out the importance of institutions and policy actors, whether for WEF cases generally or for more specific cases associated with traditional irrigated landscapes in the western U.S. (Scott et al., 2011; Hussey and Pittock, 2012; Pittock, 2011).

Given the complexity and uncertainty associated with the WEF, it can be considered as a 'wicked problem.' Since the WEF cuts across different policy areas, the very attempt to jointly manage water, energy, and food production brings increased complexity to resources governance as it brings multiple stakeholders into play. There seems to be a wide agreement that to successfully address a wicked problem, collaborative or networked governance is needed (Ansell & Gash, 2008; Kettl, 2006; O'Toole, 1997; Ostrom, 1990; Weber, 2003). However, there are no clear lessons provided to explain how a traditional irrigated system in the western U.S. might be

transformed into an integrated hydro-irrigation-restoration system capable of responding to all the demands of the wicked problem setting described above, or under what conditions this is more likely to occur.

Theories that address the interactions between multiple actors can be useful in this regard. The literature on collaborative governance, Advocacy Coalition Framework, and policy networks provides insights that might be used to address complex problems involving multi-actor settings, such as those wherein the WEF takes place. These insights have been used in research on resources management problems but usually from a sectoral approach (*e.g.*, forest, water resources, or fisheries). Applying these insights to an inter-sectoral setting (water-energy-irrigation-environment) can contribute to the literature and can shed light on understanding what factors facilitate the transitions to integrated systems. The following sub-sections will briefly present core ideas of the literature that have helped inform my research. Table 1 summarizes these insights.

Table 1 Links between the research question and relevant theory for this research

Research Question	Related Theory	Insights from Theory
Under what conditions do transitions towards integrated hydro-irrigation-restoration systems occur?		
Conditions present in the community or inherent to the type of problem	Collaborative Governance	Antecedent conditions such as interdependencies, the potential for conflict, initial social capital facilitating the emergence of collective action.
	Wicked problems	Wicked problems are better addressed by strategies that engage multiple stakeholders in the decision-making process.
Conditions related to the network or multi-stakeholders interactions	Collaborative Governance	Practices and mechanisms that facilitate inclusive, meaningful and consensus-oriented participation among stakeholders make possible for collaborative efforts to emerge and be sustained.
	Policy Networks	Characteristics of the policy networks such as

		number and interdependency/integration of its members, distribution of power and resources among them, and the type of interactions between actors (if they are dominated by conflict, bargaining or cooperation) (Adam & Kriesi, 2007) result in different policy outcomes.
	Advocacy Coalition Framework	Stakeholders with common beliefs tend to interact/coordinate/form coalitions to advance a particular policy. Within a policy subsystem (policy issue), there tend to be two or more competing coalitions. There can be different "levels" of coordination (strong/weak) within coalitions and also cross-coalition interactions. Coalitions tend to share resources/information.

3.1. Wicked problems

Originally defined by Rittel and Webber (1973), "wicked" problems refer to open-ended problems characterized by not having a definite formulation; that is, the boundaries of the problem are not clearly delimited. They are intractable, incomprehensible, and resistant to solution. Since each problem is unique, more than one explanation and solution is possible. Each problem, moreover, tends to be the symptom of another problem (Rittel & Webber, 1973; Head & Alford, 2015). In other words, they are 1) "*unstructured*, since the causes and effects are difficult to identify and model […]; 2) *cross-cutting*, because the problem space is comprised of multiple, overlapping, interconnected subsets of problems that cut across multiple policy domains and levels of government […]; and 3) *relentless*", in the sense that a definitive point of arrival is never reached; each solution affects, in some way, other policy areas increasing its complexity (Weber, Lach & Steel, 2017, p. 2).

Such problems challenge traditional modes of governance for addressing policy problems. Since wicked problems cut across different policy domains and it is not possible to dissect them into small pieces or policy silos (Kettle, 2006; Head & Alford, 2015), their definition and solution necessarily involve connecting multiple stakeholders with different interests and values in search of a solution. Moreover, in wicked problems, the problem definition is highly determined by the

social context (Rittle & Webber, 1973) and, consequently, value-laden. “Facts are [commonly] uncertain, values in dispute, stakes high, and decisions [often] urgent” (Weber, Lach, & Steel, 2017, p.4). As pointed out by Head and Alford (2015), within in the context of social pluralism and scientific uncertainty, the strategy of gathering ‘more’ scientific information will hardly contribute to finding a solution accepted by all the actors involved. To understand the nature of this problem, it is necessary to address the values, perspectives, and meanings that stakeholders associate with the problem.

The literature suggests that wicked problems require more integrative frameworks that allow for different ways of multi-actor interactions. This, in turn, makes it possible for new ways of thinking about the problem and possible solutions (Balint, Stewart, & Desai, 2011; Head & Alford, 2015; Kettle, 2006; Ney & Verweij, 2015; Weber, Lach, & Steel, 2017). As Weber, Lach and Steel (2017) posited, it becomes necessary to search for “new problem-solving methodologies, processes, institutions, and decision tools that can integrate science and other knowledge and values possessed by the diverse stakeholding groups” (p. 5). In the field of natural resources management, for example, new, more integrative forms of management have been proposed over the past three decades, including ‘adaptive management,’ ‘ecosystem-based management’ and ‘integrated natural resources management’ (Imperial, 1999). Each of these strategies shares a common emphasis on considering problems related to one resource in its connection to other resources or problems in a holistic way. They also call for more participatory, flexible decision-making process and coordination across sectors.

Weber, Lach, and Steel (2017) have identified three emergent problem-solving strategies that seem to cope well with effectively address wicked problems: knowledge-to-action networks, place-based social learning, and collaborative governance. All three recognize the limitations of scientific information in solving wicked problems and the need to integrate other kinds of knowledge. They underscore the role of values, perceptions, and interests in efforts to frame the problems, overcome potential conflicts and devise solutions. They call for participatory, collaborative decision process and dialogue among the multiple stakeholders and ‘experts.’ They consider trust and relationships among all participants as crucial components for success. They advocate the development of a new professional culture for scientists and experts, and a new set

of skills for leaders. Finally, they focus on small-scale governance (Weber, Lach, and Steel, 2017).

These strategies seem to better address the prime sources of the 'wickedness' of wicked problems: scientific and administrative complexity and uncertainty; dynamic context; multiple and diverse stakeholders; and conflicting objectives and values (Balint, Stewart, & Desai, 2011). Actual strategies can vary depending on the context. All of these strategies can adopt different shapes depending on the context (cf. Weber & Stevenson, 2017). In each setting, they will require specific institutional arrangements to sustain the multi-actor efforts. However, the bottom line is that a multi-actor, networked mode of governance is better suited for addressing wicked problems than hierarchical or market-based modes.

Thinking about the Water-Energy-Food nexus as a wicked problem makes it possible to broaden the way it is managed, helping to transcend the limits imposed by a sectoral vision of the issue. It also calls our attention to the strategies and institutions that bring stakeholders together and advance sustainable management of the WEF. Overall, the literature on wicked problems highlights the need for creating institutional frameworks or/and governance arrangements in which adaptive/integrated/nexus approach can occur. However, the literature on the WEF does not indicate how these arrangements originate; nor does it shed light on the key conditions that facilitate their emergence. The literature on collaborative governance, however, has identified these elements. Although collaborative governance is only one of the various forms to address wicked problems, as it was explained, I considered useful for my research to take from this body of literature the findings about the necessary pre-conditions for collective action.

3.2. Collaborative Governance

As explained above, the WEF involves multiple stakeholders from different policy domains and levels of government. This situation creates opportunities for collaboration. Collaboration is defined as "any joint activity by two or more organizations intended to increase public value by working together rather than separately" (Bardach, 1998, p.8). Recommended for multi-actor settings, collaboration has deemed a necessary condition to address wicked problems (Ansell & Gash, 2008; Kettl, 2006; O'Toole, 1997; Ostrom, 1990; Weber, 2003). It is considered that

collaboration allows for reaching better outcomes in which all actors win and in which all policy goals align (Weber, 2017).

The governing arrangements that make "one or more public agencies directly engage non-state stakeholders in a collective, consensus-oriented and deliberative decision-making process" is called "collaborative governance" (Ansell & Gash, 2007, p.544). In a similar way, Emerson, Nabatchi and Balogh define it as "the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished" (2011, p.2).

The literature has identified certain characteristics of the resources/problems and the community that facilitate the emergence of collaborative institutions and its duration over time (Heikkila & Gerlak, 2005). Table 2 summarizes characteristics related to the nature of the problem/resources. In sum, when problems are complex, involve different actors, and refer to various policy domains; when resources "are subject to the possibility of a tragedy of the commons" (Ostrom, 1990, L. 338[1]), and when they involve interdependence and uncertainty, collaboration is recommended as a better-suited way of addressing them (Kettle, 2006; Ostrom, 1990; Roberts, 2000; Weber & Khademian, 2008).

Table 2 Preconditions for collaboration related to the nature of the problem/resource

Characteristic of the problem/resources	Description	Cited in
Interdependence	Interdependence of goals and aspirations –the parties, need the others to achieve their goals.	Thomson and Perry (2006) Daniels and Walker (2001)
	Interdependence may even substitute the history of collaboration.	Ansell and Gash (2008)
	Commonly owned resources.	Ostrom (1990)
Complexity	Multiple parties involved; issues are rooted in a different set of values that reflect deep cultural differences and sources of knowledge.	Daniels and Walker (2001), Thomson and Perry (2006).
Power-Resource-	If power is dispersed AND not contested.	Roberts (2000)

[1] L. refers to the location of the quote in the Kindle edition of the book, which does not show the page numbers.

Knowledge (Im)balances	"Situation in which each partner has resources that other partners need" (p. 21)	Thomson and Perry (2006)
(Potential of) Conflict	Scarcity of resources rather than abundance; risk of overuse or freeride.	Ostrom (1990); Thomson and Perry (2006)
	"Incompatibility involving issues, parties, processes or outcomes" (p. 26). When parties are mutually dependent but, at the same time, perceive discrepancies in what they consider appropriate about what to do, when, and how, so that it seems that everybody's goals cannot be reached simultaneously, conflict arises.	Daniels and Walker (2001)
	"High level of conflict among the stakeholders […] there is no agreement on the problem or its solution" (p. 1).	Roberts (2000)
	"Severity of the problem and the extent to which actors depend on the resource for their livelihood" (Heikkila and Gerlak, 2005, p. 585)	Heikkila and Gerlak (2005). Also Ostrom (1990)
	"When stakeholders are highly interdependent, a high level of conflict may actually create a powerful incentive for collaborative governance" (p. 553).	Ansell and Gash (2008)

But the presence of a (potential) conflictive situation does not in itself create collaboration. For collaboration to emerge, the willingness of the parties to take into consideration all participants interests (Thomson & Perry, 2006), to "deal with conflict assertively", and to commit in "integrative negotiation" (Daniels & Walker, 2001, p. 38-39) is required. The literature also suggests there are conditions related to the community that, when present, make collaboration more likely to arise. Perhaps the most commonly cited community feature that facilitates collective action is 'social capital' or a history of working together (Ostrom, 1990; Ansell & Gash, 2008; Heikkila & Gerlak, 2005).

Social capital –the social bonds and norms that tie multiple actors together– facilitates coordinated work as it lowers the transaction costs of working separately. When bonds of trust exist, collaboration is more likely to emerge. Actors are less likely to adopt individual egoistic

behavior that may harm collective outcomes and are more likely to engage in collective action since they trust their partners would do the same (Pretty, 2003; Thomson & Perry, 2006). The parties perceive themselves as connected in a broader network "governed" by common rules and ties of reciprocity (Pretty, 2003). In this way, some degree of social capital may act as an antecedent condition that facilitates the emergence of collaboration.

However, the absence of social capital is not necessarily an insurmountable barrier (Ansell & Gash, 2008). In cases when previous collaboration does not exist, the literature suggests that leaders and policy entrepreneurs play a key role by facilitating trust-building among diverse actors who did not have much experience in collective action (Heikkila & Gerlak, 2005). Table 3 summarizes preconditions for community collaboration.

Table 3 Preconditions for collaboration regarding the community

Conditions present in the community	Cited in
Previous history of efforts to collaborate. "Experience in working together, trust, and frequent communication" (Heikkila & Gerlak, 2005, p. 586)	Tomson and Perry, 2006 Heikkila and Gerlak (2005). Also Ostrom (1990)
Relations of trust, reciprocity and exchanges, common rules, norms and sanctions; and connectedness in networks and groups.	Pretty, 2003
Stakeholders have the capacity, organizational infrastructure, skills and expertise, time, energy and liberty to meaningful participate. (If these capacities are lacking, empowerment strategies are in place).	Ansell and Gash (2008)
"Individuals have shared a past and expect to share a future..." Reputation is important for members ("keeping promises, honest dealings..."). Shared norms that establish the "appropriate" behavior.	Ostrom (1990, L. 2013)
"Stakeholders perceive achievement of their goals to be dependent on cooperation from other stakeholders" (Ansell & Gash, 2008, p. 552)	Ansell and Gash (2008) Also Roberts (2000)

These preconditions are considered key factors that motivate actors to come together and support the formation of "collective action" institutions. The literature on collaborative governance has also identified the rules and arrangements that need to be set for collaboration to be sustained (Ansell & Gash, 2008). In general, these arrangements aim to maintain (or create) the conditions

of trust and reciprocity that sparked motivation in the first place and make the initial effort successful.

The literature is specific on what these rules should include. First of all, ground rules should be clear for all participants (Ansell & Gash, 2008; Ostrom, 1990). A collaborative institution should facilitate the inclusion of a broad range of stakeholders in meaningful and consensus-oriented participation (Weber, 2013); it should provide mechanisms to allow parties to negotiate and self-govern, it should make possible the emergence of agreements and strategies of cooperation, and it should facilitate both the establishment of credible commitments and the mutual monitoring of those commitments (Ostrom, 1990). At the same time, collaborative institutions need to have clear boundaries (Ostrom, 1990) and establish procedural rules about decision-making that minimize power imbalances. These institutions also need to promote conflict resolution, monitoring, sanctions, and accountability practices (Ansell & Gash, 2008; Ostrom, 1990). Interactions among actors engaged in a collaborative process need to be based on trust, respect, commitment, deliberation, and reciprocity (Ansell & Gash, 2008; Weber, 2013). The process requires constant and "face-to-face dialogue" and deliberation (Ansell & Gash, 2008, p.558). Actors need to be able to recognize interdependencies and to develop a shared understanding of the problems and goals of the collaborative (Ansell & Gash, 2008). It is recommended to begin with the less contentious problems. Achieving small wins build trust and commitment among actors and set the stage for larger wins in the future (Weber, 2013).

Collaborative governance literature can provide useful insights to understand how more horizontal governing processes originate and are sustained in the context of the WEF. Two other theories that help explain interactions among multiple actors are Policy Networks theory and the Advocacy Coalition Framework.

3.3. Policy (and social) networks

The concept of 'policy networks' or 'issue networks' emerged in Political Science from the study of the actors involved in decision-making. Previously, the model of sub-governments and iron triangles explained that around a policy issue, there emerge 'routinized patterns of interaction' among governmental actors and interest groups that attempt to advance the policy of their interest (Theodolou, 1995). Both models (sub-governments and iron triangles) assume that there are

“small circles of participants who have succeeded in becoming largely autonomous” (Heclo, 1978, p. 70). In contrast, Heclo proposed the notion of “issue networks” to refer to “a large number of participants with quite variable degrees of mutual commitment or of dependence on others in their environment […] Participants move in and out of the networks constantly […] at any time only one part of a network may be active and through time the various connections may intensify or fade…” (Heclo, 1978 p. 70).

According to Marsh and Rhodes (1992), a “policy network” consists of linkages among a set of organizations that depend up one another and decide to collaborate to achieve a common goal by exchanging resources. They are called “policy networks” because they are usually built around policy problems or within a specific policy “sub-system”. O’Toole (1997) points out that policy networks are characterized by interdependent, informal and horizontal relations. Milward and Provan (2006) emphasize that, unlike hierarchies, networks do not have a chain of command; they “rely on trust and reciprocity” (p.6). Adam and Kriesi (2007) maintain that networks emerge when “regular communication and frequent exchange of information lead to the establishment of State relationships between actors and to the coordination of their mutual interests” (p.129). Compston (2009) explains that interactions within policy networks are based on resource exchange since actors are resource interdependent. In his view, public policy is the result of network actors’ preferences, resources exchange, joint use of strategies, and the particular rules and norms within the network.

Focusing on the study of how interactions occur within networks has led to the development of analytical models that explain the kinds of outcomes they produce and how prone to change the networks are. For example, Marsh and Rhodes (1992) developed a model to analyze intergovernmental and government-industry relations. Their typology distinguishes five categories of networks based on the degree of integration of its members and the distribution of resources among them. The five types are located in a continuum: At one end of the spectrum, we find the policy communities, which are stable, limited in the number of participants, and exhibit high levels of interdependence. Resources and power are distributed among participants in a balanced way. At the other end of the spectrum, we find issue networks, which are unstable and have a large number of members and limited interdependence. They are characterized by an unequal distribution of resources and power.

Alternatively, Adam and Kriesi (2007) proposed a typology of networks taking into account two variables: 1) the distribution of power among organizations/actors (if it is concentrated in one actor or shared/fragmented among several actors) and 2) the type of interactions between actors (if they are dominated by conflict, bargaining or cooperation). The combination of these two aspects results in six types of policy networks: dominance, competition, horizontal cooperation, hierarchical cooperation, asymmetric bargaining, and symmetric bargaining. Adam and Kriesi noted that the type of interactions within a network determines both the policy outcomes that are produced and how they are produced. Greater conflict raises the potential for rapid shift in policies. In fragmented settings, the potential for change is higher than in networks where power is concentrated.

All these studies shed light on our understanding of the kind of interactions that emerge in networked settings. The bottom line is that different network configuration and interactions result in different policy outcomes. In the specific field of natural resources governance, we find studies that focus on 'social networks' as an important factor in cases where various actors interact "to effectively deal with natural resource problems and dilemmas" (Bodin and Crona, 2009, p.367; cf. Stein et al., 2014). Bodin and Crona explain that informal networks can sometimes be more effective than formal institutions. As in policy networks, they emphasized that "the structural pattern of relations (*i.e.*, the topology) of a social network can have significant impact on how actors actually behave. This clearly has implications for actors' abilities to manage environmental challenges" (Bodin and Crona, 2009, p. 366). In their study, Bodin and Crona (2009) looked at "structural characteristics of social networks" in natural resource governance (p.367). They found that variations among networks (concerning density, cohesiveness, interconnectivity and centralization) account for differences in the governance process and policy outcomes. Moreover, they found that the most appropriate combination of these characteristics (the ones that produce better outcomes) is still uncertain. They point to this as a research gap regarding network governance.

3.4. The Advocacy Coalition Framework

The Advocacy Coalition Framework (ACF) helps us to understand how and when multiple actors coalesce and coordinate their action to produce change over time. This framework is particularly concerned with explaining the behavior and structure of those coalitions and the mechanisms they

use to achieve their policy goals. According to Jenkins-Smith *et al.* (2014), a core element in ACF is to explain coalition's formation and durability. ACF theorizes that beliefs determine with whom actors interact and build coalitions. In general, ACF analyzes the policymaking process as the interaction of competing coalitions that try to advance their beliefs and goals. Resulting policies are the translation of the beliefs of "one or more coalitions" (Jenkins-Smith *et al.*, 2014, p. 192). Therefore, a policy change implies a change in belief systems. ACF also investigates how and why policy changes over time and how and to what extent actors "learn", that is, revise and modify their beliefs system.

In ACF, the primary unit of analysis is the policy subsystem. "Policy subsystems are defined by a policy topic, territorial scope, and the actors directly or indirectly influencing policy subsystem affairs" (Jenkins-Smith et al., 2014, p. 189). The notion of policy subsystem accounts for the fact that, not only Congress, the bureaucracy and interest groups (as the idea of the 'iron triangle' suggested) are relevant actors in policymaking. Rather, the concept of policy subsystem acknowledges that there are multiple actors that influence the policy outcomes. Policy subsystems include a number of elements such as "physical and institutional characteristics [and] actor attributes, including belief systems and political resources"; they are "semi-independent but overlap with other subsystems and are nested within yet other subsystems" (Jenkins-Smith *et al.*, 2014, p. 190). The level of engagement and influence of the actors within a given subsystem varies across subsystems and over time.

In ACF, actors within a policy subsystem are aggregated into "advocacy coalitions" for analytical purposes. They may be several coalitions within a subsystem. Advocacy coalitions are defined as actors sharing policy core beliefs and resources to influence policy outcomes. Actors within coalitions coordinate their actions using a variety of strategies and policy instruments. ACF is concerned with explaining how coalitions behave. For example, it suggests that actors form coalitions to overcome obstacles that stand in the way of collective action, since "similar beliefs among allies reduce the transaction costs for coordination" (Jenkins-Smith *et al.*, 2014, p. 197). In this way, the idea of 'coalition' is similar in meaning to that of 'network.'

Regarding the characteristics of the structure of the coalitions, ACF acknowledges that power and resources may be unevenly distributed among actors. There may be a single powerful actor that

occupies a central position in the network and “rarely interacts with their allies” (Jenkins-Smith *et al*., 2014, p. 197). In a subsystem, there may be a “dominant” coalition that controls resources and decision-making, and “minority” coalitions that struggle to become visible and influence the policy outcome.

Besides beliefs systems and patterns of interactions, ACF also aims to explain how actors within coalitions use resources. ACF identifies six categories of resources that coalitions may use. They include “formal legal authority to make policy decisions, public opinion, information, mobilizable supporters, financial resources, and skillful leadership” (Jenkins-Smith *et al*., 2014, p.198). Those resources may be shared with allies. Resources (owned or shared) are a core element in ACF that help explain the capacity of coalitions to influence the policy process.

Coalitions operate “interact, debate and possibly negotiate” in *forums* or venues. These forums may vary on “the degree of openness in participating (open versus closed forums) and the extent that participating actors share a common analytical training and norms of conduct” (Jenkins-Smith *et al.,* 2014, p.198). These characteristics of the forums, together with the degree of conflict among coalitions, the kind of experiences and information actors acquire, and the individual attributes of coalition actors determine how they interact and how they learn from each other.

Finally, ACF proposes different paths to policy change. Policy change may be the result of external or internal events. Events external to the subsystem can be changes in "socioeconomic conditions, regime change, outputs from other subsystems, and extreme events such as some crises and disasters” (Jenkins-Smith et al., 2014, p.202). Events internal to the subsystem can be scandals or failures of past policies. In these kinds of events, coalitions respond, reorganize and shift strategies that may lead to policy change. The policy change may also be the result of coalitions learning, although this path is usually slower and usually produces change when coupled with an internal or external event or perturbation. The last path to policy change is through negotiation between previously rival coalitions.

Together, Collaborative Governance, Policy Networks and ACF literature provide insights to understand and explain the structure and dynamics of multi-actor interactions and the way such

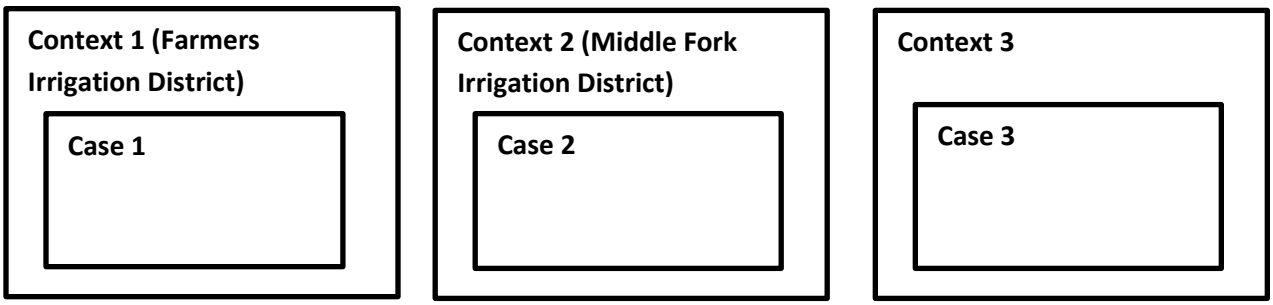
factors drive different ways of governance and outcomes. Table 6 and 7 (below) present a summary of the main insights from this literature that will inform this research.

4. Research design and methods

Since through the research question, I aim to understand the ***context, processes*** and the ***structure*** and ***dynamics of interactions*** as key conditions that may facilitate or hinder transitions, I consider qualitative methods to be the most appropriate for this inquiry (cf. Maxwell, 2013; Lofland & Lofland, 2006). Also, responding to this research question requires talking directly with people from different stakeholder groups (governmental and non-governmental) for the purposes of developing a detailed understanding of the complexity of joint management of water, energy and food production. For all these reasons, this research will rely on qualitative methods as the most appropriate tool for meeting the study objectives.

According to Creswell (2014), a **case study** approach is useful when analyzing in-depth a "bounded system", often a process or multiple individuals within a group. Also, a case study is particularly useful when investigating a phenomenon within its context, especially "when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014, p. 16). Social processes such as the way a community addresses the wicked problem of managing water, energy, and food production together depend a great deal on its context. For this reason, I chose to design this research as a case study. Specifically, it will be designed as a **comparative-case study**, since the goal is to understand why in contexts facing a wicked problem collaborative efforts emerged and facilitated a transition, while in other contexts this did not happen (in Yin's typology: "multiple-case holistic design" [see Figure 1]).

Figure 1 Comparative or Multiple-case holistic design (Adapted from Yin, 2014, p. 50)



4.1 Sites selection

According to George and Bennet, in a comparative case study, "cases should be selected to provide the kind of control and variation required by the research problem" (2005, p. 83). Since the phenomenon to be examined is the process of transition (initiated or not, successful or not) from traditional water delivery systems towards integrated hydro-irrigation-restoration systems, all the cases selected as units of analysis will represent instances of communities facing a WEF related problem with some cases being successful in such transition and others not. This will allow me to compare and contrast results (Yin, 2014).

Farmers Irrigation District (FID) and Middle Fork Irrigation District (MFID), both located in Hood River, Oregon, represent instances of a *critical case* (Yin, 2014) since they illustrate the process of a successful transition in the irrigation system (FCA, 2013). In both cases, the Irrigation District integrated small-scale hydropower plants within their water delivery systems. A study conducted by Farmers Conservation Alliance (FCA) (2013) showed that these projects had a net positive impact in their communities.[2] The change in the irrigation system allowed generating revenues of almost $90 million. These funds made it possible to improve the infrastructure for irrigation which in turn, resulted in greater water flow during the summer. They also allowed removing fish passage barriers, all while favoring collaboration among the members of the community (FCA, 2013).

These projects, while solving the problem of water demand for irrigation and ecological flow, also addressed the problem of aging and inefficient infrastructure, promoted water conservation, and the generation of energy, which is owned and managed locally. This, in turn, has produced local jobs. The study also emphasizes that ecological impacts have been minimal since the incorporation of energy generation does not add more diversions from the river system, since it uses the water that is already diverted for irrigation (FCA, 2013).

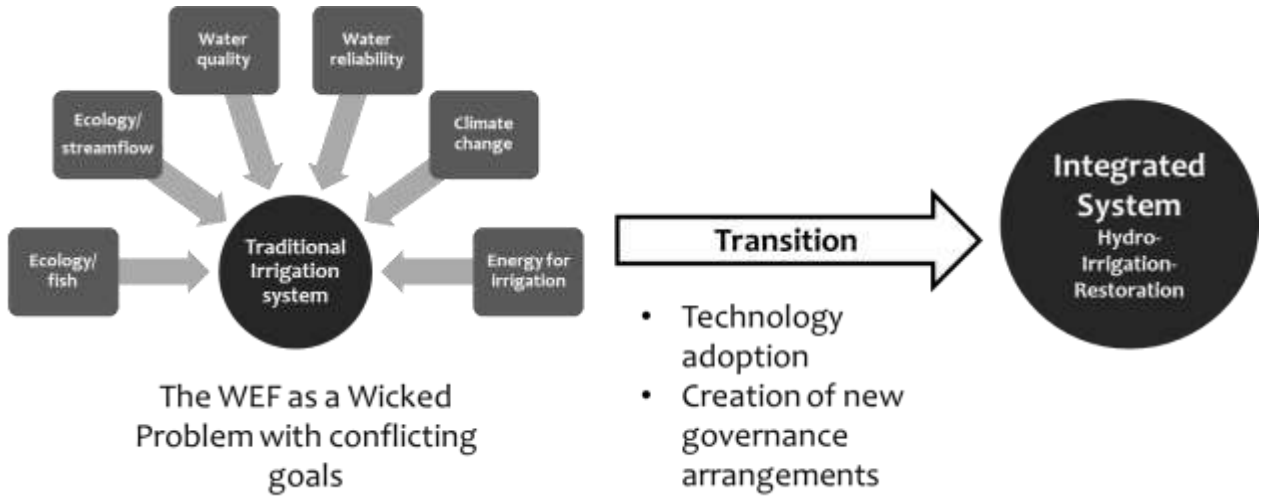
The management transition that occurred in FID and MFID in eastern Oregon involved technical solutions that made it possible to respond to multiple policy goals with an "integrated hydro-irrigation-restoration system" (Weber, 2017, p.108). Table 4 compares the responsiveness of an

[2] In my research, I do not aim to evaluate the impacts of these projects, but rather to understand the process that originated and developed within these communities.

integrated system as presented by Weber (2017) and the preliminary data from FID and MFID, as presented in FCA (2013). But it seems that the transition also included multi-stakeholder collaboration process, as it is depicted in Figure 2. This research will further examine this process.

As explained by Yin (2014), in a comparative case design, "each individual case study consists of a 'whole' study […]; each case's conclusions are then considered to be the information needing replication [or contrast] by other individual cases" (Yin, 2014, p. 59). Therefore, the selection of the third case of study will depend on the findings in the FID and MFID cases. I will first delve into these cases to identify the factors that facilitated this solution. The third case will be selected to allow the variation needed to fully compare and contrast both the process and outcomes in each of the case studies (George and Bennet, 2005). The third case may be a case of failure in transitioning from traditional to integrated water delivery systems in the American West.

Figure 2 Processes involved in transitions towards integrated hydro-irrigation-restoration systems



Source: Own representation

Table 4 Comparison between system responsiveness to the wicked problem set in the Whychus Creek Watershed, Farmers Irrigation District and Middle Fork Irrigation District (Weber, 2017, p. 108; FCA, 2013)

Policy Goals	Traditional Water Delivery System	Integrated Hydro-Irrigation-Restoration System	Farmers Irrigation District	Middle Fork Irrigation District
Energy Production	No	Yes	Yes 2,255,000 kilowatt hours annually increase Enough low-impact hydropower to supply over 2,000 homes	Yes 25,000,000 kilowatt hours annually generated Enough power produced annually to supply over 2,100 homes
Responsiveness to Climate Change (carbon-free energy source)	No	Yes	Yes Certified as a producer of low impact hydro.	Not certified yet as low impact hydro producer.
Ecology/Fish	No, lack of "fish friendly" screens & fish passage blocked	Yes, screening fixed & fish passage restored	Yes Water diversions eliminated: 22. Horizontal fish screen installations: 9.	Installed horizontal fish screen. Removal of 8 barriers to fish passage, including one major diversion dam removal. "Pending the completion of some identified projects addressing fish passage and temperature assessment" (FCA, 2013, p.32).
Ecology/Adequate Streamflow	No	Yes	?	Yes Flow monitoring in-stream to ensure they are meeting the requirements.
Water Quality (meeting CWA temperature standards)	Problematic/ regular exceedances	Yes, in most all cases	Yes Temperature monitoring program on the main stem of the Hood River	?
Riparian Zone Health	Poor	Significant & continuing restoration progress	Significant & continuing restoration progress	Significant & continuing restoration. Over $10 million in restoration and conservation projects.

Economic Benefits, General (water to support on-farm revenues)	Yes, water & agriculture revenues	Yes, water & agriculture revenues	Yes $45 million in revenue (over time)	Yes Over $44 million in revenue (over time)
Additional Economic Benefits to Users • **lower energy costs** • **increased revenues from water sales** • **more water to use** • **lower liability costs**	No	Yes, on all counts	"More water available in the system [...] and a more efficient system with less operation and maintenance costs" (FCA, 2013, p.19).	
Water Reliability (high certainty/guaranteed delivery to *all* users)	Problematic in dry and/or drought years	Yes/High, even in dry and/or drought years	Yes "The system delivers less than 13,000 acre feet while meeting the needs of FID patrons, (a decrease of nearly 52% compared to the old system)" (FCA, 2013, p.19).	Yes "3,200 acre feet conserved annually through the complete elimination of overflows and end spills" (FCA, 2013, p. 34).

4.2 Data collection methods

To decide which data collection methods are more appropriate for this research, I established a relationship between the research question and the kind of information needed to respond to it (Maxwell, 2013). Table 5 shows these links. As a first step, and in order to understand the context and the outcomes that are produced in each case, I will collect biophysical, institutional, economic, and social information from public documents or websites.

Table 5 Linking the research question and methods (Adapted from Maxwell, 2013)

What do I need to know (Research Question)	What kind of data will answer the question (Methods and sources of evidence)?	Analysis methods
Under what conditions do transitions towards integrated systems occur?	Oral histories from semi-structured interviews.	Coding, develop themes. Qualitative Social Network Analysis in combination with ACF
	Organizational documents (that account for organizational beliefs and practices such as plans or programs).	Content analysis
	Minutes of meetings, progress reports, other internal records (in the cases there was a collaborative process ongoing).	Content analysis
	Formal studies or reports of the situation in each case (*e.g.*, state of the water resources in the watershed).	Content analysis

<u>Identifying the conditions under which management transitions occur</u>

A primary purpose of this study is to understand the conditions that seem to facilitate or hinder management transitions in the WEF. In particular, the type of transitions under study here seems to be the result of collaboration among stakeholders (see Figure 2 above). The literature on Collaborative Governance suggests that there are some conditions regarding the type of problem and the community dynamics that, when present, make collaboration between the parties more likely (see Table 6). The first phase of this research will delve into how, and to what extent these conditions were present in FID and MFID cases (or absent in other cases) and how they facilitate (or hinder) the management transition.

To fully understand these contextual conditions, I consider relevant to talk directly to people involved in the process (or affected by the problem). **One-on-one interviews** are deemed an appropriate data collection method when the objective is to "elicit views and opinions from the participants" (Creswell, 2014, p. 190). For selecting the participants, I will follow a **purposive sampling** technique (Bryman, 2012) to ensure that I include participants relevant to the research question. Thus the interviewees will be members of the community from different stakeholders groups (*e.g.*, Irrigation District, farmers, federal, state and local government agencies, water management organizations, land development organizations, and environmental organizations) in each case. The sample will be created from available lists of stakeholders in websites or public documents. This sample will be complemented with a snowball sampling technique, that is, with the suggestions from initial interviewees. The sample size will depend on the context of each case. I will include a broad spectrum of the different stakeholder's groups. The interviewing process will continue until I reach the point of **saturation,** that is, "when gathering fresh data no longer sparks new insights or reveals new properties" (Creswell, 2014, p. 189).

Since the primary purpose of the interviews is to explore experiential knowledge of the collaborative/transition process and what the stakeholders perceived to be factors that facilitate the transition, the type of interview conducted will be **semi-structured interviews**. This will allow respondents to express their ideas broadly and deeply. The content of the interviews and the kind of questions asked will be informed by the insights provided by the literature. Table 6 shows typical conditions that facilitate collaborative and transition processes that are potentially relevant to this research.

Table 6 Identifying interview themes in the literature

What do I need to know (Research Question)	Typical factors mentioned in the literature	References
1. Under what <u>conditions</u> do transitions towards integrated systems occur?	Common use (ownership, management) of resources.	Ostrom, 1990.
	Interdependence of goals and aspirations.	Thomson and Perry, 2006; Daniels and Walker, 2001; Ansell and Gash, 2008.
	Power, resources, knowledge imbalances.	Roberts, 2000

	(Actual or potential) Conflict.	Ostrom, 1990; Thomson and Perry, 2006; Daniels and Walker, 2001; Roberts, 2000; Ansell and Gash, 2008.
	Initial social capital. Previous experience in "working together, trust, and frequent communication" (p. 586).	Ostrom, 1990; Heikkila & Gerlak, 2005.
	Stakeholders have the capacity, organizational infrastructure, skills and expertise, time, energy and liberty to meaningful participate.	Ansell and Gash, 2008

Since a case study design is designed to gather information from several sources, I will include organizational documents as another source of data. Such materials will be helpful in identifying organizational beliefs and practices. They may consist of organization's websites, plans or programs, minutes of meetings, progress reports, or/and other internal records. This variety of sources will help me collect information about multiple aspects of the phenomenon under study and expand and check on one another the data I will be relying on for my analysis (Maxwell, 2013).

Understanding the stakeholders' dynamics and interactions

Each case in this research represents the interplay of a variety of stakeholders (affected by or trying to advance a solution) in one or more of the policy goals in conflict. The second step in this study will focus on describing and understanding the interactions of these multiple actors to explain the collaborative/transition process and its outcomes.

According to Hollstein (2011), **qualitative social network analysis** helps "to explicate the […] linkages between network structure and network actors, as well as questions relating to the constitution and dynamics of social networks" (p.2). The author explains that there are six areas which are most suitable for qualitative social network analysis. This research relates to three of them: i) to understand network practices, ii) to explain the effects of networks and iii) to understand network dynamics. This method is helpful to investigate "the concrete acts, practices, interactions, and communication patterns in light of the respective contexts in which they occur"

(p. 406), as well as the mechanisms and conditions that drive specific outcomes (in this case, management transition). For this reason, the social network analysis is deemed an appropriate method to respond the question.

Following Hollstein (2011), the method for data collection for this stage of the research will be the **one-on-one interviews** used for the first step. Thus, the interviews will also explore topics such as the breadth of relationships/partnerships with other actors (both formal and informal; mandatory or voluntary); whether one actor or set of actors holds a central position in the network (*e.g*., regarding power and resources distribution); whether organizations are willing to work with other stakeholders; whether there is frequent communications/exchanges of information or other resources among organizations; the level of coordination/cooperation with/among different levels of government/other stakeholders; which outcomes have been due, at least in part, to linkages with other actors (*e.g.* inter-institutional plans or strategies, and whether they are implemented). The literature on Policy Networks, Collaborative Governance, and Advocacy Coalition Framework will inform this part of the research and interviews. Table 7 summarizes the typical attributes of the networks of actors and their interactions that will be key focus of this research.

Table 7 Identifying interview themes in the literature – Attributes of the networks

What do I need to know (Research Question)	Examples of typical attributes of the networks mentioned in the literature	References
1. Under what <u>conditions</u> do transitions towards integrated systems occur?	Network density, centralization, diversity, cohesiveness, effectiveness.	Bodin and Crona, 2009
Conditions related to the network or multi-stakeholders interactions	Process is participatory, transparent and inclusive.	Ansell & Gash, 2008; Daniels & Walker, 2001; Ostrom, 1990; Weber, 2013.
	Integrates technical expertise and other kinds of knowledge. Leadership/champions, cost sharing, focus on real-world results, sufficient autonomy of action.	Weber, 2013.

	There are conflict resolution mechanisms.	Ostrom, 1990
	Interactions (With whom stakeholders interact?) Type of resources the actors exchange and with whom. Categories of resources: "formal legal authority to make policy decisions, public opinion, information, mobilizable supporters, financial resources, and skillful leadership."	Jenkins-Smith et al., 2014, (p. 198)

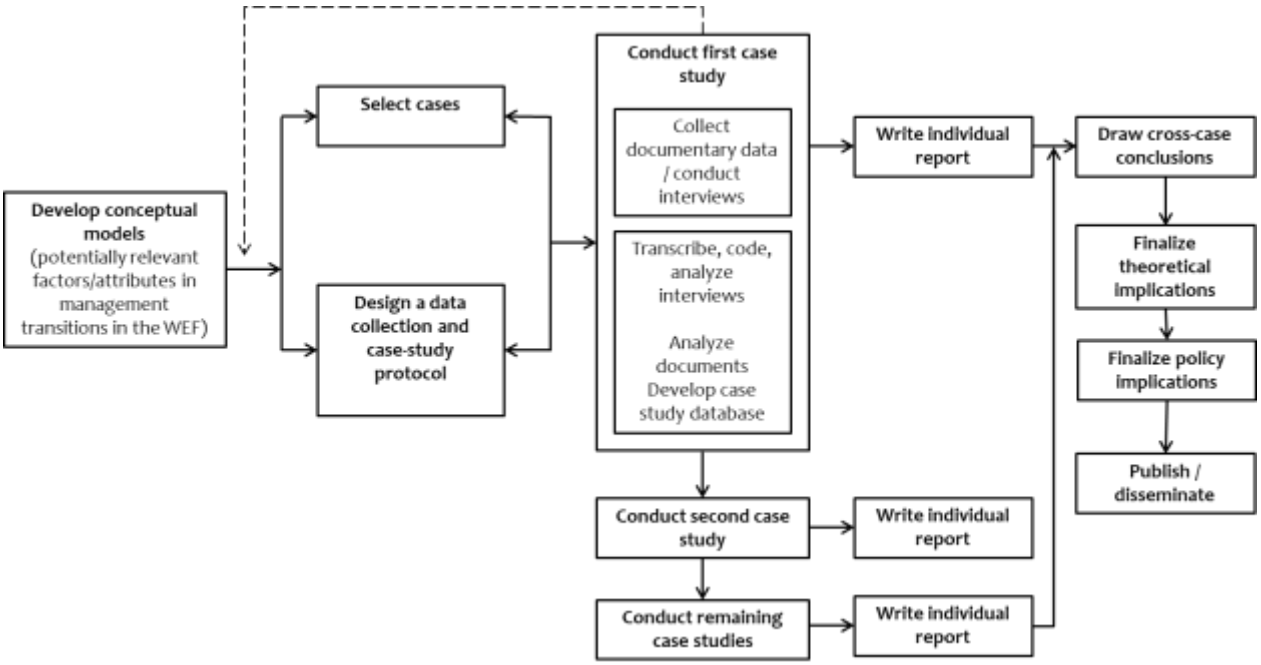
4.3 Data analysis

The one-on-one interviews will be recorded when possible (and with the interviewees' consent), then transcribed, returned to the interviewee for comments, and coded for analysis. Following Lofland and Lofland (2006), I will carry out a double process of **coding**: *open coding* and *focused coding*, moving from categorizing the raw data to broad labels and more conceptual codes that emerge from the conceptual framework and the analysis. I will make use of software designed for this purpose. As suggested by Lofland and Lofland (2006), during the process of coding, I will generate code **memos** to help me keep track of the coding labels, the underlying assumptions when using them, and possible relationships between codes. I will develop a **qualitative codebook** (Creswell, 2014) with the themes and codes that emerge from the data and are informed by the literature, its definitions, a brief explanation of when to use or not each code, and exemplary quotes. I will follow a similar process for the **content analysis** of documents.

Quantitative analysis of social networks "aims to measure their formal properties, notably the strength, intensity, frequency and direction of network relations" (Heath, Fuller & Johnston, 2015, p. 645). In contrast, a common strategy for qualitative analysis of social networks is "to give a detailed account of individual cases by way of 'thick descriptions' that are geared toward tracing how actions or events unfold and the impact they have" (Hollstein, 2011, p. 413). The goal in my qualitative analysis would be to "represent the regular patterns of relations connecting a set of entities, and to explain both why they occur and what their consequences are" (Heath, Fuller & Johnston, 2015, p. 646).

Finally, I will conduct a cross-case analysis (Yin, 2014) with the purpose of interpreting the findings for each case and synthesizing the findings across cases. The research will follow the process depicted in Figure 3, although this process will likely be more iterative and less linear than the figure suggests.

Figure 3 Comparative Case-Study Procedure (Yin, 2014, p. 60)



5. Validity, reliability, and generalization issues

Following Maxwell (2013) and Yin (2014), I examined potential alternative explanations that may pose a validity threat. Table 8 shows these possible validity threats and the methods that I will use to address them. An important validity threat due to personal bias may be to assume that collaboration is required for and invariably leads to sustainable transitions. The research design addresses this possible bias by the case selection strategy described above.

Table 8 Validity Matrix (Adapted from Maxwell, 2013)

What do I need to know (Research Question)	Potential Conclusions	Alternative Explanations (Validity Threats)	Methods to Investigate Alternative Explanations
Under what conditions do transitions towards integrated systems occur?	Initial social capital, leadership, and resources play a significant role. Win-win solutions are achieved when all stakeholders have the capacity and willingness to engage with other stakeholders. Willingness to collaborate may depend on the organizational values in each specific site. Key stakeholders play a leadership role that facilitates the outcome.	Researcher bias in data collection and/or interpretation (collecting only data that "stands out" to me or trying to confirm the literature).	Avoid leading questions. Check interpretation with stakeholders (Creswell, 2014; Maxwell, 2013). Triangulate with other stakeholders and documents (Creswell, 2014; Maxwell, 2013). After completing the first case study, select subsequent cases that allow searching for "discrepant evidence." (Maxwell, 2013).

Regarding reliability –the "consistency and repeatability of the research procedures" (Yin, 2014, p.240)– I will follow Creswell (2013) and Yin (2014) and document as many of the procedural steps I follow in the first case, using memos and developing a database for each case study. In this way, I can minimize variation in the research procedures over the course of the study.

2.6 Ethical considerations

I consider that this research does not involve any potential harm to participants or their organizations. Nor does it imply a particular benefit for participants outside the dissemination of research results. However, some participants may feel uncomfortable talking about the practices and values of the organization in which they work. All the interviewees will be guaranteed anonymity and will be informed beforehand about the purpose of the interview and the intent of publication. They will have the opportunity to review their comments once the interviews are transcribed. In all the cases, I will ask the participants for consent to record the interview before it

starts. If an interviewee refuses to give his or her consent, I will not record the interview, but only take notes.

Because this is a research topic related to organizational practices, I do not consider it to involve sensitive matters, so it is not necessary to hide the objectives of the research or my identity. I will inform all participants about the goals of the investigation. I will present myself as a Ph.D. student conducting my research project.

Regarding data protection, I will store the records and transcriptions in a way that prevents unauthorized dissemination of the information. As the interviewer, I will be diligent about not sharing the information from one respondent with another. Upon completing the research, I will send a brief report of the main findings of the research to all the participants that express interest in it.

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