Understanding Collaborative Governance of the Food-Energy-Water Nexus:

The Cases of Phoenix and Cape Town

by

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ABSTRACT

The food-energy-water (FEW) nexus refers to the interactions, trade-offs, and relationships between the three resources and their related governance sectors. Given the significant interdependencies, decisions made in one sector can affect the other two; thus, integrated governance can reduce unintended consequences and lead towards increased resource security and sustainability. Despite the known benefits, many governance decisions continue to be made in "silos," where stakeholders do not coordinate across sectoral boundaries. Scholars have begun to identify barriers to the implementation of integrated FEW nexus governance, yet there is still minimal understanding of the reasons why these barriers exist and no theoretical framework for evaluating or assessing FEW nexus governance. Integrating the theory of collaborative governance with the concept of the FEW nexus provides an opportunity to better understand the barriers to and structures of FEW nexus governance and to propose solutions for increased collaborative FEW nexus governance in practice. To investigate this governance system, I examined the collaborative governance of the FEW nexus in the context of extreme urban water challenges in two urban case cities: Phoenix, Arizona, USA and Cape Town, South Africa. First, I performed a media analysis of the 2018 Cape Town water crisis to understand the impact of the water crisis on the FEW nexus resource system and the collaborative governance employed to respond to that crisis. Second, I conducted a systematic case study of FEW nexus governance in Phoenix, Arizona to understand barriers to collaborative governance implementation in the system and to identify opportunities to overcome these barriers. Finally, I presented a framework of indicators to assess the collaborative governance of the local FEW nexus. This dissertation will

advance the sustainability literature by moving the concept of FEW nexus governance from theory and conceptualization towards operationalization and measurement.

DEDICATION

To God, who has given me my purpose in pursuing this degree. He is the one who made completing this doctorate possible and who makes it all worth it. All glory to God for the completion of this work.

To Peter Crank, who has been my number one supporter, encourager, and partner in the completion of this research.

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INTRODUCTION

1.1 INTRODUCTION

The food-energy-water (FEW) nexus refers to the interactions, trade-offs, co-benefits, and relationships between the three resources and their related governance sectors (Bazilian et al. 2011). Given these interrelationships, decisions made in one sector can affect the other two; thus, integrated decision-making can help to manage the uncertainties within the systems and enhance sustainability, as stakeholders build capacity to anticipate and manage risk (Lele et al. 2013). It can also increase justice through more equitable access and distribution of FEW nexus resources (Sharma and Kumar 2020). Despite the proposed benefits of integrated decision-making (Leck et al. 2015; Rasul and Sharma 2016), many decisions within food, energy, and water sectors continue to be made in "silos," with limited consultation across sectoral boundaries for decision-making or knowledge co-production (Daher et al. 2019). This can lead to fragmented knowledge generation and incoherent policy that can expose the linked systems to vulnerabilities, uncertainties, and external shocks. Scholars have begun to identify some barriers to integrated FEW nexus decision-making, such as differences in policies and procedures, power asymmetries, and limited communication channels (Howarth and Monasterolo 2016; Liu et al. 2018). There is, however, still minimal understanding of the reasons why these barriers exist (Weitz et al. 2017a); limited empirical scholarship on governance and decision-making of the integrated FEW nexus system (Ringler et al. 2013; Liu et al. 2018), especially using stakeholder engagement (Wahl et al. 2021) and qualitative methods (Albrecht et al. 2018; Newell et al. 2019); and

no established frameworks for assessing FEW nexus governance. Investigating these research gaps will improve basic understanding of effective FEW nexus decision-making and governance by individuals, groups, and society.

The purpose of this research is to (i) better understand the interactions between the three governance sectors in practice, (ii) identify the barriers to FEW nexus governance and examine why they exist, and (iii) develop an approach that moves from theoretical conceptualization of the FEW nexus towards assessment. In order to achieve this goal, I first integrate the developed theory of collaborative governance and the newer concept of the FEW nexus to explore two empirical urban case studies—the Phoenix, Arizona, USA and the Cape Town, South Africa metropolitan areas—to investigate FEW nexus governance in practice. Then, I use the approach of sustainability indicators to develop a preliminary framework that moves FEW nexus collaborative governance towards operationalization and measurement. The remainder of the introduction proceeds as follows. First, I present the theoretical background for the food-energy-water nexus, collaborative governance, and sustainability science and indicators. Second, I provide an overview of the case descriptions for the two case cities. Third, I provide a discussion on the integration of the literatures to achieve the research goal. Finally, I conclude with an outline of following chapters of the dissertation.

1.2 THEORETICAL BACKGROUND

1.2.1 Food-Energy-Water Nexus

As an integrated system, the food-energy-water nexus was first introduced at the 2011 World Economic Forum in Bonn, Germany (Hoff 2011). The FEW nexus was built

off of existing considerations of the two-way interactions between water, food, and energy systems introduced as early as the 1980s (Cohen and Allsopp 1988) and the concept of integrated food, energy, and water systems introduced in the late 2000s (Hellegers et al. 2008). Initially, it was proposed as an approach to address securities of the three resources in the wake of the global food crisis of 2008, in conjunction with drought conditions due to climate change and the need for greater energy security (Hoff 2011; Allouche and Middleton 2015). Yet research surrounding the FEW nexus has increased rapidly and has expanded from a resource-security perspective to include broader framings (Pahl-Wostl 2019). Based on the themes from a bibliometric analysis of FEW nexus literature from Opejin et al. (2020), these framings can be categorized into six main conceptualizations: (1) governance and collaboration (e.g., Leck et al. 2015; Weitz et al. 2017b), (2) the Sustainable Development Goals (SGDs) (e.g., Rasul 2016; Bleischwitz et al. 2018), (3) physical resource flows and quantitative trade-offs (e.g., Chang et al. 2016; Berardy and Chester 2017; Hussien et al. 2017), (4) resource security and political stability (e.g., Rasul and Sharma 2016; Kurian 2017), (5) ecosystem services and environmental management (e.g., Finley and Seiber 2014; Bell et al. 2016), and (6) new technologies and innovations (Villarroel Walker et al. 2014; Daher and Mohtar 2015). In this exploration of the FEW nexus, I focus on the first two conceptualizations.

1.2.1.1 FEW Nexus Governance and Collaboration

FEW nexus governance is conceptualized as the communication and collaboration among stakeholders and decision-makers across the sectoral boundaries of food, energy, and water for integrated governance of the system (Lele et al. 2013). Integrated governance is needed to achieve resource security by considering the interdependencies

of the three nexus resources. Understanding these interactions is key for comprehensive decision-making and governance (Bazilian et al. 2011), and collaboration between the sectors is needed to address security across them (Finley and Seiber 2014). Scholarship on FEW nexus governance has included a diversity of themes, including public engagement for integrated FEW nexus governance (Kurian et al. 2018), stakeholder engagement approaches (Melloni et al. 2020; Kliskey et al. 2021), science-policy considerations (Daher et al. 2020; van Gevelt 2020), and barriers to governance in practice.

Focusing on the latter theme of barriers to FEW nexus governance, much literature has focused on identifying these barriers to coordinated efforts, on understanding the structures of FEW nexus governance systems, and on developing strategies to overcome them. Scholars have identified several key barriers to implementation of FEW nexus governance in practice, including lack of communication, differences in decision-making processes and in regulations, power asymmetries, differing domain interests, and rigid single-sector policies (Howarth and Monasterolo 2016; Weitz et al. 2017b; Liu et al. 2018; Huckleberry and Potts 2019; Pahl-Wostl 2019). To address these barriers, scholars have identified stakeholder engagement as a potential solution (Weitz et al. 2017b; Albrecht et al. 2018; Liu et al. 2018). Many stakeholder groups are aware of the theoretical interactions between the three resources, yet they disagree on whether to focus on advancements of data and science or on integrated policy (Bielicki et al. 2019). Conducting research through stakeholder engagement, then, provides an opportunity to understand local stakeholder perspectives to align nexus research and tools with the values of specific practitioners and policymakers.

Despite the promise of integrated FEW nexus governance, there are several critiques of the conceptualization. One major critique is the ambiguity in the definition and purpose of FEW nexus governance (Smajgl et al. 2016), which has led some scholars to go so far as to call the FEW nexus a "meaningless buzzword" (Cairns and Krzywoszynska 2016). This lack of clarity can prevent practical application without a common understanding among governance stakeholders. A unified framework for nexus governance would provide clarity and consensus on its definition and provide greater support for the practical implementation of the concept (Endo et al. 2017). Additionally, other scholars have challenged the value of considering the three sectors together, noting that each sector is individually complex and that other attempts at integrated governance, such as Integrated Water Resource Management, have fallen short of their purported benefits (Wichelns 2017). A third critique is that FEW nexus governance has put a greater emphasis on theoretically understanding the system and on theory development that on creating tools and implementation approaches (Ringler et al. 2013; Liu et al. 2018). This has led to limited operationalization of FEW nexus governance and minimal measurement, evaluation, and assessment of it.

1.2.1.2 Sustainable Development Goals and the FEW Nexus

A second major conceptualization of the FEW nexus is as a pathway for practical implementation of the SDGs. The United Nations (UN) Sustainable Development Goals are a set of seventeen goals, with a total of 169 targets underneath them, intended to address the major development challenges of our modern world. Introduced in 2015, these goals were designed to be an extension of and improvement from the UN Millennium Development Goals, which were introduced in 2000. The three goals most

relevant to the FEW nexus are Zero Hunger (goal 2), Clean Water and Sanitation (goal 6), and Affordable and Clean Energy (goal 7). Scholars have argued that the FEW nexus can help improve policy, management, and governance to successfully achieve the SDGs (Rasul 2016; Liu et al. 2018; Pahl-Wostl 2019; Bollino et al. 2020). It can identify synergies, co-benefits, trade-offs, and unexpected consequences between the resources and can lead towards greater coordination in the implementation strategies for achieving the goals (Liu et al. 2018).

Several frameworks have been created to integrate the FEW nexus and the SDGs; I highlight several here. Rasul (2016) proposes a framework, based on FEW nexus trade-offs within the SDGs, for integrating nexus policy into practice in South Asia. Liu et al. (2018) provide a conceptual map of how the food-energy-water nexus can be used as a tool to contribute directly to the three nexus-related SDGs, which in turn connect all 17 goals to one another either directly or indirectly; this includes practical steps for implementing a FEW nexus approach in practice for integrated development outcomes. Fader et al. (2018) provide a method to consider the trade-offs and co-benefits between the targets of the three nexus-related SDGs by using a matrix of the targets to identify instances of compatibility and contrast. Using an expanded nexus of the food-energy-water-land-materials nexus, Bleischwitz et al. (2018) conduct a network analysis to understand how the seventeen goals are related to these five nexus resources, arguing that the incorporation of a synergistic approach to achieve the SDGs can overcome the silo mentality. Venghaus and Dieken (2019) use relevant indicators from the SDGs to create a composite indicator of FEW resource security. Finally, Yuan and Lo (2020), use the

relevant targets and indicators within the SDGs to create an adapted indicator set called the Linked Indicators for FEW AvaialbilitY (LIFEWAY) indicators.

Though there are theoretical advantages to an integrated approach to the SDGs through a FEW nexus lens, there are challenges to the practical integration of the two frameworks. For one, there is more time, expertise, coordination, and financial resources needed to implement a nexus approach in comparison to traditional siloed governance (Liu et al. 2018). Additionally, the FEW nexus concept has often omitted direct considerations of livelihoods and the environment (Simpson et al. 2019a). As much of the key purpose of the SDGs is to secure resources for livelihood improvement and environmental conservation, the FEW nexus does not provide a direct avenue towards achieving these goals.

1.2.2 Collaborative Governance

Collaborative governance is an approach and process to shape public policy, management, planning, and implementation by engaging multiple actors across sectors and scales to influence decision-making process, public policy, management, and governance (Ansell and Gash 2008; Emerson et al. 2012; Yeboah-Assiamah et al. 2016; Newig et al. 2017; Sullivan et al. 2019). Beginning in the public administration field in the 1990s (Freeman 1997), collaborative governance has grown and been applied to a wide range of contexts from economic policy (e.g., Agranoff and McGuire 1998) to natural resource management (e.g., Koontz and Thomas 2006). Within natural resource management, collaborative governance has been promoted as a paradigm that supports effective resource governance by overcoming challenges of power asymmetries,

enhancing accountability of the decision-making entity, increasing transparency of the decision-making process, including stakeholders directly in knowledge generation, and facilitating cross-sector coordination and planning (Ansell and Gash 2008; Emerson et al. 2012). Collaboration of actors from across scales and disciplines can lead towards greater credibility, legitimacy, and salience in the decision-making process, which can result in reduced vulnerabilities in the natural resource system (Cash et al. 2003).

Two key frameworks have been created to understand the process of collaborative governance. The first was created through a literature review by Ansell and Gash (2008). This framework focuses on understanding the factors that contribute towards success and failure in the collaborative process. Most central to collaborative governance is the collaborative process itself, which is dependent upon the iterative cycle of face-to-face dialogue, trust building, commitment to the process, shared understanding, and intermediate outcomes. It is heavily influenced by factors such as previous history of conflict or cooperation, power imbalances, and incentives for participation (Ansell and Gash 2008). A second key framework was created by (Emerson et al. 2012) to improve on the first by emphasizing the iterative and dynamic nature of collaborative governance in practice. This framework is centered around the Collaborative Governance Regime (CGR), which considers how principled engagement, shared motivation, and capacity for joint action work together toward shared outcomes (Emerson et al. 2012). Beyond these frameworks, numerous empirical studies (e.g., Medema et al. 2017; Sullivan et al. 2019) and theoretical scholarship (e.g., Yeboah-Assiamah et al. 2016; Newig et al. 2017) have considered approaches for success and failure of collaborative governance. Others have designed approaches for evaluating and assessing how collaborative governance

influences decision-making processes and outcomes (e.g., Thomas and Koontz 2011; Muñoz-Erickson 2014; Biddle 2017; Abrams et al. 2020), which is important to understand its potential benefit and limitations in practice (Conley and Moote 2003)

Despite the potential benefits of collaborative governance, there are several critiques. Some scholars have critiqued the concept for the ambiguity and lack of consensus in the definitions and operationalization of collaborative governance (Emerson et al. 2012; Plummer et al. 2012), which presents challenges for measurement, evaluation, and assessment of collaborative governance approaches (Potts et al. 2016). Others have questioned whether collaborative governance actually affects environmental outcomes in practice (Koontz and Thomas 2006). Finally, collaborative governance has also been critiqued for failing to sufficiently incorporate and address issues of power (Brisbois and de Loë 2016; Eberhard et al. 2017). Notwithstanding these critiques, collaborative governance offers opportunity to address integrated governance within the FEW nexus and to improve decision-making of the complex FEW nexus system.

1.2.3 Sustainability Science and Indicators

Sustainability science seeks to address complex problems between human, natural, and economic systems in the face of external drivers (Kates 2011). The field encompasses interactions on the local to global scale, requires innovations to address issues within the human-nature system, and combines different ways of learning and thinking (Kates et al. 2001). Sustainability science seeks to address the complexity of the interconnected relationship between society and the environment through interdisciplinary approaches of problem-solving (Clark and Dickson 2003). Though

sustainability concepts can be traced back to at least the late 1800s, stress on the earth system through increasing population growth and per capita consumption in the mid-twentieth century advanced the conversation about the need for sustainable practices (Du Pisani 2006). Conversations surrounding our modern conceptualization of sustainability initiated around the 1970s with the global oil crisis, shifts in economic development, and shifting world perspectives on environmentalism, among other discussions (Du Pisani 2006). Formal conceptualization of sustainability emerged from the 1987 Brundtland report, *Our Common Future*, which conceptualized sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations 1987, p. 383). From the concept of sustainable development, sustainability science emerged in the 1990s to expand the sustainable development conversation and put greater focus on complex system challenges across social, environmental, and economic domains (Clark 2007; Kates 2011).

Since the 1990s, publications in sustainability have increased rapidly (Kates 2011). With continued awareness of complex external challenges, such as climate change and poverty, increasing focus has been placed on utilizing sustainability science to explore the complexities of these issues (Clark 2007; Wiek et al. 2011). This has resulted in a diversity of perspectives and approaches, including transdisciplinary work (Lang et al. 2012), systems thinking (Wiek et al. 2011; Anderies et al. 2013), resilience thinking (Walker et al. 2004; Folke et al. 2010; Redman 2014), social-ecological systems (Ostrom 2009), studies of common pool resources (Ostrom 1990, 2005), and sustainable development (Parris and Kates 2003; Hopwood et al. 2005; Kates et al. 2005). Much of

the research in sustainability focuses on understanding the complexity of coupled human-nature systems (Clark and Dickson 2003; Miller et al. 2014). One of the key similarities across all conceptualizations is the focus on transdisciplinary work that incorporates systems thinking across scales and sectors. As sustainability continues to develop, the future of sustainability science is moving towards increased focus on solutions-based research that addresses relevant challenges in our changing world (Miller et al. 2014).

One of the main approaches to implementing different conceptualizations of sustainability is through the creation and application of indicators. Indicators help to move from conceptualization to operationalization and measurement, using information about the social, economic, and environmental aspects of a complex system to provide manageable units for evaluation and assessment (Böhringer and Jochem 2007). As symptoms or signs of sustainability, indicators can be useful in policy making and for communication (Singh et al. 2009). Sustainability indicators have been applied to a large number of concepts such as sustainable development (e.g., the Sustainable Development Goals (United Nations 2015)), ecosystems services (e.g., the ecological footprint (Wackernagel and Rees 1998)), wellbeing (e.g., the Well-Being Index (Prescott-Allen 2001)), and economics (e.g., the Genuine Progress Indicator (Cobb et al. 1995)). Though sustainability indicators have been helpful in strengthening the conceptualization of the discipline (Verma and Raghubanshi 2018), several scholars have criticized the approach. Indicators have been critiqued for having little standardization in the creation process and for failing to reflect the entirety of sustainability (Böhringer and Jochem 2007). Additionally, the lack of clear consensus on term definition within sustainability allows for multiple interpretations of the concept and the relevant indicators (Tanguay et al.

2010), resulting in numerous indices without standardization. Within sustainable development specifically, there is debate over the top-down verses bottom-up approaches to indicator development (Turcu 2013). Despite these critiques, indicators offer the most widely accepted opportunity for sustainability measurement in research, practice, and policy. This dissertation seeks to contribute to sustainability indicator research by creating a framework that integrates top-down scientific approaches with bottom-up stakeholder engagement approaches, which scholars had identified as a needed approach (Rametsteiner et al. 2011).

1.3 CASE DESCRIPTIONS

1.3.1 Phoenix, Arizona, USA

The Phoenix, Arizona metropolitan area is located in the Southwestern region of the United States. Home to approximately 4.5 million people, it is considered one of the fastest growing cities in the nation, with an expected 2050 population of about 7 million residents. The climate of the region is semi-arid, with an average annual rainfall of approximately 9 inches. Figure 1 provides an image of the study area for the Phoenix area.

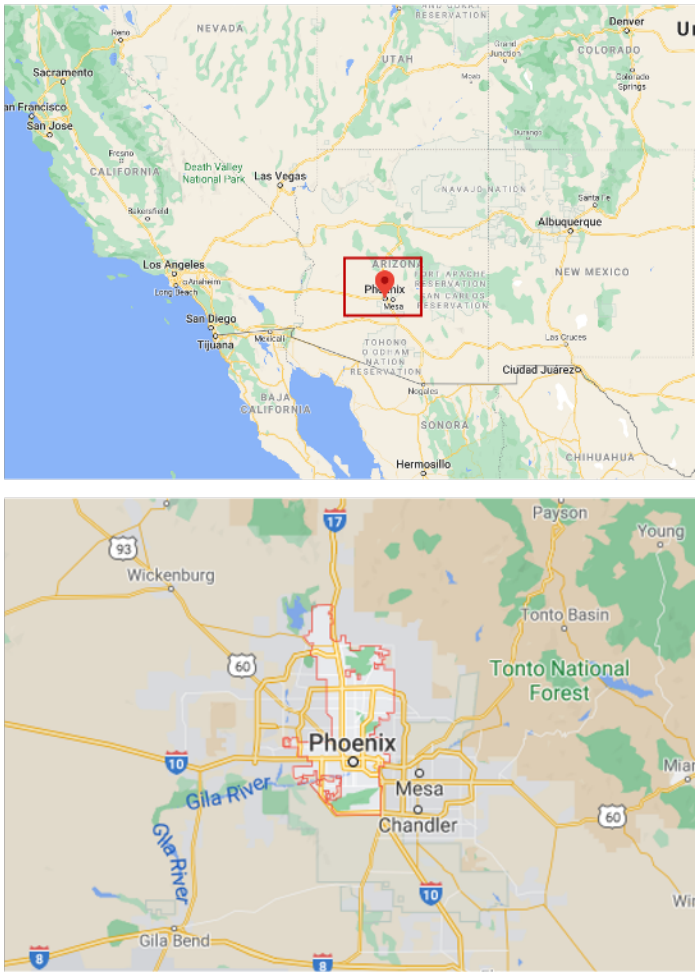

Figure 1: Map of Phoenix, Arizona, USA and the surrounding metropolitan area.

In order to support the area, water is supplied from four sources: local surface water, imported water from the Colorado River, groundwater, and reclaimed water (Larson et al. 2013). Water governance is complex and consists of a diversity of actors at the regional and local scales, which are responsible for the supply, delivery, demand, and outflow of water resources (Larson et al. 2013). One of the complexities of water management in Phoenix is Arizona's location within the Colorado River Basin, a watershed which has over-allocated water rights. Arizona is one of seven states in the

basin, and one of the three states in the Lower Basin, along with Nevada and California. Between these states, each has agreed to reduce their withdrawals from the river system in the event of a water shortage that leads to a significant reduction in Lake Mead, a major reservoir for the lower basin states (Sullivan et al. 2019). To plan for how the shortage will impact various sectors within Arizona, the state established a Drought Contingency Plan in January 2019 with negotiated voluntary water use reductions and conservation approaches (Sullivan et al. 2019). Though a shortage was initially predicted to occur in 2019, winter rains and conservation managed to avoid a shortage from happening. However, a second complexity is that a megadrought continues throughout the region, thus there is an increasing probability of the first-ever water shortage in Lake Mead occurring in the near future. Here, a megadrought is defined as a drought of great intensity that lasts for two decades or longer (Cook et al. 2007). The region has experienced the most extreme drought in a century, causing water levels in many reservoirs to drop to historic lows (Udall and Overpeck 2017; Overpeck and Udall 2020). With climate impacts exacerbating the drought, it is expected that the region will experience more extreme heat and more frequent and extreme drought with more variable precipitation (Gonzalez et al. 2018), which are threats to the security of food production, energy generation, and water security.

Water is a limiting natural resource within the Phoenix area, and this has strong implications for the interlinkages between the food, energy, and water nexus (White et al. 2017; Clark et al. 2019; Guan et al. 2020). Agriculture is important to the culture and history of Arizona, with farms ranging in size from small, family-owned farms to large commercial ones. Though agriculture in the region is declining, irrigation still accounts

for much of the water demand in the area. Agricultural governance is generally decentralized. While most decisions are made at the farm-level or through local collaborative organizations such as irrigation districts and lobbying associations (e.g., AZ Cattlemen's Association, Cotton Growers Association), the state and national Departments of Agriculture set some regulations (Eakin et al. 2016). In addition, energy is also intricately tied to the water system. Energy is used for conveyance of surface water, water distribution, groundwater pumping, drinking water and wastewater treatment, and cooling of the Palo Verde Nuclear Power Plant, the largest nuclear plant in the country (Bartos and Chester 2014). Additionally, much energy is needed to support the Central Arizona Project (CAP) canal, which brings water 336 miles over nearly 3000 feet in elevation change to deliver water from the Colorado River to central and southern Arizona (Bartos and Chester 2014). CAP is the single largest user of electricity in the state, using 2.8 million MWh to deliver 1.6 million acre-feet of water (Bartos and Chester 2014). Energy governance is centralized around a few sub-regional actors, including the utility companies and the AZ Corporation Commission.

1.3.2 Cape Town, South Africa

The Cape Town metropolitan area is located in the Western Cape region of South Africa. Figure 2 provides an image of the location of the study area for the case. It contains a population of approximately 4 million people, with a growth rate of 0.9% each year (Western Cape Government 2017). The region has a Mediterranean climate characterized by warm and dry summers, with mild and wet winters (Sousa et al. 2018). Water management in the Cape Town metropolitan area has the challenges of an uneven

distribution of water both spatially and temporally (Wright and Jacobs 2016; Ololade 2018) and of limited space for increased water storage capacity (Herrfahrdt-Pähle 2013).

Figure 2: Map of Cape Town, South Africa and the surrounding metropolitan area.

Water governance is multi-leveled with much governance occurring at the regional, basin scale, though some power is held at the national level and some is allocated to the municipality (Beck et al. 2016). Though droughts in the region have resulted in water restrictions in Cape Town previously, the water crisis of 2018 led the city to almost run out of water. After a three-year drought, in January 2018 city officials

marked a date in mid-April for "Day Zero," the day when the dams would reach 10% capacity and all non-emergency taps would be shut off as the remaining water could not be mined from the reservoirs (Sousa et al. 2018). Increased demand on the water system from rapid population growth, increasing tourism, and expanding agriculture led to stress on the water system and stretched limited water resources (Sousa et al. 2018). In order to avert Day Zero, the city implemented strict water restrictions of 50 liters of water per person per day, and the agricultural sector was allocated 30% less water for irrigation. Thankfully, with plentiful winter rains and substantial water conservation, the city was able to avoid Day Zero completely and relaxed the water restrictions in October 2018. However, in the face of climate change, water challenges are expected to persist in the region with droughts becoming more common and severe in the Western Cape (Pascale et al. 2020).

The Cape Town metropolitan area contains strong interlinkages between the three resources of food, energy, and water within the context of the water crisis. Agriculture surrounds Cape Town, sharing the water supply that feeds into the city. This water is critical for both large-scale exports, such as wine in the world-renowned wine regions of Stellenbosch and Franschhoek, and for small-scale subsistence farmers. Thus, impacts on the agriculture sector from the water crisis could have major impacts on economics and livelihoods. Governance of agriculture is highly decentralized, generally managed at the farm level and the local level through Water User Associations (Termeer et al. 2018). Unlike agriculture, energy governance is highly centralized at the national level, with the single utility Eskom providing 95% of the country's electricity (Inguscio 2017). Regulation, management, and tariff setting of electricity is also managed through the

national government (Kelly and Geyer 2018). In the Cape Town metropolitan area specifically, the increasing population has led to greater demand on the electricity grid, which contributed towards a local energy crisis in 2008 (Jaglin 2014) and still leads to planned load-shedding as recently as 2020. The strained electrical grid has a direct impact on water availability, as energy is needed for water distribution, for drinking-water and wastewater treatment, and for some groundwater pumping and conveyance. Additionally, with desalination as a current plan for increased water augmentation, increased electrical capacity would be needed to support existing residents and industry as well as increased water augmentation.

1.3.3 Case Selection

I chose to focus on the urban level of FEW nexus governance because cities are a relevant decision-making scale, with many resource decisions made at the local level (White et al. 2017; Mounir et al. 2019) and because there are limited FEW nexus studies at the urban scale (Newell et al. 2019; Zhu et al. 2020; Wahl et al. 2021). These two specific cases were selected for several key reasons. First, the two cases share several key elements for food, energy, and water governance. Both cases contain strong interlinkages between the three FEW nexus resources, and both have similar governance structures for each of the resource sectors: centralized energy governance, distributed food and agriculture governance, and multi-leveled water governance. Second, both cases represent instances where extreme drought led to imperative water decision-making to mitigate the impacts on interconnected sectors. These cases thus are exemplars of the phenomenon of interest, instances of severe drought, and they provide unique yet diverse

contexts for examination. Additionally, the difference in the type of drought that occurred between the two cases—a chronic, megadrought in Phoenix and an acute, severe drought in Cape Town—provide opportunity to consider differing contexts of severe water stress. Third, these cases provide examples of "nexus hotspots," which are systems with numerous interactions between food, energy, and water resources and governance sectors (Mohtar and Daher 2016; Daher et al. 2018). As this study includes only two cases, there may be limited generalizability to other contexts (Stake 2006; Ember and Ember 2009). However, the richness of the cases provides analysis that will present an initial understanding of the collaborative governance of FEW sectors within situations of water stress and provide theoretical propositions for greater understanding of FEW nexus collaborative governance.

1.4 DISCUSSION

The goal of this dissertation is to understand the collaborative governance of the urban FEW nexus in practice under conditions of water stress and to propose a framework that moves the concept of FEW nexus governance from theory towards assessment. To achieve this goal, I combine the distinct literatures of the theory of collaborative governance and the concept of food-energy-water nexus governance. First, despite the prospect that it offers to understand and implement collaborative approaches to policy, management, and governance, the theory of collaborative governance has not yet been applied to the concept of the FEW nexus. Integrating the two disparate literatures of collaborative governance and the FEW nexus offers opportunity to further advance, understand, and develop the concept of FEW nexus governance. Though

collaboration across all resource sectors may not be effective, certain resources could greatly benefit from collaborative approaches. Collaboration specifically between food, energy, and water resources is important because of the strong interdependencies between them (Lele et al. 2013; Leck et al. 2015). Knowledge sharing, data sharing, and policy making are areas where collaboration across the three sectors could lead towards collaborative benefits. These approaches can help reduce uncertainty and risk, as real-world water governance and sustainability problems are complex and span across multiple disciplines (Dewulf et al. 2007). Additionally, collaboration allows for complex learning and problem solving (Ansell and Gash 2008). An example of the benefit of collaborative governance for the FEW nexus can be seen through a case study of the Renewable Energy Sources Act in Germany. The Act was created through input from all three FEW nexus sectors and regulation power is delegated to both the agricultural and energy sectors (Märker et al. 2018). Through this collaboration, the Act focuses heavily on increasing biomass production as a renewable source for electricity and was successful in mitigating potential trade-offs such as increasing the amount of cultivated land to produce biomass (Märker et al. 2018). This provides an example of effective collaboration within decision-making between the FEW nexus sectors, providing support for the implementation of collaborative FEW nexus governance in other contexts as well.

Second, moving from theory towards operationalization and measurement is key for understanding collaborative FEW nexus governance. While indicator sets for the FEW nexus have been created (Willis et al. 2016; Venghaus and Dieken 2019; Yuan and Lo 2020), these focus on physical resource flows and resource security instead of integrated governance. To move towards measurement of collaborative FEW nexus

governance, I incorporate key approaches for sustainability indicator sets and design processes, which provides the opportunity to design an indicator framework to begin the process of moving toward assessment of collaborative FEW nexus governance. To do this, I identify twelve concepts of collaborative FEW nexus governance. I identified these concepts through a targeted, though not comprehensive, literature review of collaborative governance concepts, FEW nexus governance components, and sustainability indicators. I continued to add new papers until data saturation was reached. Data saturation is the point at which additional scholarship reveals no new information about the concept of interest (Guest et al. 2006; Saunders et al. 2018). This resulted in a list of twelve concepts that are important for collaborative governance to take place. These twelve concepts can be seen in table 1. Chapter 4 provides additional detail about the concept selection process. These twelve concepts mark the backbone of the dissertation research and provide a thread between the chapters. In sum, I combine the two literatures of collaborative governance and the FEW nexus, and use the approach of sustainability indicators, to advance the scholarship of FEW nexus governance through an exploration of collaborative FEW nexus governance in practice and through the creation of an indicator framework.

Table 1: Twelve concepts for collaborative FEW nexus governance

Concept	Definition
Institutions	Roles and rules of actors in engagement and the structure of actor organizations
Actor Inclusivity	Inclusion of a diversity of actors across the three FEW nexus sectors in engagement
Resources	The sharing of finances, time, skills, personnel, or capital resources across the FEW nexus sectors
Shared Values	Shared interests, values, or perspectives between actors across FEW nexus sectors; efforts made to accept and understand different cultures, perspectives, or values of other FEW nexus sectors
Power	Efforts to overcome an asymmetry of power dynamics between actors; an understanding of these imbalances and attempts to achieve fairness in the process
Knowledge	Shared knowledge and information across FEW nexus sectors to address a problem or engage in collaboration
Trust	Presence of trust across FEW nexus sectors; belief that all actors are acting in good faith or with good will and intentions
Shared Goals	Shared purpose, vision, or goals across FEW nexus sectors
Communication	Effective, open, and/or iterative communication or dialogue across FEW nexus sectors
Leadership	Intentional leadership by an actor or organization to bring actors to the table, keep the process moving, and facilitate and mediate the collaborative process
Commitment	Shared commitment or dedication to the collaborative process and a willingness to participate across FEW nexus sectors
History*	Prior history of cooperation between actors across FEW nexus sectors; low levels of conflict between sectors

**History impacts all the collaborative FEW nexus governance concepts. Thus, it may be examined separately from the other concepts.*

1.4.1 Knowledge Gaps

This research addresses three knowledge gaps within the FEW nexus literature. First, several scholars have called for increased scholarship on the governance of the FEW nexus (Opejin et al. 2020; Urbinatti et al. 2020). While there is notable literature on governance of the FEW nexus, FEW nexus scholarship has focused heavily on physical resource flows and scholars argue for needed attention to focus specifically on integrated

FEW nexus governance. Second, there is a call for increased research using empirical study and participatory approaches (Ringler et al. 2013; Liu et al. 2018; Urbinatti et al. 2020), especially using qualitative analysis (Endo et al. 2017; Albrecht et al. 2018; Newell et al. 2019) and stakeholder engagement methods (Wahl et al. 2021). Furthermore, scholars have called for these empirical studies to focus increasingly on the local scale instead of the macro-level (Mounir et al. 2019; Simpson et al. 2019a; Zhu et al. 2020). Finally, there are critiques of limited operationalization and measurement of the FEW nexus (Allan et al. 2015; Endo et al. 2017; Wahl et al. 2021); this is even more true within the FEW nexus governance theme, where no frameworks for governance measurement, evaluation, or assessment have yet been established. Tools have been developed to engage stakeholders and frameworks have been created to strive to move from theory to practice, but strategies to evaluate and assess FEW nexus governance itself have not yet been developed.

1.4.2 Intellectual Contribution

This dissertation addresses these knowledge gaps and contributes towards advancing intellectual knowledge in several ways. First, this dissertation contributes towards the focal and methodological limitations identified as research gaps within the FEW nexus literature. By specifically focusing on FEW nexus governance, instead of physical resource flows or technical tool development, this dissertation addresses the calls for increased scholarship on FEW nexus governance. Additionally, the research conducts an empirical study, uses qualitative methods, and focuses on the local, urban scale to understand FEW nexus governance in practice. These methodological

components further advance previous calls for the future direction of FEW nexus scholarship.

A second intellectual contribution of this dissertation is that this research advances the study of FEW nexus governance by moving toward an approach to assessment. Despite the growing call for increased implementation of FEW nexus approaches to policy, management, and governance, there are not yet methods for evaluating and assessing the level of collaboration within those engagements. Assessment of FEW nexus governance is important as it can provide a baseline of the existing level of collaboration, can identify where increased collaborative effort is needed, and can shed light on the effectiveness of collaboration in improving desired outcomes (Conley and Moote 2003). This dissertation research moves FEW nexus scholarship from theoretical framing towards assessment. It thus provides a strong methodological contribution to the concept of the FEW nexus.

Third, this study contributes towards the intellectual scholarship of collaborative governance theory by providing a framework towards measurement of multi-disciplinary collaborative governance for assessment of cross-sector collaborative governance arrangements. Currently, the scholarship on measurement, evaluation, and assessment of natural resource collaborative governance has focused on evaluating collaborative governance within a single sector. While some cross-disciplinary applications do exist, such as those of environmental governance, they generally do not consider multiple resource sectors and their interconnections. By designing an approach to collaborative governance based on the multi-disciplinary FEW nexus system, the framework presented

here provides an opportunity for interdisciplinary assessment approaches for collaborative governance of other multi-sector and interdisciplinary resource systems.

Finally, this study contributes towards the field of sustainability science by increasing scholarship of solutions-based and stakeholder-focused research. Scholars have argued that the future of sustainability science must be focused on solutions-based research that leads to practical change (Miller et al. 2014). This dissertation provides recommendations for improved collaborative governance of FEW nexus sectors in practice, which can lead to increased resource security and system sustainability. With climate chance increasing the uncertainty of decision-making, these proposed recommendations may be helpful for decision-makers and stakeholders to engage in FEW nexus approaches that lead towards integrated decision-making, policymaking, and resource management in practice. Additionally, engaging stakeholders through the research process is important for applying sustainability to real-world contexts (Lubchenco 1998). Through the stakeholder engagement process in the methods of this research, this study can encourage stakeholders to implement collaborative governance approaches to their decision-making in the FEW nexus system governance for increased sustainability.

1.5 CONCLUSION

The goal of this research is to understand the collaborative governance of the urban FEW nexus under conditions of environmental stress. It seeks to address this goal by integrating the disparate literatures of collaborative governance and the FEW nexus through multiple approaches and case examples. It advances the concept of FEW nexus

governance to encourage greater collaborative governance in practice. This dissertation contains three central research components: (1) investigating the role of collaboration and the impacts of the Cape Town water crisis on the local FEW nexus, (2) identifying and understanding barriers to collaborative governance and recommending processes to overcome these barriers through a case study of Phoenix, Arizona, and (3) creating an indicator framework to assess the collaborative governance of the FEW nexus in practice. The remainder of this dissertation will proceed as follows:

Chapter 2: Media framing of the Cape Town water crisis

In the second chapter, I conduct a media analysis of news articles surrounding the Cape Town water crisis. As the 2018 Cape Town water crisis captured the attention of national and international news outlets, media framing provides a unique perspective of the crisis, which can shed light onto the perceptions of society and onto potential influences on policymaking. The goal of this chapter is to use media framing to understand the discourse of news about the water crisis, to investigate the role of collaborative governance in responding to the crisis, and to understand the impact of the crisis on the interconnected FEW nexus sectors. Through content analysis, this chapter investigates the media to understand the collective action framing of the crisis and its intersection with collaborative governance components and FEW nexus impacts.

Chapter 3: Understanding barriers to collaborative governance for the food-energy-water nexus

In the third chapter, I perform a structured case study of collaborative governance of the FEW nexus in Phoenix, Arizona, USA. The Phoenix metropolitan area contains strong interconnections between the three FEW nexus resources; however, theoretical

scholarship of FEW nexus governance suggests that there is limited collaboration between the three governance sectors. Yet collaborative governance in the FEW nexus can lead towards greater system sustainability and resource security. The purpose of this study is to identify key barriers to implementing FEW nexus governance in practice, to understand how stakeholders experience those barriers, to make propositions of why they are in place, and to propose recommendations to overcome these barriers. Using interview and participant observation data with qualitative coding analysis, this case study is designed around theoretical propositions put forward from previous literature. The results of this study will be important for increasing the understanding of barriers to collaborative FEW nexus governance and to move towards greater collaborative approaches in practice.

Chapter 4: Assessment of food-energy-water nexus governance

In the fourth chapter, I present a framework and accompanying indicator set for assessment of the collaborative governance of the FEW nexus system at the urban scale. Through literature review of collaborative governance, FEW nexus governance, and sustainability indicators, this framework includes a theoretical framework of collaborative governance within the context of FEW nexus governance and an accompanying indicator set to assess the key components of the framework. This framework is then applied to the two urban cases of Phoenix and Cape Town, providing preliminary examples of the application and utility of the framework and indicators. This framework moves the FEW nexus governance scholarship from theory towards assessment.

In the fifth chapter, I conclude with a summary of the key findings from the previous chapters, important overarching conclusions, and propositions for future research. Ultimately, this research seeks to understand the nature of collaborative FEW nexus governance in the urban system. This will help to increase the implementation of collaborative FEW nexus approaches to governance in practice, as collaborative governance can lead towards increase resource security and system sustainability, goals of FEW nexus governance. This dissertation will advance the scholarship of FEW nexus governance by integrating the FEW nexus literature with the theory of collaborative governance to (i) understand FEW nexus governance in practice across two urban case studies, (ii) address several knowledge and methodological gaps identified by previous scholars, and (iii) move the concept of FEW nexus governance from theoretical conceptualization towards assessment through the creation of a preliminary framework and indicator set.

CHAPTER 2

MEDIA FRAMING OF THE CAPE TOWN WATER CRISIS PROVIDES INSIGHTS INTO COLLABORATIVE GOVERNANCE OF THE FOOD-ENERGY-WATER NEXUS

2.1 INTRODUCTION

In 2018, the metropolitan area of Cape Town, South Africa experienced a severe water crisis, due to the effects of an extreme drought and exacerbated by mismanagement and rising demands from agricultural expansion, population growth, and tourism (Sousa et al. 2018). In January 2018, the city identified a date in mid-April when dam levels would reach 13.5% capacity and all non-emergency taps would be shut-off; this was dubbed "Day Zero" (Sousa et al. 2018). On Day Zero, residents would have to queue at one of 200 public water distribution sites around the metropolitan area to collect 25 liters of water per person per day. To avoid Day Zero, the city enacted severe water restrictions, defined as level 6B shortage, where citizens were limited to 50 liters of water per person per day, with high fines for violations. Fortunately, with plentiful rains and high residential water conservation, the city avoided Day Zero and relaxed water restrictions in October 2018. However, as the climate crisis is expected to increase the risk of meteorological droughts in Cape Town (Pascale et al. 2020), the city must prepare for future drought, and lessons learned from the crisis can inform other water-stressed cities.

The water crisis attracted global attention, as urban water managers evaluated their own vulnerability in water management approaches and media outlets highlighted the events leading up to Day Zero and beyond. Media coverage has been shown to shape

public opinion and behavior (Slater 2007) and media framing shapes public discourse (Ryan et al. 2001), thus influencing public policy and management, which can potentially constrain options or open up policy windows. Examining media framing of the Cape Town water crisis reveals one key perspective to improve our understanding of the causes and responses to the events. This understanding may also inform our ability to anticipate and adapt to future crises, in Cape Town and beyond.

The purpose of this research is to understand the media discourse surrounding the 2018 Cape Town water crisis, the nature of collaborative governance between key actors, and the impact of the crisis on the related food and energy sectors. I address the following research questions:

(1) What is the media framing of the governance of the Cape Town water crisis? How does media reveal diagnostic, prognostic, and motivational frames in discourse?
(2) How does media framing reveal collective action frames of collaborative governance?
(3) How does media framing construct the impacts of the water crisis on the food-energy-water (FEW) nexus?

To answer these questions, I conducted a media framing study using content analysis of news articles. The media framing approach was selected because framing can influence what society, and thus decision-makers, deem important, as frames spread through discourse, and framing can be indicative of how decision-makers respond to a crisis (Benford and Snow 2000). Understanding the media framing around collaborative governance and the FEW nexus can also shed light onto the value of integrated FEW nexus decision-making. With the strong interlinkages between the food, energy, and

water resources, collaborative governance between them is important for long-term resource security and sustainability of the system. Understanding the role of collaboration between the FEW nexus governance sectors is thus important to present best practices to move towards greater integrated governance in practice.

Environmental problems, including challenges with water and drought management, can be considered collective action problems (Bodin 2017). Using collective action framing thus provides an opportunity to examine the collaborative governance and the FEW nexus system of the water crisis. By analyzing the co-occurrence of concepts between collective action framing, collaborative governance, and the FEW nexus, this research has several novel contributions. First, I apply media framing methods through empirical observation of the FEW nexus, responding to the call for increased FEW nexus scholarship using empirical approaches (Liu et al. 2018), qualitative methods (Albrecht et al. 2018), and a focus on the governance perspective of the FEW nexus (Opejin et al. 2020). Second, I extend previous FEW nexus research in Cape Town to add qualitative depth to previous modeling studies on resource interactions and to examine the inter-sectoral governance of those resources. Finally, I provide an example case of the urban governance response to a major water crisis, where lessons learned from Cape Town's response can be implemented in other water-stressed cities to improve management approaches and prevent future water crises. As the Cape Town water crisis became an international media headline, many cities began to consider their own water security and plans for future management. Based on media reporting, this research provides an understanding of the nature of the water crisis based and the of the

discourse that was provided to international cities that are using this case as an example in calls for improved water management agenda setting.

2.2 THEORETICAL BACKGROUND

2.2.1 Framing Theory

Framing has been examined in a diversity of different contexts within environmental science and policy, including environmental social movements (e.g., Barthel et al. 2015), urban resilience (e.g., McGrail et al. 2015), and discourse analysis of environmental policy (e.g., Hajer and Versteeg 2005; Hall and White 2008; Leipold et al. 2019). Frames, the central unit of analysis in framing theory, are schemas of interpretation, used for the identification or perception of life events and occurrences (Snow et al. 1986). Framing, then, is the use of certain words or phrases to promote one interpretation of a set of facts and discourage others (Benford and Snow 2000; Hall and White 2008). While this process occurs naturally in discourse, framing is also used strategically for rhetorical, political, and persuasive communication. Frames then are a particular manifestation of understanding that simultaneously reflect and shape the broader discourse. Frames are dynamic overtime. Those with greater credibility and that are perceived to align well with events in the world will increase and diffuse throughout society in a process known as frame resonance (Benford and Snow 2000).

Collective action framing is one well-developed approach that examines frames as diagnostic, prognostic, and motivational (Benford and Snow 2000). Diagnostic framing refers to the identification of the problem and the attribution of blame or responsibility for those problems. Prognostic framing is defined as articulation of a proposed solution or

plan of attack. Motivational framing is the call to action or rallying of people. One venue for the exploration of collective action frames is through the media. This is because media has the ability to shape social movements that lead towards change (Gamson and Wolfsfeld 1993). Studying media framing illustrates how frames influence public and political perceptions, actions, and responses to a specific phenomenon (Scheufele 1999). Extensive media coverage can influence public opinion of the phenomenon and the public perception of the cause of said phenomenon (Althaus and Tewksbury 2002; Slater 2007). Media can also elevate a particular concern to gain increased political visibility and influence public policy (Birkland 1996; Settles and Lindsay 2011). Thus, examining media framing is valuable for understanding both the public perception and the potential policy responses of a particular event or phenomenon.

The high volume of media attention given to the Cape Town water crisis provides an opportunity to capture a diversity of frames and to understand the nature of collaborative governance of the crisis and its impacts. Specifically, it allows us to gain insight into *both* the public perception (Slater 2007) and the potential influence on public policy (Birkland 1996). Some research has begun to examine the media framing of the Cape Town water crisis. Grammer (2018) used quantitative and qualitative approaches to explore the media on the water crisis generally and to identify the key frames or themes that were used to discuss the crisis. Simpson et al. (2019) created a chronology of media articles that demonstrate key turning points in the framing surrounding the drought in Cape Town that led into the 2018 water crisis. These studies provide valuable background about the frames surrounding water scarcity in the Cape Town metropolitan area. However, they do not capture the frames around its impact on related natural

resource sectors, the interdisciplinary nature of the water crisis, or the scope of collaborative governance in response to the water crisis.

2.2.2 Collaborative Governance

Collaborative governance is an approach to public policy and management that engages actors across sectors and scales for integrated decision-making (Ansell and Gash 2008; Emerson et al. 2012). Though it began in the public policy discipline, collaborative governance expanded and has become common for understanding natural resource management (e.g., Yeboah-Assiamah et al. 2016; Sullivan et al. 2019). Taking this collaborative approach to governance may have benefits, including supporting effective resource governance by overcoming challenges of power asymmetry, enhancing accountability of the decision-making body, increasing transparency in the decision-making process, and facilitating cross-sector coordination (Ansell and Gash 2008; Emerson et al. 2012). Scholars have argued that collaborative and interdisciplinary approaches to water management are necessary for successful resource stewardship (National Academies of Sciences, Engineering, and Medicine 2018). Other scholars, however, have critiqued the collaborative governance approach for lacking consensus on the definitions and operationalization of key terms (Emerson et al. 2012; Plummer et al. 2013), which presents challenges to evaluation of collaborative approaches (Potts et al. 2016).

Despite need for ongoing refinement of key constructs, the theoretical lens of collaborative governance sheds light on qualities and processes necessary for effective environmental policy. These include trust, inclusion of a diversity of actors, shared goals,

attempts to overcome power asymmetries, and effective communication, among other factors (Ansell and Gash 2008; Emerson et al. 2012; Yeboah-Assiamah et al. 2016; Medema et al. 2017; Newig et al. 2017; Porter and Birdi 2018; Sullivan et al. 2019). Identifying the presence of these characteristics can exemplify the presence of collaborative efforts to address complex problems.

2.2.3 Food-Energy-Water Nexus

Food-energy-water nexus governance can be one application of collaborative governance. The FEW nexus is a concept that refers to the interactions, trade-offs, relationships, and co-benefits between the three resources and their related governance sectors (Bazilian et al. 2011). FEW nexus governance, then, seeks to understand how food, energy, and water stakeholders and decision-makers collaborate to manage the trade-offs and co-benefits between the three resources (Lele et al. 2013). Considering the three resources together is important for comprehensive decision-making and governance of the resource sectors (Pahl-Wostl 2019). Management and policy decisions made in one sector can affect the other two; thus, integrated decision-making and governance between the three sectors has been argued to decrease unintended consequences and help manage uncertainties of the system (Leck et al. 2015; Rasul and Sharma 2016). This can lead towards holistic management of an integrated system, increased resource security, and improved sustainability of the system (Lele et al. 2013; Kurian et al. 2019). Despite the known benefits associated with collaborative management between the three resources, many decisions continue to be made in isolation from one another without communication and collaboration across sectoral boundaries (Lebel et al. 2020). This can

lead to fragmented policies and incomplete knowledge generation, which can present challenges for achieving resource sustainability and security in practice.

While research on the FEW nexus has been conducted at the national level in South Africa, limited studies have examined the urban context of Cape Town. In one urban study, Currie et al. (2017) used an urban metabolism approach to discuss the knowledge, resource, and personnel flows between food, energy, and water resources. In another, Ding et al. (2019) created an agent-based model approach to compare how two policy scenarios, a business-as-usual scenario and a holistic adaptive management scenario, would impact the resources of food, energy, and water within the Cape Town water crisis. Both of these studies are useful in understanding the interconnections between the three nexus resources; however, they use solely modeling-based, quantitative approaches that do not fully encapsulate the human dimension of the FEW nexus. This paper seeks to add to the current literature on the FEW nexus in Cape Town by examining some of the qualitative impacts of the water crisis on the FEW nexus sectors and the role of collaborative governance.

2.3 METHODS

2.3.1 Case Description

The metropolitan area of Cape Town, South Africa, located in the southwestern province of the Western Cape, is home to approximately four million people. The region is characterized by a Mediterranean climate with mild, wet winters and warm, dry summers (Sousa et al. 2018), and the region is vulnerable to drought (Pascale et al. 2020). Water governance is multi-leveled, with leadership distributed between the national,

regional, and municipal levels (Beck et al. 2016). The national Department of Water and Sanitation holds the greatest level of authority, as it is responsible for developing policy, implementing infrastructure, and administering water regulation, monitoring, and enforcement (Enqvist and Ziervogel 2019). The regional-level governance includes catchment management areas, regional water utilities, and water boards, which manage regional water resources and can provide bulk water (Beck et al. 2016; Enqvist and Ziervogel 2019). Additionally, regional water forums and catchment management forums provide venues for civic engagement and involvement (Enqvist and Ziervogel 2019). At the municipal level, the municipality or water service authority and provider ensures provision of water conservation, recycling, supply, and sanitation (Enqvist and Ziervogel 2019). With the multi-level governance of water resources, collaborative governance is key for successful management of drought. The National Water Resource Strategy emphasizes the importance of collaboration, and the Cape Town Water Strategy in 2019 calls for a collaborative approach to water management.

2.3.2 Research Design

To examine media framing in the Cape Town water crisis, I conducted a content analysis of news articles. First, I searched all major South African and international newspapers for articles related to the Cape Town water crisis. The LexisNexis database was selected because it produced the most complete collection of articles from both national and international news outlets. I conducted an advanced news search in LexisNexis using the following search string: ALL FIELDS ({Cape Town water} AND ({crisis} OR {shortage} OR {restriction} OR {drought})) AND PUBDATE BEF

October 31, 2018 AND PUBDATE AFT January 1, 2018. As Day Zero was declared on January 18, 2018 and water restrictions were relaxed on October 1, 2018, this timeframe allows for a focus on the phenomenon of the water crisis itself. This returned 365 distinct articles. The news articles were then read and screened manually to remove any duplicates that were not detected automatically and to select for inclusion only those that met the following additional criteria: subject matter (primary focus of the article was on the Cape Town water crisis) and language (English). This resulted in 188 articles included for full analysis. These articles were imported into MAXQDA 2020 qualitative data analysis software for content analysis.

Content analysis is the reading and analyzing of a set of texts to discover key themes to explore the meaning of those texts (Krippendorff 2018). Deductive coding was conducted using the preestablished codebook. I developed the codebook using collective action frames, collaborative governance codes, and the FEW nexus components (see table 2). The collective action codes of diagnostic, prognostic, and motivational framing were operationalized following Benford and Snow (2000). The collaborative governance codes were determined through a systematic, though not exhaustive, literature review, whereby the components of collaborative governance from key articles (e.g., Ansell and Gash 2008; Emerson et al. 2012; Sullivan et al. 2019) were compared in a matrix to determine the essential constructs. Papers continued to be read until data saturation was reached. At this point, there were 12 codes that appeared in more than 50% of the papers, and I used these codes to operationalize collaborative governance. The codebook was then refined by the two coders until finalized. Both coders separately coded a random sample of news articles using the codebook, measured the level of intercoder reliability,

and discussed discrepancies. This process was repeated for a total of three rounds, until an acceptable level of Cohen's Kappa was achieved (Cohen 1960). The final kappa was 0.82, which is considered high reliability (Bernard et al. 2017). I, the first coder, then completed the coding of the remaining articles in accordance with the finalized codebook, adding memos to identify inductive themes for further discussion.

Table 2: Overview of the codebook used for deductive coding of the news articles

Codes	**Code Definition**
Collective Action Framing	
Diagnostic	The problem or the entity who is to be blamed
Prognostic	The solution or the plan of attack
Motivational	Call to action or rallying of people
FEW Nexus Interactions	
Food Interaction	Intersections between the water crisis and the food or agriculture sector
Energy Interaction	Intersections between the water crisis and the energy, power, or electricity sector
Collaborative Governance	
Institutions	Institutional design; roles and rules of actors and the structure of their engagement
Actor Inclusivity	Inclusion of different actors or organizations in engagement
Resources	The sharing of finances, time, skills, personnel, or capital resources
Shared Values	Shared interests, values, or perspectives between actors; efforts made to accept and understand different cultures, perspectives, or values
Power	Efforts to overcome an asymmetry of power dynamics between actors; an understanding of these imbalances and attempts to achieve fairness in the process
Knowledge	Shared knowledge and information necessary to address the problem the collaboration seeks to address
Trust	Presence of trust; belief that all actors are acting in good faith or with good will and intentions
Shared Goals	Shared purpose, vision, or goals
Communication	Effective, open, and/or iterative communication or dialogue
Leadership	Intentional leadership by an actor or organization to bring actors to the table, keep the process moving, and facilitate and mediate the collaborative process
Commitment	Shared commitment or dedication to the collaborative process and a willingness to participate
History	History of cooperation between parties; low levels of conflict between parties

2.4 RESULTS

The results contain four sections. First, I present the collective action framing of the water crisis by discussing the diagnostic, prognostic, and motivational frames of the water crisis. Second, I discuss the role of cross-sector collaborative governance surrounding the water crisis. Third, I consider the impact of the water crisis on the interconnected FEW nexus. Finally, I examine the interconnections between collaborative governance and the FEW nexus.

2.4.1 Collective Action Framing

Our analysis identified a total of 671 instances of collective action frames in the data, including 243 diagnostic frames, 341 prognostic frames, and 87 motivational frames. Figure 3 shows the percent of news articles with each frame type over the 10-month duration of the water crisis. The percent of articles with diagnostic frames decreased slightly over time, while those with prognostic frames varied but remained relatively high. Motivational frames, however, decreased during the first half of the crisis and then increased during the second half.

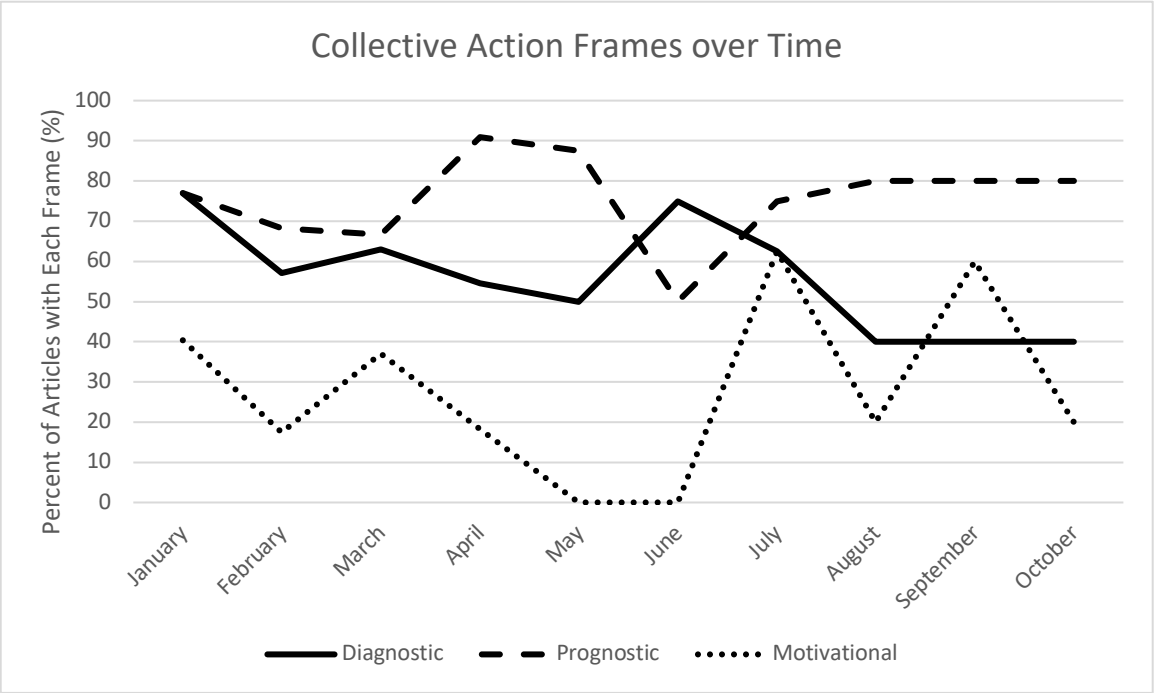

Figure 3: The proportion of articles each month containing diagnostic, prognostic, and motivational collective action frames throughout the duration of the water crisis

The diagnostic frames focused the blame for the crisis on four main causes: drought, politics, poor management, and overuse of water. The first theme included instances of drought, climate change, and lack of rainfall being blamed for causing the water crisis. For example, one article stated, “Cape Town was about to run out of water due to the most severe drought that has gripped the city in history” (CPT71). The second theme, politics, blamed political motivation for exacerbating the crisis, through the tension and animosity of both the local government and the national government and their dominant political parties. Another article stated, “There appears to be a strong undercurrent of political point-scoring around the Cape Town water issue, which does not serve the public interests” (CPT13). The third theme focused on blaming poor water management and limited planning for l the crisis. An article noted simply, “The water

crisis in Cape Town is a water management crisis" (CPT150). This theme included blaming poor management for a lack of investment in water supply infrastructure, for a lack of maintenance in leaky pipes, and for the lack of creating formal management plans. The last major theme of high water usage put blame on water use from population growth, excessive use by citizens, and agricultural water use. An article said, "Cape Town was excessive in its water use…Around 2015, we were using around 235 liters per person per day" (CPT340).

The prognostic frames identified the solutions of demand management and increasing supply. To manage demand, frames focused on decreasing residential and agricultural water use, mainly by raising awareness about the crisis and by implementing water restrictions and high tariffs for those who use more than their allocation. One article noted, "For the past several months, Cape Town citizens have been told to drastically cut their water consumption, a tactic which the city says is starting to work" (CPT176). Other components of demand management included reducing agricultural water allocations and commercial water use. To increase supply, strategies mentioned included both low-investment approaches, such as fixing leaks, capturing rainwater, and drilling small boreholes, and large-scale infrastructure projects, including inter-basin water transfers, desalination construction, water reuse implementation, increased dam capacity, and large-scale groundwater extraction. These prognostic frames included current plans for expansion and ideas for the future.

The motivational frames focused on calls for coming together to defeat the water crisis. More specifically, many called for people to join together in conserving water. "Day Zero is avoidable if we each do the little we are asked to do to save water. Our

enemy is failure to manage water and that is what we must tackle together" (CPT68). Secondarily, motivational frames called for increased government action and new approaches to water management. One article stated, "Cape Town urgently needs a long-term solution to prevent the water crisis from relapsing. All levels of government need to unite…the implementation of long-term solutions needs to happen sooner rather than later to avoid another Day Zero scare" (CPT351). Additional motivational frames included calls to rise above politics and financial gain, calls to share resources with others, and calls to elevate one's voice through protests and activism.

2.4.2 Collaborative Governance

Of the twelve collaborative governance themes, the codes resources (34 articles), communication (32 articles), and actor inclusivity (32 articles) were most present. Figure 4 provides an overview of the number of codes for each collaborative governance variable. Based on the data, this may imply that sharing resources, communicating effectively, and including a diversity of actors in water management were seen as the most prominent collaborative approaches for addressing the water crisis. Shared resources mainly included partnership to provide funds to invest in additional water augmentation or to provide excess water directly, particularly through aid organizations. For example, one aid organization partnered with others' resources to bring water to Cape Town. "Gift of the Givers will use the [financial] donation to drill boreholes as well as supply bottled water to organizations in desperate need" (CPT208). Communication codes were mainly centered around the use of the city's media campaign to make residents aware of their water using habits and encourage conservation. For example, "In

its media campaigns, the city emphasized that everyone needed to save water to prevent the catastrophe of Day Zero" (CPT222). Secondarily, some codes discuss communication between different levels of government and related stakeholders. Finally, actor inclusivity focused on collaborating across government entities and with parties outside of government to address the crisis. For example,

> "In meeting its obligation to protect human rights, South Africa's national government should assist Cape Town's municipality to develop strategies for lasting solutions to the crisis. This should involve city residents, paying particular attention to groups at increased risk from poor water and sanitation conditions, such as women, people with disabilities, older people, and those living in poverty" (CPT92).

Trust (3 articles), commitment (3 articles), and history (2 articles) were the codes with the fewest occurrences. The evidence from the data may suggest that trust, commitment to the process, and a history of previous collaboration may have been absent in the governance of the crisis. The low occurrences of history codes may suggest that there are limited historical instances of collaboration between parties to address water issues. Few commitment codes may suggest that there is limited commitment by parties to collaborate and engage with one another on the water crisis, especially in long-term engagements. This may be because of the acute nature of the crisis, where long-term commitment to water governance had yet to be established. Finally, the low presence of trust codes in the data may suggest that there is not a strong level of trust in the decision-makers who are addressing the crisis. Existing occurrences of the trust code in the data focused on calls for increased trust in the government.

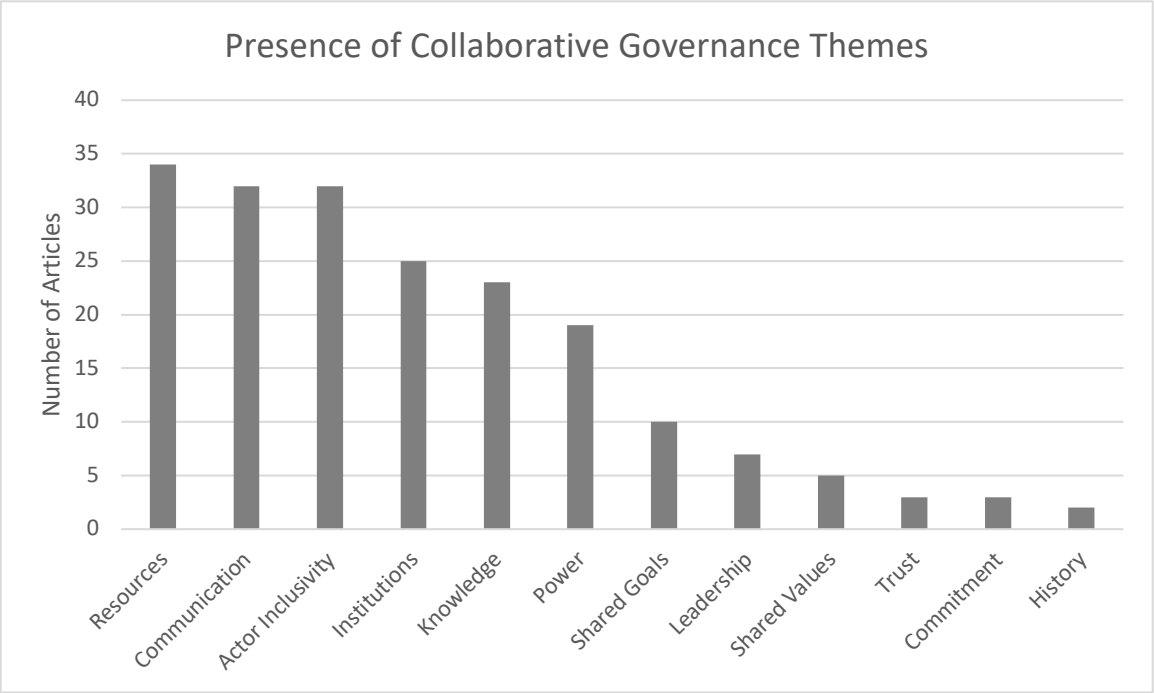

Figure 4: The number of articles containing each of the twelve collaborative governance themes that were examined.

In looking at the co-occurrence of collaborative governance codes and collective action frames, table 3 provides the instances where collaborative governance and collective action frames were present together. This is important as it shows how collaboration was considered in the crisis—as a problem, as a potential solution, or as a call for further action—and which components of collaborative governance were most present across those collective action frames. From this analysis, collaboration was seen as more of a solution than a problem or call for action. Specifically, suggestions for collaborative governance solutions involved shared resources, effective communication, and shared knowledge. However, with only 40 of the 341 total prognostic codes having

overlap with collaborative governance, the data may suggest that collaborative governance was not framed as a major solution to the crisis in the media.

Table 3: Proximity matrix of the co-occurrence of codes for the collective action frames and collaborative governance. Darker colors indicate higher frequency.

	Diagnostic	**Prognostic**	**Motivational**
Institutions	2	2	-
Actor Inclusivity	1	8	4
Resources	2	10	1
Shared Values	-	-	-
Power	-	1	3
Knowledge	3	6	3
Trust	-	-	-
Shared Goals	-	2	-
Communication	1	9	2
Leadership	1	1	-
Commitment	1	1	-
History	-	-	-
Total	11	40	13

2.4.3 Food-Energy-Water Nexus

With the strong interconnections between food, energy, and water resources, governance of the water crisis impacted the related sectors of food and energy. The impacts of the water crisis on the food sector were mentioned in 43 news articles, or 23% of the total articles. The impacts of the water crisis on the energy sector were mentioned in 64 news articles, or 34% of the total articles.

The food sector in Cape Town includes nearby agriculture that relies on the same water sources (consisting of both small- and large-scale farmers and a major wine region), urban farming, restaurants, grocery stores, and other food distributors. The water crisis impacted all of these dimensions in various ways. Primarily, the crisis led to water cuts and strict water restrictions for irrigation of surrounding farming districts. “Despite

strict restrictions, 45% on domestic and 60% on agricultural users, the abstraction rate from the Western Cape water system has increased" (CPT47). Less water for agriculture, both from the drought itself and from lower allocations of stored surface water, led to strains on agricultural production and negative economic impacts. One article stated, "The lack of water impacts the agricultural economy, potentially causing cutbacks and layoffs for seasonal workers. Less water also means lower yields for vineyards, fruit orchards and vegetable crops" (CPT282). The drought also had a major impact on the wine regions surrounding Cape Town, which had economic disadvantages, as the region is a major international wine exporter. With lower crop production, fears of rising food prices and interrupted food distribution arose. Grocery stores noted the potential for supply disruption, as an article stated about a grocery store chain, "The pending Day Zero will have an impact on operations in the Western Cape and they expect it may impact staff availability, product availability, and store operations" (CPT131). Additionally, several schools in poorer neighborhoods, which provide meals to students, were unable to continue providing hot means and instead resorted to less nutritious cold options. Finally, many restaurants had to adapt: some removed pasta and boiled vegetables from their menu and many resorted to only disposable dishes to reduce the water needed for cleaning. Some restaurants even reported that they had to close.

The energy sector in Cape Town is mainly composed of electricity. Eskom is the electrical utility for the country of South Africa and controls 95% of the electricity in South Africa, including in Cape Town (Inguscio 2017). In the news articles, energy was generally discussed less directly, but instead was inferred through the implementation of water augmentation approaches that are energy dependent. For example, one article

stated, “The city is meanwhile implementing an emergency plan for desalination, groundwater and water reuse to make more water available, said [former] mayor Patricia de Lille” (CPT18). In the discussion of these water augmentation approaches, many articles note the high financial cost and high energy needs. One article stated, “Water is heavy, so pumping it from underground reservoirs or across long distances is requiring large amounts of pumps and electricity. Desalination plants might be the only option for locations like Cape Town, but these, too, are very energy intensive and expensive” (CPT256). Implementing these water augmentation approaches would put greater strain on the electrical grid, which already experienced an electricity crisis in 2008 (Jaglin 2014) and still faces occasional load-shedding due to high energy demand.

Besides water augmentation approaches, several articles provided direct examples of how the water crisis was impacting the energy sector. For example, Koeberg, the only nuclear plant on the continent of Africa, requires a reliable water supply to cool the reactors, and thus had to make adjustments to continue operation during the water crisis.

> “Eskom’s Koeberg nuclear power station has today launched a mobile groundwater desalination plant, which will take care of the stations water needs, thus easing the pressure on the City of Cape Town’s water supply…we had to respond with a sustainable solution as a responsible corporate citizen…[It] provides 50% of the Western Cape’s and approximately 5.6% of South Africa’s energy needs…This power station can only operate about two weeks without off-site potable water. The desalination solution was therefore quite important to ensure continuity of supply” (CPT153).

Energy suppliers did their best to maintain electricity generation to prevent a joint water and energy crisis, but high-energy intensive water augmentation approaches such as desalination could counteract their efforts and put greater strain on the electricity grid as well.

In considering the co-occurrence of codes for the FEW nexus and collective action framing, table 4 provides an overview of the overlap between the concepts. The intersection between diagnostic and food codes consists of the blame on the agriculture sector for causing and exacerbating the water crisis. The intersection between diagnostic and energy codes focuses on blaming the government for failing to implement alternative water augmentation strategies earlier. However, the moderately-low level of overlap between the codes may highlight that there is not significant blame on the food or energy sectors for causing the crisis. The overlap between prognostic framing and food codes refers to the reduction in water use by the agricultural sector, which freed up water to be used by Cape Town residents. Thus, this may be considered one of the main factors that helped alleviate the water crisis. The high level of overlap between prognostic codes and energy codes includes the use of energy for water augmentation approaches as a solution to the water crisis, one of the main frames of energy overall. Low numbers of motivational frames for food and energy may point to few calls to action that directly include food and energy stakeholders or changes to the governance of those resources.

Table 4: A proximity matrix of the co-occurrence of codes for the FEW nexus and collective action framing. Darker colors indicate higher frequency.

	Food	**Energy**
Diagnostic	15	12
Prognostic	32	76
Motivational	2	4

2.4.4 Food-Energy-Water Nexus and Collaborative Governance

In considering the co-occurrence of codes for the FEW nexus and collaborative governance, table 5 provides an overview of the overlap between the concepts. In the

food sector, collaboration occurred mainly through actor inclusivity in groups and meetings that were working to address the water crisis and plan for the future. One article described that, "Through these efforts a Water Indaba [conference], bringing together the whole of government, the private and agricultural sectors along with academics and experts, was convened to look into various possible solutions and actions necessary to avert a water black-out" (CPT30). Secondarily, food actors collaborated by having shared goals of ending the water crisis, providing shared resources to offset the crisis, and participating in join agreements of institutions. In the energy sector, collaboration occurred through shared resources, as actors from across different sectors came together to consider high-energy water augmentation approaches to address the crisis. For example, an online event provided the opportunity for various stakeholders to discuss technological solutions to the water crisis.

> "Power and energy magazine ESI Africa will host a free-to-air webinar next month, addressing the Cape Town water crisis and the possible technologies and strategies that can be used to combat the problem…[It] will have input from industry experts…'By having this open discussion, which gives online attendees the opportunity to engage with our panelists, the challenges that the city has endured will be unpacked, along with its forward-thinking roadmap, looking at viable case studies, best practice and the finance and policy that will guide decisions by stakeholders and industries,' says Nicolette Pombo-van Zyl, editor of ESI Africa" (CPT184).

Overall, however, there was low co-occurrence between collaborative governance codes and food and energy codes, which may imply limited collaboration with these two sectors in addressing the crisis.

Table 5: Proximity matrix of the co-occurrence of codes for the FEW nexus and collaborative governance. Darker colors indicate higher frequency.

	Food	**Energy**
Institutions	2	1
Actor Inclusivity	3	2
Resources	2	6
Shared Values	-	-
Power	-	1
Knowledge	1	2
Trust	-	-
Shared Goals	2	-
Communication	1	-
Leadership	-	-
Commitment	-	-
History	-	-

2.5 DISCUSSION

Media framing both reflects and shapes broader discourse and plays a pervasive role in public opinion and policy agendas (Althaus and Tewksbury 2002). Frames presented in the media can resonate through society if they are perceived to align well with events (Benford and Snow 2000). Thus, media framing analysis provides insights not only into the perceptions of the media but also perceptions of the public and political entities regarding the water crisis causes, solutions, and impacts. This study of the Cape Town water crisis reveals several notable insights. First, the collective action framing communicated through the media highlights several potential water management challenges. The content analysis revealed that the primary problem frames in the media focused on failures of politics and management. If these problem framings are effectively linked to wider cultural values and concerns, they may resonate to shape public opinion and policy agendas, affecting, and potentially constraining, the decision space and decision-making venues. Framing the problem explicitly in political and management

terms may also foreground certain actors (e.g., Department of Water and Sanitation) and background others (e.g., regional water forums). The prognostic frames in the media focused on the need for water augmentation through immediate construction of desalination plants and investment in groundwater supply sources. Water supply diversification solutions would likely reduce the impact of future drought on surface water resources, as the water portfolio of the city would include groundwater, recycled water, and/or desalinated water (LaVanchy et al. 2019; Olivier and Xu 2019; Taing et al. 2019; Ziervogel 2019). Yet, as the crisis abated, discussion of the implementation of water augmentation approaches died down as the acute need lessened. This framing reflects a failure to maintain focus on the long-term diversification of water sources, which may present future challenges, as a retreat from urgency can be a barrier to collaborative governance (Sullivan et al. 2019). Despite these challenges, though, the motivational frames from the media highlight opportunities to collaborate, where individuals came together to "defeat Day Zero" and break down organizational silos (Ziervogel 2019).

Second, while some collaboration certainly occurred within the response to the crisis, greater efforts are warranted. The findings provide insight into the specific aspects of collaborative governance that appear most pressing. Based on the co-occurrence between collection action frames and collaborative governance codes, specific aspects of collaborative governance were highlighted as solutions to the water crisis, as there were more co-occurrences between collaborative governance codes and prognostic frames than with diagnostic or motivational frames. Shared resources was the collaborative governance code that had the highest number of co-occurrences with prognostic frames.

Communication, actor inclusivity, and shared knowledge were also expressed as potential collaborative governance solutions. This suggests that leveraging these four factors could provide an opportunity for increased collaborative governance, by expanding the collaboration to additional stakeholders in the network. However, the lack of co-occurrence between prognostic frames and shared values, trust, and history codes suggests that the governance response did not focus on these aspects of collaborative governance. This suggests that successful collaborative governance for the future should focus on establishing shared values between stakeholders, building trust, and setting a historical precedent for collaborative culture. This recommendation is supported by other studies of the Cape Town water crisis, which have noted that the lack of trust between governance actors and between government and the public, in addition to a history of animosity between government bodies, prolonged the response to address the crisis (Visser 2018; Rodina 2019; Ziervogel 2019).

Finally, the findings suggest that collaborative governance across the food, energy, and water sectors may provide benefit to future water management. The co-occurrences between FEW nexus codes and collective action framing suggests that solutions to the water crisis could include changes related to both the food and energy sectors. However, with limited co-occurrences between the nexus resource sectors and collaborative governance, the framing analysis also suggests that there may not be notable governance collaboration across the FEW nexus currently. As the media analysis has identified the opportunity for water management solutions from the connected FEW nexus system, a systems approach to management could benefit resource governance across all three sectors. Without collaboration between the three sectors, unintended

consequences from the crisis, such as overcapacity of the electrical grid and strain on national food supply and farming economies, could be exacerbated. Thus, cross-sector FEW nexus collaboration could provide opportunities to prevent these negative consequences in the future, lead towards greater resource security, and create more holistic approaches to governance (Leck et al. 2015; Rasul and Sharma 2016). This call for greater systems' approaches to management is supported by previous studies examining the outcomes of the Cape Town water crisis as well (Enqvist and Ziervogel 2019; Ziervogel 2019). In sum, this research suggests that there is limited collaborative governance between the nexus sectors, which is consistent with previous literature (Leck et al. 2015; Lebel et al. 2020), but it also provides needed empirical evidence to support theoretical claims of limited collaborative governance between food, energy, and water sectors (Ringler et al. 2013; Liu et al. 2018). Finally, the Cape Town water crisis provides insight into the outcomes that can occur from a governance system with siloed decision-making over integrated nexus governance.

2.6 CONCLUSION

The Cape Town water crisis in 2018 led the metropolitan area to nearly run out of water. While plentiful winter rains and decreased demand allowed the city to avoid cutting off taps, the crisis had major impacts on the related food and energy sectors, and there is still a possibility for drought in the future (Pascale et al. 2020). The purpose of this research was to examine the media surrounding the Cape Town water crisis to understand the framing of the phenomenon. I explored the collective action frames of media articles about the crisis to understand the framing of the crisis, the role of

collaboration in the governance response, and the impact of the crisis on the related food and energy sectors.

Drought, politics, poor management, and overuse of water supplies were blamed for the crisis as presented in the media, while reducing water use through strict restrictions and increasing water supply through large-scale infrastructure projects were presented as solutions. This suggests a focus on short-term approaches to prevent Day Zero, without a focus on long-term collaboration and water portfolio diversification that could make the crisis more resilient to future shocks and stressors. As various governance entities worked to address the crisis, existing collaboration between them in the media focused on the use of shared resources, effective communication channels, and inclusion of a diversity of actors in decision-making. However, greater efforts are needed for effective collaborative governance. Particularly, the crisis impacted the related sectors of food and energy through decreased crop productivity and through water augmentation infrastructure that may strain the electrical grid, respectively. Overall, the media had limited discussion of collaboration, especially between water actors and the food and energy sectors, which suggests that collaborative approaches may not have been heavily emphasized and implemented in response to the crisis. Yet with the strong interconnections between food, energy, and water, collaborative governance of the three sectors could increase resource security against future drought. I encourage other water-stressed cities to consider collaborative governance approaches across the food-energy-water nexus for holistic resource security.

Future research through case study analysis or ethnography would provide further depth in understanding the nature of the governance approaches in response to this crisis

and in how collaborative governance occurred between stakeholders. This will display how the media is consistent or contrasting with stakeholder perspectives and will provide further understanding of opportunities for increased collaborative governance between food, energy, and water actors.

CHAPTER 3

UNDERSTANDING BARRIERS TO COLLABORATIVE GOVERNANCE FOR FOOD-ENERGY-WATER NEXUS: THE CASE OF PHOENIX, ARIZONA

3.1 INTRODUCTION

The food-energy-water (FEW) nexus refers to the trade-offs, relationships, co-benefits, and interactions between the resources and related governance sectors (Bazilian et al. 2011). Given the social and environmental interconnections, collaboration can promote policy coherence, sustainability, and resource security (Lele et al. 2013; Leck et al. 2015). Despite the benefits of integrated governance, however, stakeholders from public, private, and nonprofit sectors do not always effectively coordinate across sectoral boundaries. This may lead to incomplete knowledge, fragmented governance, and unintended consequences of policy decisions, which may exacerbate vulnerabilities to risks, uncertainties, and external shocks. While prior research has identified some barriers to collaboration, there is currently limited understanding of how stakeholders experience and navigate these barriers in the context of the food-energy-water nexus (Weitz et al. 2017a). Collaborative governance, the process of engaging multiple actors across scales and sectors to collaborate for joint policy and management, presents an opportunity to best understand FEW nexus governance barriers. This research addresses the gap in FEW nexus scholarship by integrating the theory of collaborative governance and the concept of the FEW nexus to provide a more complete explanation of the limitations to collaboration between the food-energy-water nexus and the structures and drivers that reinforce those barriers. This knowledge may provide insights for more effective environmental policy.

The Phoenix, Arizona in the southwestern United States presents a unique opportunity to examine the barriers to and opportunities for collaborative governance for the FEW nexus. There are numerous interactions between food, energy, and water resources in the region, establishing it as a "resource nexus hotspot" (Mohtar and Daher 2016; Daher et al. 2018). The Phoenix metro area is located in a water scarce, semi-arid region with a large and rapidly growing urban population, with a significant extent of peri-urban agriculture, and with considerable electricity generation. The area is experiencing increased water stress and extreme heat, exacerbated by the climate crisis, which is intensifying risks for interdependent infrastructure systems (Clark et al. 2019). Furthermore, the region is characterized by a complex environmental governance regime, which creates additional challenges that could benefit from novel collaborative approaches (Larson et al. 2013; Sullivan et al. 2019).

This paper examines the mechanisms of barriers to collaborative governance for the food-energy-water nexus. Examining the case of the Phoenix, Arizona metropolitan area, I address the following research questions:

1. What are the barriers to collaborative governance of the food-energy-water nexus in a water scarce, semi-arid urban context?
2. How do stakeholders experience barriers to collaborative governance for the food-energy-water nexus ? Why do these barriers exist?
3. How can concepts of collaborative governance be applied to understand and overcome these barriers?

To classify and understand the barriers to FEW nexus collaborative governance and stakeholders' experience of those barriers, I apply the theoretical framework of

collaborative governance to the FEW nexus in Phoenix, using a structured case study method (Creswell and Poth 2017; Yin 2018). This approach establishes theoretical propositions from the literature to guide the data analysis and results (Yin 2018). In the next section I draw from the literature on food-energy-water nexus and collaborative governance, to develop a series of three theoretical propositions that guided the inquiry. I then describe the case context, focusing on the interactions between food, energy, and water systems in the Phoenix metropolitan area. In the methods section, I discuss the data collection approach, which includes multiple sources of evidence incorporating social network analysis, participant observation, and individual interviews. The analysis of this data relies on a structured, theoretically driven qualitative coding process incorporating multiple coders and inter-coder reliability verification along with pattern matching analysis to synthesize the case to address the research questions. The results section is organized around each of the three theoretical propositions, and the respective rival explanations. The findings are illustrated through evidence from the interviews and participant observations. Finally, I discuss the results in light of the literature as well as the potential transferability of my results to similar FEW nexus contexts.

3.2 THEORETICAL BACKGROUND AND STUDY PROPOSITIONS

3.2.1 Food-energy-water nexus governance

The FEW nexus is defined as an interconnected system of the resources and their related governance sectors, considering trade-offs, interactions, and co-benefits (Bazilian et al. 2011). Food-energy-water nexus governance then refers to the communication and collaboration among multi-level stakeholders across sectoral boundaries of the resources

for decision-making of the integrated system (Lele et al. 2013). This integrated approach offers promise to improve resource security and reduce unintended consequences to manage uncertainty and improve sustainability outcomes from governance (Leck et al. 2015; Kurian et al. 2019). Despite the known benefits of collaborative governance for the FEW nexus, in practice, decisions are often made within sectoral silos with inadequate coordination (Leck et al. 2015). This can lead to fragmented knowledge and incoherent policy, exposing the linked systems to vulnerabilities, uncertainties, and external shocks.

While the FEW nexus perspective offers several conceptual advantages, there is critique in the literature. First, FEW nexus research has been criticized for focusing narrowly on quantitative and modeling approaches and scholars have called for greater attention to interpretive and qualitative approaches (Albrecht et al. 2018; Newell and Ramaswami 2020). Additionally, scholars argue that FEW nexus literature in practice highlights one resource over the others, with water typically being prioritized (Smajgl et al. 2016). Other scholars, however, note that focusing on the implications of one resource on the other two allows for more manageable analysis and more meaningful implementation (Ringler et al. 2013; Finley and Seiber 2014; Allan et al. 2015; Pahl-Wostl 2019). Finally, much existing literature focuses on the speculative benefits of collaborative governance of the nexus (Lele et al. 2013; Finley and Seiber 2014; Leck et al. 2015; Rasul and Sharma 2016). With this heavy focus on conceptual understanding, there are calls for more empirical studies, tool creation, and implementation approaches (Ringler et al. 2013; Liu et al. 2018; Opejin et al. 2020). Further, research should employ empirical and qualitative approaches to understand the drivers and structures behind

identified barriers to collaborative nexus governance in practice, as experienced by stakeholders and practitioners.

Several empirical studies of FEW nexus governance focus on identifying the barriers to implementation (Howarth and Monasterolo 2016; Pahl-Wostl 2019). For example, Howarth and Monasterolo (2016) found in the United Kingdom that lack of communication, differences in the decision-making process within each sector, differences in term definitions, and the presence of uncertainties were barriers to nexus governance. Additionally, power asymmetries (Pahl-Wostl 2019) and rigid sectoral regulations and planning procedures (Liu et al. 2018) create further challenges. There is, however, limited understanding derived from stakeholders' views about why these barriers are in place and the structures that uphold the barriers to collaborative FEW nexus governance (Weitz et al. 2017a). Based on existing literature, the first proposition in the case study is as follows:

Proposition 1: *Barriers to collaboration between nexus actors in the Phoenix area consist of ten key difficulties: lack of communication, lack of trust, lack of responsibility, rigid decision-making processes, institutional structures, conflicting interests, unequal power distribution, unequal access to resources, disconnect from the impacts, and different goals (Howarth and Monasterolo 2016; Weitz et al. 2017b; Liu et al. 2018; Pahl-Wostl 2019).*

3.2.2 Collaborative governance

Collaborative governance is a process to shape public policy, management, planning, and implementation by engaging multiple actors across sectors and scales to affect the decision-making processes (Emerson et al. 2012). I define collaborative governance as the processes and structures to engage multiple stakeholders across different levels of governance from public, private, and civic domains to intentionally and collectively influence decision making, public policy, management, and governance outcomes (Ansell and Gash 2008; Emerson et al. 2012; Yeboah-Assiamah et al. 2016; Newig et al. 2017; Sullivan et al. 2019). Collaborative governance has been promoted as a paradigm that addresses the challenges of power asymmetries, enhancing accountability of the decision-making entity, increasing transparency of the decision-making process, including stakeholders directly in knowledge generation, and facilitating cross-sector coordination and planning (Ansell and Gash 2008; Emerson et al. 2012). Collaboration of actors from across scales and disciplines can lead towards greater credibility, legitimacy, and salience in the decision-making process, which can result in reduced vulnerabilities in the natural resource system (Cash et al. 2006).

Interdisciplinary collaboration provides opportunities to explore the complexities of resource management for holistic governance with reduced uncertainty. Though collaboration across all resource sectors may not be effective, certain resources could greatly benefit through collaborative approaches. Collaboration specifically between food, energy, and water resources is important because of the strong interdependencies of the resources (Lele et al. 2013; Leck et al. 2015; Rasul and Sharma 2016). Applying the developed theory of collaborative governance to the newer concept of the FEW nexus

can provide an avenue to better understand and empirically study FEW nexus governance. Based on the literature and expert understanding of the case, I present the second and third propositions in the case study as follows:

Proposition 2: *The barriers to collaboration exist because of rigid inherent institutional structures, processes, and mindsets that were created at different levels and scales and were not designed to facilitate collaboration but to focus on minimizing risk within the individual sector.*

Proposition 3: *Overcoming these barriers require shifts in mindsets and restructuring of institutions to facilitate collaboration.*

The research reported here addresses the critiques within FEW nexus theory and literature in several ways. First, I complement quantitative and modeling studies through a structured qualitative case study approach, contributing to greater diversity in methods for analyzing FEW nexus systems. Second, this empirical case study elicits perspectives directly from stakeholders and practitioners, including through participant observation of collaboration in naturalistic settings, providing evidence about the opportunities for collaborative governance of the nexus in situ. Third, I address a gap in the literature by focusing on reasons behind barriers. Understanding why identified barriers are in place provides opportunity to create structures and approaches to overcome these challenges and lead towards collaborative governance of the FEW nexus in practice. Finally, in line

with recent research (e.g., Mounir et al. 2019; Guan et al. 2020), I focus on the metropolitan scale, complementing existing national, regional, and state scale studies.

3.2.3 Study Context: Phoenix, Arizona

The Phoenix, Arizona metropolitan area, in the southwestern United States, has a population of about 4.5 million people as of 2019. This water-scarce region is among the most rapidly growing, urbanizing, and diversifying areas in the country; high agricultural demand, growing municipal demand, land use changes, aging infrastructure, and the deleterious legacies of past policies are pressing concerns (Gober 2018). Since 2000, the region has experienced the most extreme drought in a century and among the worst droughts in the last 1,200 years (Udall and Overpeck 2017; Overpeck and Udall 2020), causing water levels in the major reservoirs to drop to historic lows and depleting groundwater resources. The regional impacts of climate change mean that the region will experience higher temperatures, more frequent and extreme drought, more extreme heat, more variable precipitation, and greater wildfire risks, posing major risks for agriculture, energy, and water security, according to the Fourth National Climate Assessment (Gonzales et al. 2018).

There are strong interlinkages between food, energy, and water in the region (White et al. 2017; Clark et al. 2019; Guan et al. 2020). Agriculture is historically important to the economy, history, and culture in the region, and while agricultural acreage in the region is declining, irrigation still accounts for much of the water demand in the area. Energy is also intricately tied to the water system. Energy is used for local water distribution, groundwater pumping, water treatment, and conveyance of surface

water. For example, the Central Arizona Project (CAP) canal brings water 336 miles over nearly 3,000 feet in elevation to deliver water from the Colorado River to central and southern Arizona, and CAP is the single largest electricity user in the state (Bartos and Chester 2014). Additionally, water is needed to support the energy system, such as to cool power plants including the Palo Verde Nuclear Power Plant, the largest nuclear plant in the country (Bartos and Chester 2014).

Food, energy, and water governance in the region is multi-scalar and multi-level. Agriculture governance is largely decentralized, with many actors making decisions at the farm-level or through local collectives such as irrigation districts, farm bureaus, and lobbying associations (e.g., AZ Cattlemen's Association, Cotton Growers Association) (Eakin et al. 2016). State level policy is developed by the Department of Agriculture and the Arizona Legislature. In contrast, energy governance is largely centralized, with a few actors controlling most of the decision-making authority. These actors include the two major electricity utilities in the metro area, Arizona Public Service (APS) and Salt River Project (SRP), the Arizona Corporation Commission, which regulates public utilities, and the state legislature. Water governance is multi-scalar and multi-level. At the state level, the Arizona Department of Water Resources (ADWR) and Central Arizona Project (CAP) are powerful actors. At the regional level, SRP and Arizona Municipal Water Users Association (AMWUA) play a significant role. Local decision-making includes individual cities, such as the City of Phoenix, and private water companies, among others.

3.3 METHODS

We employed a case study approach (Yin 2018) to understand the barriers to collaborative governance between the FEW nexus sectors. Case study is appropriate when the research examines a complex, contemporary phenomenon within its natural context using multiple sources of evidence (Creswell and Poth 2017; Yin 2018). The Phoenix area was selected because it is an exemplar of the interconnected food-energy-water resources, also called a "food-energy-water nexus hotspot" (Mohtar and Daher 2016; Daher et al. 2018).

3.3.1 Data Collection

Participants and public meetings were identified using centrality measures from a social network analysis. Social network analysis quantifies and visualizes the interactions, relationships, and knowledge flows between actors within a defined system (Borgatti et al. 2009) and is a well-defined approach to stakeholder analysis and collaborative governance (Baird et al. 2016; Fliervoet et al. 2016). This social network identified 93 stakeholders in the case and evaluated their collaboration. I ranked stakeholders degree centrality, which is the number of other entities a single actor is connected to (Freeman 1978). I then placed stakeholder organizations into an interest-influence diagram based on their ranked degree centrality and on my expert knowledge of the case. A subset of this sorting of actors can be seen in figure 5. From this diagram, I selected stakeholders from the top-right quadrant (high influence-high interest), the top-left quadrant (low influence-high interest), and bottom-right quadrant (high influence-low interest). Actors from the bottom-left quadrant were not selected as they have low

influence over governance of FEW resources and low interest in the interconnection of FEW nexus resources.

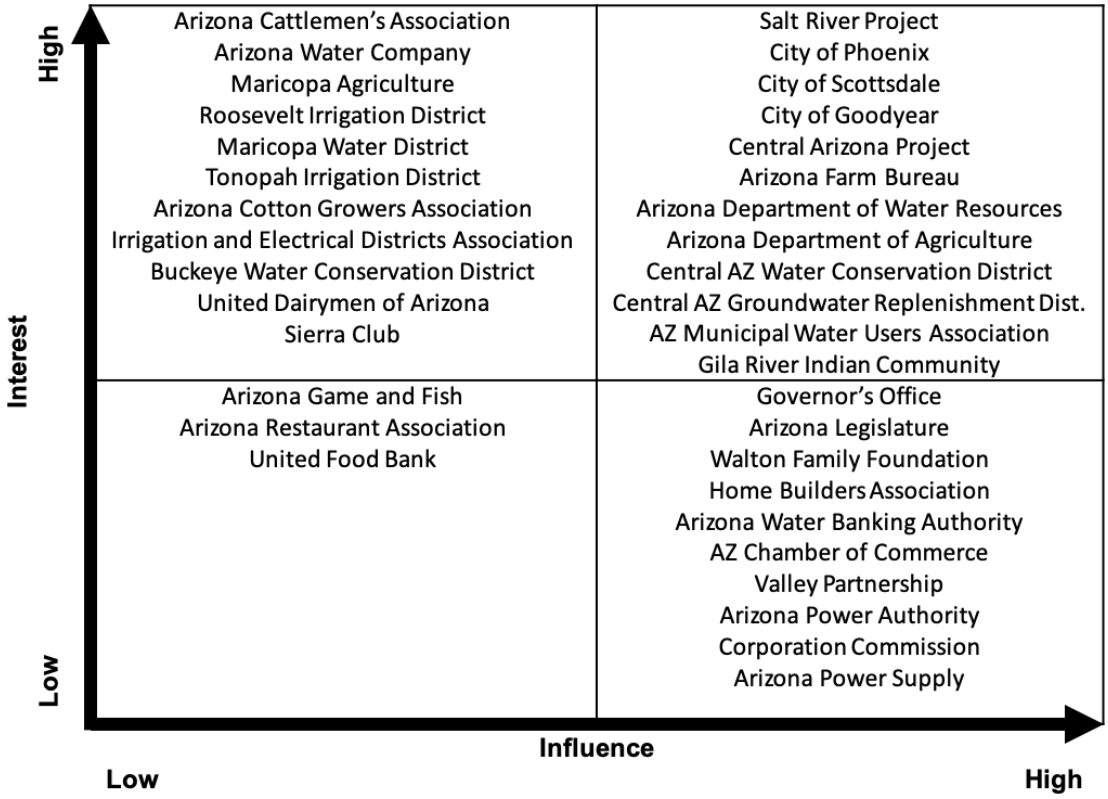

Figure 5: Interest-influence diagram for stakeholder analysis of actors identified through social network analysis of the case region.

From this stakeholder analysis, I conducted participant observation of six public meetings, including for the Arizona Municipal Water Users Association (AMWUA), the Arizona Power Authority, and Arizona congressional committees. The lead author wrote fieldnotes as data for these engagements. Additionally, I conducted 17 interviews with key stakeholders. This included actors from the City of Phoenix, irrigation districts, local farmers, the Department of Agriculture, and electricity utilities. Interview questions

focused on the approaches to and nature of previous collaborative engagements, on their perspective on relevant nexus actors in the region, and on the barriers that they encountered in collaborating with other stakeholders. Interviews were pretested on a small group of stakeholders before being conducted with the full sample of respondents. Each interview was labeled with the letter "P" followed by a number, such as P3. Table 6 provides an overview of the organizations that were included in the participant observations and the interviews.

Table 6: An overview of the stakeholder organizations for participant observation and interviews, in alphabetical order.

Organization	**Organization Type**	**Nexus Sector(s)**
Participant Observation		
Arizona Corporation Commission	Utility Regulator	E
Arizona House Committee on Natural Resources, Water, and Energy	State Legislative Committee	W/E
Arizona Municipal Water Users Association	Nonprofit Corporation	W
Arizona Power Authority	State Body Corporate and Politic	E
Arizona Senate Committee on Water and Agriculture	State Legislative Committee	W/F
Central Arizona Project	Surface Water Supplier	W
Interviews		
Agribusiness and Water Council	Nonprofit Trade Association	F/W
Arizona Cattlemen's Association/AZ Farm and Ranch Group	Nonprofit Organization/Lobbing Organization	F
Arizona Department of Agriculture	State Agency	F
Arizona Farm Bureau	Nonprofit Corporation	F
Arizona Municipal Water Users Association/City of Peoria	Nonprofit Corporation	W
Arizona Power Authority	State Body Corporate and Politic	E
Arizona Water Banking Authority	Groundwater Recharge Authority for the Arizona Department of Water Resources	W
Central Arizona Groundwater Replenishment District	Groundwater Replenishment Authority for CAP	W
Central Arizona Project (CAP)	Surface Water Supplier	W
City of Phoenix – Environment Department	Municipal Government	F
City of Phoenix – Water Department	Municipal Government	W
City of Scottsdale	Municipal Government	W
Duncan Farms	Farm	F
Roosevelt Irrigation District	Municipal Corporation	W/F
Salt River Project – Water	Utility Cooperative and State Agency	W
Salt River Project – Power	Utility Cooperative and State Agency	E
Sierra Club	Environmental Nonprofit	CC

3.3.2 Data analysis

The transcribed interviews and the fieldnotes from participant observation were imported into MAXQDA 2020 software for coding. First, a codebook was created deductively, including codes from a systematic, though not comprehensive, literature review of collaborative governance scholarship. In this literature review, a matrix was used to capture the key components of collaborative governance and compare them across multiple peer-reviewed articles. The most frequent components for collaborative governance were selected to be used in the codebook. Then, the documents were coded inductively to denote the barriers to collaborative FEW nexus governance and approaches to overcoming those barriers that emerged in the data. Finally, the deductive codebook was applied to the data. Once all the codes were applied to all the text, pattern matching was used to synthesize the case study analysis. Pattern matching is the process of comparing patterns uncovered in the empirical data to the expected patterns made prior to data collection (Trochim 1989; Yin 2018). Pattern matching is a widely used approach to case study analysis and has been used in studies in disciplines ranging from urban planning (e.g., Bradshaw 1999) to sustainability (e.g., Hörisch 2018) to public administration (e.g., Cordella and Paletti 2019). This process involved comparing the inductive codes from the data to the set of pre-determined deductive codes identified prior to data collection. The pattern matching was used to determine how well the data align with the theoretically driven understanding of collaborative governance. This allowed to synthesize the case to address the research questions.

3.4 RESULTS

The results section is organized around each of the three theoretical propositions. For each proposition, a rival explanation is presented. The results then either present evidence to support the proposition or present evidence that supports the rival explanation to refute the proposition.

3.4.1 Proposition 1: *Barriers to collaboration between nexus actors in the Phoenix area consist of: lack of communication, lack of trust, lack of responsibility, rigid decision-making processes, institutional structures, conflicting interests, unequal power distribution, unequal access to resources, disconnect from the impacts, and different goals.(Howarth and Monasterolo 2016; Weitz et al. 2017b; Liu et al. 2018; Pahl-Wostl 2019)*

Rival explanation 1: Barriers to collaboration consist of factors not previously identified in the literature.

The results from the analysis supported proposition 1, but also uncovered additional barriers, as collaborative governance of the FEW nexus faces numerous barriers and challenges. This study revealed 19 barriers to collaboration within the nexus context, presented in table 7. Ten are consistent with previous literature and nine were uncovered inductively from the data. The barriers to collaborative governance were arranged based on pattern matching between the empirical results of this study and prior literature. This revealed four categories of codes: (i) structural asymmetries, (ii) process asymmetries, (iii) coordination challenges, and (iv) external influences.

Table 7: List of the barriers identified through the case study. Codes denoted with an asterisk (*) were consistent with previous literature.

Structural Asymmetries	Process Asymmetries	Coordination Challenges	External Influences
Institutional structure*	Lack of responsibility*	Lack of communication*	Unfavorable context
Unequal power*	Decision-making processes*	Lack of trust*	History of conflict
Conflicting interests*	Lack of commitment	Lack of openness	External risk
Unequal resources*		Selfishness	
Disconnect from impacts*		Arrogance	
Different goals*		Lack of knowledge	
Rigidity			

3.4.2 Proposition 2: *These barriers exist because of rigid inherent institutional structures, processes, and mindsets that were created at different levels and scales and were not designed to facilitate collaborative governance but to focus on minimizing risk within the individual sector.*

Our findings generally support proposition 2. FEW nexus sectors were designed to minimize risk and uncertainty in decision-making, while developing independent structures and processes to governance. Thus, the differences between these structures and processes uphold barriers to collaborative governance. And while collaborative governance does occur within sectors, cross-sector collaboration is more limited. To explain how the findings support proposition 2, I have divided this proposition into four sub-propositions below.

Proposition 2a: Food, energy, and water organizations were designed to maximize efficiency and minimize risk within each sector.

Rival explanation 2a: Food, energy, and water organizations were designed for purposes other than maximizing efficiency and reducing risk.

Our analysis supported part proposition 2a. Food, energy, and water sectors were designed in ways to minimize their risk and to reduce decision-making uncertainty. Stakeholders perceive that their respective organizations were designed to manage these considerations. First, regarding risk, a water stakeholder stated, "I think one thing that the water supply community, the people that I work with, inherently have built in is that it is an extremely risk-adverse profession…people do tend to be inherently overly conservative in their supply planning" (P8). Second, regarding reducing uncertainty, an agriculture stakeholder emphasized that the goal of their organization was to reduce uncertainty in the water supply. "Our motivation for our board in negotiating the settlement that I just completed was some level of reliability…[the decision-making] was all based on a reliability aspect and how reliable we can make our sources in the future" (P13). While uncertainty and risk were the focus of most organizations, a few focused on maximizing resource efficiency and reducing costs.

In the decision-making process, organizations use data and information available to them to manage that uncertainty and risk. Some participants noted that they prioritize gathering data through collaboration. In discussing their decision-making process, an agriculture stakeholder emphasized this point, noting, "There are other people around. And some of the best ones are really at Salt River Project that try to predict what's going to happen year by year in the river system" (P7). Others noted that decisions are often deadline driven. For example, a water stakeholder noted that, "You have what you have, and you have a deadline and that's it…you do the best you can with limited resources"

(P3). In summary, food, energy, and water actors make decisions to manage risk and uncertainty, basing decisions on the best available data under pressing deadlines.

Proposition 2b: Organizations within each sector independently developed institutional structures and organizational process not designed to facilitate collaborative governance.

Rival explanation 2b: Organizations have developed institutional structures and/or organizational processes that are designed to facilitate collaborative governance across sectors.

Our findings did not directly support or refute proposition 2b. While actors in all three FEW nexus sectors do engage in collaborative governance practices, they collaborate in different ways. Water actors tend to collaborate both within their sector and with food and energy stakeholders. In finding consensus within the water sector, at an Arizona Municipal Water Users Association meeting, one board member stated that a bill was "an opportunity for all of us in the water sector to work together on legislation." Similarly, a water stakeholder said,

> "Everyone is always involved in stakeholder processes all the time. And what I have found is they've always seemed to bring in people from different organizations...it's not just one group. They'll have folks from agriculture, they'll have folks from cities, they'll have small water providers, they'll have some environmental groups, they really try to cover a wide swath of the water community" (P9).

Agriculture actors, however, tend to collaborate mostly within the food sector. One participant from the food sector discussed collaborating mostly with other food sector actors.

> "Our partners, not just all the agriculture organizations that we're connected with, but also Local First Arizona, as an example. And the food banks, we're very

> connected with them…on the national level, it would be everyone from the American Farm Bureau Federation to the national Cattle Growers Association. And then on the state level, we have the United Dairymen's Association, the Arizona Pork Council, the Arizona Beef Council. Gosh, we have so many that we're partnering with on our efforts" (P12).

The participant went on to discuss attempts to collaborate with environmental groups, noting challenges. "We also reach out to the environmental groups that sometimes, I must confess, kind of throw us under the bus every once in a while, but we do reach out to them" (P12).

In the energy sector, some stakeholders collaborate exclusively with organizations like them, while others make efforts to reach across sectoral boundaries. One energy stakeholder emphasized the similarities they had with their collaborative partners, noting, "We work pretty extensively with [hydropower company]. We seem to be in lockstep there. They are a similar agency with regards to function…We try to work collaboratively with them" (P4). However, a different energy stakeholder noted the extensive stakeholder engagement work they had done with updating the organizations' sustainability goals. "I went and visited with about 20 stakeholders from across the [Phoenix] valley…and we got feedback" (P16). The differences in how these organizations collaborate may be that the former is an energy-only organization while the latter focuses on both energy and water.

Proposition 2c: Barriers from differences in structures and decision-making processes emerged because these structures and processes were designed independently.

Rival explanation 2c: Barriers emerged because of factors other than independently designed sector structures and processes.

Our findings supported proposition 2c. In the results, barriers to collaborative governance for the FEW nexus occur for three key reasons: (1) structural asymmetries, (2) process asymmetries, and (3) challenges in coordination. First, the results revealed how power imbalances, insufficient resources, and differences in organizational structures can limit collaborative FEW nexus governance. A water actor noted, "A lot of water policy has been built on the idea of, 'I'm building my portfolio of needs.' This kind of silo effect. I think that's really been a real barrier and actually continues to be a barrier" (P2). While all the three sectors were designed with similar purposes, reducing risk and uncertainty, the entity to be managed differs across the three sectors. These structural differences are further upheld by the power imbalances between the organizations. A cross-cutting stakeholder discussed their frustrations with collaboration because a small group of actors held most of the decision-making power. "In Arizona, there's a group of water interests that people refer to as the water buffalos…they're the ones that have been calling the shots on what happens with our water laws and policies for a pretty long time" (P6). Furthermore, unequal access to resources such as time, personnel, and finances, can inhibit collaborative governance. To collaborate with others, one energy actor notes that, "We have a lot of communities who are interested in collaborating, but they don't have the resources necessary to do it" (P16). The challenge of structural differences, reinforced by power and resource imbalances, uphold barriers to cross-sector collaborative governance.

Second, these differences in structures can lead to differences in processes. While organizations tend to have similar overall purposes—increasing reliability, efficiency, and affordability—the way in which each sector's organizations do this is different. One

food policy stakeholder noted the challenges of working across scales when sectors have different timescales, stating, “The tough part is being able to continue those collaborations and that relationship given our sometimes slow, bureaucratic process” (P11). Additionally, achieving the goals of one actor may be inherently counteracting to achieving the goals of another sector, as also noted by other scholars (e.g., Fader et al. 2018). A water stakeholder noted that, “Every community, every area has their own interest. And so, what makes [collaboration] harder is communities competing interests” (P10). Differences in processes that exist at various governance and temporal scales can exacerbate other differences between organization structures and uphold barriers to collaborative governance.

Third, challenges to coordination also exacerbate barriers to collaborative governance for the FEW nexus. The analysis specifically revealed codes of self-interest, poor communication, limited trust, and lack of openness. Participants identified self-interest of others, including pride and arrogance, as a major hinderance to collaborative governance, as it can lead a stakeholder to prioritize their needs over finding a compromise. In discussing the biggest challenge to collaboration, an energy stakeholder stated, “Selfishness…sacrifice, self-sacrifice is hard for people” (P4). A food stakeholder similarly noted, “Self-interest can be the worst element in trying to find a solution. Everyone has a self-interest. And I’m saying self-interest isn’t bad. It’s just that if you cannot see the other person’s view and understand it, then you are not able to come to some conclusion that is beneficial to all” (P17). Second, communication challenges also hinder collaboration. At a Central Arizona Project board meeting, lack of communication about bills currently being heard in the state legislature led to disagreement about how the

organization should support or oppose the bills. As another example, in an interview a food stakeholder said about collaboration, “If you are a poor communicator, that right there just immediately makes it difficult” (P15). Third, limited trust is a major challenge. One water stakeholder reflected on challenges to expanding water storage capacity in the state, noting, “You can’t build a storage project because there isn’t trust” (P13). Finally, a lack of openness can prevent some actors from participating in collaborative processes. In discussing the Drought Contingency Planning Committee, an energy stakeholder noted, “Their drought contingency plan moved so quickly that they limited who could be in the room. Power was not in the room” (P4). Discussing the same committee, a cross-cutting actor stated that, “[We] push our way in the door because we are not generally invited to sit at the tables relative to making these decisions” (P6). Self-interest, lack of communication, limited trust, and lack of openness are barriers in many attempted engagements that often exist unconsciously. These exacerbate challenges in collaborative governance and uphold barriers of structural and process asymmetries.

Finally, external influences can also create barriers. A history of conflict is a barrier that can prevent future collaborative governance. For example, as noted by one water stakeholder, “Any meeting with the tribal communities is going to start with how 100 years ago you stole our water and we still haven’t forgiven you for it. And I mean, it’s very relevant but you say that to an Anglo decision maker, and you know you can’t do anything with that” (P3). Additionally, changes in circumstances can present challenges. For example, in discussing the failed attempt to collaborate to prevent the closure of a large coal power plant, one water actor noted, “The main issue was the fact that natural gas was so inexpensive now, that it couldn’t compete with coal” (P7).

Historical conflict and changing circumstances are phenomena that can inhibit collaborative governance, but often are outside the control of any specific individual or organization.

Proposition 2d: Collaborative governance does occur within sectors, but to a lesser extent across sectors.

Rival explanation 2d: Collaborative governance occurs both within sectors and across sectors at the same frequency.

Our findings support proposition 2d. Collaborative governance readily occurs within sectors, especially within the food and water sectors; however, collaborative governance across sectors is less present. Within-sector collaborative governance of the food sectors occurs because the agriculture gains the benefit of the economy of scale when a predominately disaggregated set of actors can come together over a common purpose or shared resources. For example, one food actor discussed how several organizations came together to purchase a unit of a local power plant. "It's been really great because we've been able to get that economy of scale of owning a power plan without actually have to own, construct, build, or operate one. So, we get all the benefits" (P13). In the water sector, collaborative governance is needed to effectively manage limited water resources that span across political jurisdictions. One water actor noted that, "The [city] has a really robust portfolio…But we can't rely solely upon that, and just ignore the fact that there are cities around us…that will be impacted…so we've been trying to work with others to increase their sustainability and resiliency" (P2). They emphasized that water extends beyond the political bounds of their city, and that

partnering with neighboring cities is necessary for comprehensive management of water resources.

In cross-sector collaborative governance, the water sector more readily engages outside of its resource sector. This may be because water is the fulcrum of natural resource management and the FEW nexus in central Arizona, due to the semi-arid climate of the region (White et al. 2017). For example, one stakeholder discussed how a diversity of actors were included in the process of creating the Groundwater Management Act. "Everyone was involved in that binding: agriculture, cities, ag districts, everybody was involved, but not everybody got what they wanted…And I visualize as we go forward, that will continue. That we'll always have full collaboration by all water users and energy users" (P7). While the agriculture and energy sectors do partner with the water sector in collaborative governance, they rarely engage with one another. When asked who else they would like to collaborate within in the future, food and energy actors stated people like them. One food actor said, "We'll collaborate with whomever we think has similar interests, similar thoughts, similar strategies to get good policy done" (P5). Promisingly, the inclusion of different stakeholder sectors has increased over time. For example, one water actor said, "The stakeholder processes have actually become more inclusive over time" (P9). However, collaborative governance still exists predominately within sectors as opposed to across them, and cross-sector collaborative governance is primarily initiated by the water sector.

3.4.3 Proposition 3: *Overcoming these barriers require shifts in mindsets and restructuring of institutions to facilitate collaboration.*

Rival explanation 3: Overcoming these barriers requires something other than different mindsets and restructured institutions.

Our findings generally supported proposition 3. While overcoming barriers may require institutional shifts in processes and structures, a foundation of open mindsets and cordial engagement is first needed. Participants identified seven approaches to overcoming barriers to collaboration: building trust, shifting mindsets, finding common ground, transparency, shared resources, finding mutual benefit, and responding to times of crisis. (1) Building trust was identified as a foundational element to collaboration and moving beyond barriers. One stakeholder said, "I think the way that you would remove all those barriers is for people to operate with complete trust" (P15). (2) Shifting mindsets involves putting aside one's differences, removing selfishness, and eliminating personal biases. An energy stakeholder said that overcoming the barriers to collaboration "would require the need to be so great that people would put aside their self-serving nature" (P4). Furthermore, a food stakeholder greatly emphasized the need to reflect on our own positionality. "I think if we could remove the biased behavior from the different groups, I think our collaboration successes would be way beyond what we could even imagine" (P12). (3) Finding common ground through understanding others' perspectives and being open to compromise can move collaboration across barriers. A food actor said, "You try and come to some understanding of where other people are coming from. And then you try and help everyone find a solution that works for everyone" (P17). (4) Engagement through transparency, openness, and communication can move past existing barriers. In describing the organization's experience with the DCP process, a cross-cutting participant described how the barriers that prevented collaboration could have been

overcome. “[It requires] open and transparent communication, collaborating publicly, and not moving important discussions and decisions behind closed doors” (P6). (5) Resources, including time and money, are necessary to engage in collaboration. Increasing access and availability to said resources can help facilitate collaborative engagement. One food actor suggested, “identifying resources for those who maybe don’t have resources to be at the table” (P6). (6) Finding mutual benefit and win-win solutions between all the parties in collaboration provides an incentive for actors to commit to collaborative processes, despite the challenges. A participant stated, “Once they recognized that there’s an opportunity for mutually beneficial partnerships, I think we’re going to see more collaboration with them” (P5). (7) Finally, times of crisis or disaster can promote collaboration by forcing different parties to come together to address the immediate challenge. One water actor said, “Sometimes it takes a major disaster, a major event to bring people together” (P1).

3.5 DISCUSSION

In this study I examined barriers to collaborative governance for the food, energy, and water nexus in the Phoenix metropolitan area in the southwestern U.S., which is an exemplar case of a nexus hotspot city in a water scare region (Daher et al. 2018). While the findings and conclusions of this study are based upon a close contextual examination of naturalistic settings for environmental policy and decision making, the insights may be transferable to other cities with comparable social and environmental contexts. I propose three noteworthy contributions to scholarship on collaborative governance and the FEW nexus governance.

First, I conceptualize barriers to collaborative governance of the food-energy-water nexus in four categories: structural asymmetries, process asymmetries, coordination challenges, and external influences. The first three categories of barriers are consistent with prior empirical research (e.g., Howarth and Monasterolo 2016) and theoretical conceptualizations of these barriers (Weitz et al. 2017b; Liu et al. 2018; Pahl-Wostl 2019). However, the barrier of external influences had not been noted in the literature. External influences are crucial to understanding the context of FEW nexus governance, as this context can encourage or hinder collaborative governance between the sectors. Thus, the context in which the FEW nexus governance system is situated may need to change to allow for greater collaboration, such as overcoming conflict from previous engagements. Systems that are unable to overcome this barrier, though, may not be suitable for collaborative governance of FEW nexus sectors.

Second, while the goals for each resource sector may be similar, mismatches in approaches to achieve those goals and in the decision-making timelines hinder collaboration. For example, there may be differences in the temporal scales in which decision are made between FEW nexus sectors or differences in the geographic jurisdiction of organizations between them. These mismatches become particularly evident when considering the cross-scale and cross-level interactions of governance that occur within and between sectors (Cash et al. 2006). Similar to the scale mismatch discussed in environmental governance and social-ecological-systems (Gibson et al. 2000; Cash et al. 2006; Cumming et al. 2006; Pahl-Wostl et al. 2020), then, this *"sector mismatch"* relates to the differences between food, energy, and water governance systems that make them inherently challenging to collaborate with one another.

Understanding the mismatch between governance organizations can be key for successful collaborative governance (Plummer et al. 2013). However, the water sector has begun to overcome existing barriers to initiate cross-sector collaboration. This may be because water is the limiting resource within the local FEW nexus, and thus connects to both the food and energy sectors. Energy is needed to ensure sufficient water supply in the Phoenix area and water is needed to ensure sufficient cooling in power plants, while water is also needed to maintain food and agriculture production. In this way, many water actors may serve as boundary organizations within the nexus. Boundary organizations are institutions that sit across the divide between policy and science and are an approach to overcoming mismatches between governance challenges related to scale (Cash and Moser 2000). Thus, Phoenix water organizations, which conduct research, influence and advise policy teams, and inform decision-making, intersect with both the energy and food sectors, linking the local Phoenix FEW nexus. Therefore, in sum, the barriers between FEW nexus governance sectors in the Phoenix area exist because of *"sector mismatch,"* though existing cross-sector collaborations may be explained by the presence of water boundary organizations, a strategy to overcome scale mismatch. This is consistent with previous scholarship that has noted the need for better consideration of the importance of scale in understanding governance challenges and proposed solutions (Pahl-Wostl et al. 2020).

Third, seven approaches to overcoming these barriers to collaborative governance of the FEW nexus were identified by stakeholders. These include building trust, shifting mindsets, finding common ground, improving transparency, increasing resources for collaboration, establishing win-win solutions between parties, and addressing times of

crisis. This suggests three requirements in moving towards implementing these strategies in practice. First, certain conditions, such as trust and common understanding, are essential foundations for institutional change to occur (Nilsson and Eckerberg 2009; Weitz et al. 2017b); establishing a shared foundation of these conditions across sectors is thus necessary for successful collaborative governance. Second, as suggested by recommendations such as win-win solutions and shared resources, there needs to be a motivation and an incentive to engage in collaboration. These require a common definition of FEW nexus governance and a shared understanding of its goal. In practice, however, the term "nexus" has been critiqued for not having a clear definition (Cairns and Krzywoszynska 2016) and in practice has experienced challenges from a lack of common understanding of the shared goal of engagement (Weitz et al. 2017b). Thus, a common understanding of FEW nexus governance in practice needs to be established for each collaborative engagement. Finally, while overcoming *sector mismatch* is the key for collaborative governance across the FEW nexus sectors, the focus of the stakeholders on the lack of foundational components for collaboration suggest that foundations for collaboration generally need to be established first. This may promote more within-sector collaborative governance as well as cross-sector governance.

3.6 CONCLUSION

As an approach to increase resource security and system sustainability, the food-energy-water nexus argues that it can overcome the weaknesses of siloed governance. However, many decisions continue to be made without communication and coordination across the resource sectors. While much theoretical research has explained the presence

of siloed FEW nexus governance (Liu et al. 2018; Pahl-Wostl 2019), and some empirical studies have identified barriers to integration (e.g., Howarth and Monasterolo 2016), there is minimal understanding of why these barriers exist (Weitz et al. 2017a). This in-depth case study begins to address this research gap by exploring the structures and processes behind barriers to collaborative governance within the Phoenix, Arizona metropolitan area. The results of this study identified the key barriers to cross-sector collaborative governance, relating to differences in structural dimensions, differences in decision-making processes, challenges with coordination, and unfavorable settings that do not lend themselves towards collaboration. These barriers exist because of *"sector mismatch,"* where institutional differences between food, energy, and water organizations do not align in ways that naturally lend themselves to collaboration. Nevertheless, within-sector collaboration does occur, and the water sector has initiated cross-sector engagements with the food and energy sectors. To move towards true collaborative governance of the FEW nexus, though, these mismatches must be overcome. However, first, as recommended by stakeholders, an essential foundation for collaboration needs to be established, including establishing trust and overcoming barriers of negative character. This research provides an opportunity for greater collaborative FEW nexus governance in practice. Though this case study produces evidence from only one system, this research it does provide an opportunity to generalize these results to other urban spaces, as the Phoenix metropolitan area contains many of the same characteristics of other urban FEW nexus hotspots (Daher et al. 2018).

From these findings, I recommend future research should take several approaches. First, future investigation can consider other cities to understand the generalizability of

the structure of barriers. To my knowledge, this is one of only a few empirical studies that has examined the barriers to collaboration in FEW nexus governance (see Schreiner and Baleta 2015; Howarth and Monasterolo 2016; Bielicki et al. 2019; Melloni et al. 2020). Investigation of additional cities provides an opportunity to synthesize across cases and create triangulation for identifying generalizable barriers to collaborative governance of the FEW nexus. Additionally, future study should seek to address how collaborative governance of the FEW nexus impacts outcomes to see if collaboration does indeed improve management of food, energy, and water resources. While much literature has argued that collaboration can reduce unintended consequences across the FEW nexus (e.g., Lele et al. 2013; Leck et al. 2015; Rasul and Sharma 2016), empirical studies have yet to explore the causal relationship between collaborative FEW nexus governance and resource outcomes. This would provide greater support for the effectiveness of FEW nexus governance in influencing outcomes.

CHAPTER 4

AN ASSESSMENT FRAMEWORK OF FOOD-ENERGY-WATER NEXUS GOVERNANCE

4.1. INTRODUCTION

The food-energy-water (FEW) nexus refers to the interactions, trade-offs, co-benefits, and relationships between the three resources and their related governance sectors (Bazilian et al. 2011). Specifically, governance of the FEW nexus argues for a cross-sector approach to management, policy, and planning that considers the three resources and their interactions together in the decision-making process (Lele et al. 2013). A FEW nexus approach to governance has been argued to increase resource security, decrease unintended consequences, and improve system sustainability (Finley and Seiber 2014; Leck et al. 2015). Despite the known benefits of managing the three resources synergistically, many decisions are often made in isolation from one another, without coordination and communication across sectors (Leck et al. 2015). This lack of collaboration can inhibit goals towards sustainable resource management for food, energy, and water.

Research on FEW nexus governance has yet to produce an agreed-upon approach for measurement, evaluation, or assessment of the efficacy and nature collaboration. Evaluation and assessment of governance is important as it can help determine the benefit of specific governance approaches in practice, can address criticisms of the governance approach, and can assess and improve the approach (Conley and Moote 2003). Indicator sets for evaluation and assessment currently exist to consider the FEW nexus at the national scale (e.g., Yuan and Lo 2020), but these indicators focus on physical flows over

collaborative approaches. A limited number of indicator sets have been created at the local scale, with existing sets focusing exclusively on physical resource flows (e.g., Biggs et al. 2015). Further, while the U.N. Sustainable Development Goals (SDGs) are one of the most wide-reaching indicator sets within sustainability and have been adapted to apply to the FEW nexus (e.g., Bleischwitz et al. 2018; Fader et al. 2018), I believe that the SDG framework is insufficient as it does not explicitly consider resource trade-offs and its measures for governance are insufficient measures of collaboration (Bollino et al. 2020). Thus, no approaches or indicator sets have yet been created to sufficiently evaluate or assess FEW nexus governance, particularly at the community or urban scale.

It is important to assess the collaborative governance within the FEW nexus for several reasons. First, assessment allows us to identify and understand the challenges to and opportunities for greater collaboration in practice, as the assessment process considers how strongly or poorly each component of the collaborative system is performing (Conley and Moote 2003; Secco et al. 2014). Second, it can produce empirical evidence for or against the theoretical benefit of integrated FEW nexus governance, as I can apply the framework to an example case to see if the collaborative governance actually leads to improved outcomes (Koontz and Thomas 2006; Muñoz-Erickson et al. 2007). Third, assessment can help to improve approaches to cross-sector governance by identifying specific areas for improvement (Conley and Moote 2003; Ferreyra and Beard 2007). In this study, I focus on assessment at the urban level. Cities are a relevant decision-making level as many resource governance decisions come from the local level and this scale has been understudied within the FEW nexus governance literature (White et al. 2017; Mounir et al. 2019; Zhu et al. 2020). Thus, assessing FEW

nexus governance at the urban level provides a relevant and needed venue for understanding how food, energy, and water resources interact within decision-making across environmental and human spheres. Additionally, with rural to urban migration and global population growing, urban populations are estimated to exceed rural populations (Brueckner and Lall 2015). Therefore, resource management within cities must adapt to meet the demands of this increasing urban population.

An approach for assessing collaborative governance is important to move the FEW nexus governance concept from theory to operationalization and measurement. Thus, here I create a framework for assessment of FEW nexus governance to move towards this goal. This research addresses this gap by presenting a framework for assessing urban FEW nexus governance. By assessment here, I refer to the estimation of the nature and quality of the process of collaborative governance process. This is similar to the education literature, where assessment refers to the feedback about the process of teaching, and evaluation refers to the judgement of the outcome of student learning (Rotenberg 2010). Likewise, evaluation in the economic and human development literature considers evaluation to be a judgement of the effectiveness or outcome of an implemented program, project, or action (Bartik and Bingham 1997). With a focus on understanding the process of collaborative FEW nexus governance, over providing a judgement of the outcome from collaborative engagement, assessment provides the appropriate framing for the research here.

Drawing from the multiple literatures of collaborative governance and sustainability indicators, in combination with multiple empirical case studies, this study provides an approach to move FEW nexus governance forward. This contributes towards

the literature in several ways. First, there are calls for increased study of the FEW nexus that provide empirical evidence to support theoretical claims (Ringler et al. 2013; Finley and Seiber 2014; Liu et al. 2018) and for increased scholarship focused specifically on FEW nexus governance over nexus physical resource flows and technical approaches (Albrecht et al. 2018; Opejin et al. 2020). This study seeks to advance the FEW nexus concept by contributing towards both of these calls. Second, this study moves FEW nexus governance from conceptualization to operationalization and measurement. FEW nexus governance literature has been critiqued for being too conceptual (Ringler et al. 2013; Liu et al. 2018) and for having limited application of diverse methods (Albrecht et al. 2018). Providing an approach to measuring the collaborative governance of the FEW system can overcome these barriers and provide an approach to analyzing the practice of FEW nexus governance. Finally, this research contributes towards the collaborative governance literature by providing an approach to multi-disciplinary collaborative governance. The vast majority of collaborative governance frameworks and implementation focus on one domain, such as on water governance or forest management. Some cross-disciplinary implementations exist, such as those focusing on environmental management. However, frameworks for true multi-disciplinary and interdisciplinary systems are still missing. While the approach presented here is specific for the food-energy-water nexus, it provides opportunities for other multi-disciplinary environmental systems as well.

This paper presents a framework for assessing urban FEW nexus governance. The remainder of this paper is structured as follows. In section two, I provide background on FEW nexus governance, collaborative governance, and sustainability indicators

scholarship. The integration of these three bodies of literature provides the structure for the created framework. Section three presents the proposed framework for FEW nexus governance assessment and the methods used in the construction of the framework. Section four presents two cases, Phoenix, Arizona, USA and Cape Town, South Africa, as examples of how the framework can be used to assess FEW nexus governance. Finally, the paper concludes with a discussion of the usefulness of the framework and opportunities for future work. In this research, I make the assumption that collaboration is normatively good and leads towards beneficial outcomes. While there is some critique that collaborative governance has not been shown to lead to improved outcomes (Koontz & Thomas 2006), collaborative governance offers the opportunity for increased understanding and application of collaborative processes within governance of integrated resource systems (Ansell & Gash 2008), which is believed to improve the ability to address the complexities within the system (Cash et al. 2006).

4.2 BACKGROUND

Food-energy-water nexus governance and collaborative governance have not been directly considered together in the literature. However, applying the established theory of collaborative governance to the newer concept of the FEW nexus provides an approach to understand and improve FEW nexus governance. Additionally, it provides a greater understanding of collaborative governance theory in addressing multi-disciplinary resource systems, which has been minimally examined thus far. Finally, implementing the sustainability indicators approach to assessment provides an opportunity to assess the collaborative governance of the multi-disciplinary FEW nexus governance system.

4.2.1 Food-Energy-Water Nexus

The food-energy-water nexus provides the opportunity to examine and understand the specific interactions between the three resources within a complex human-environment system. It was introduced as an approach to consider the trade-offs, interactions, and co-benefits between the three resources. The integrated approach provides an opportunity for increased resource security and decreased unintended consequences (Hoff 2011). Though two-way interactions between the resources were introduced in the 1980s (Cohen and Allsopp 1988) and the concept of integrated food, energy, and water systems was introduced in the late 2000s (Hellegers et al. 2008), the unified concept of the FEW nexus did not come about until the 2011 World Economic Forum in Bonn, Germany (Hoff 2011). It was introduced as an approach to address the global food and energy crises (Allouche and Middleton 2015). Since its introduction, research surrounding the nexus has increased rapidly (Newell et al. 2019; Opejin et al. 2020) and has expanded from merely a resource-security perspective to broader framings of the nexus (Pahl-Wostl 2019).

The perspective of FEW nexus governance considers how multiple actors across sectors can come together within the decision-making process (Lele et al. 2013). This is important because many food, energy, and water decisions are made in silos without consideration of the cross-sector relationships and trade-offs (Lele et al. 2013; Lebel et al. 2020). This can lead to fragmented knowledge and incoherent policy and planning that can expose the system to vulnerabilities, uncertainties, and external shocks. Incorporating systems thinking within FEW nexus governance of the urban system can enhance

sustainability, reduce unintended consequences, and increase system resilience (Leck et al. 2015; Kurian et al. 2019). Studies have begun to identify the barriers to these collaborations, such as power asymmetries, rigid sectoral regulations and planning approaches, lack of communication, differences in decision-making processes, and the presence of uncertainties (Howarth and Monasterolo 2016; Liu et al. 2018; Pahl-Wostl 2019). Despite the proposed benefits of the FEW nexus approach to governance, there has been some critique. Some scholars have criticized the ambiguity of the term definition and purpose (Smajgl et al. 2016; Endo et al. 2017), while others have even called it a meaningless "buzzword" (Cairns and Krzywoszynska 2016). Much of this comes from limited methods for measurement and operationalization.

Several approaches have been created to measure, evaluate, and assess the interactions within the FEW nexus. In a review by Albrecht et al. (2018), the authors note that nearly three-quarters of the FEW nexus studies use quantitative over qualitative methods and only about one-quarter of studies use social science approaches. The most common methods for evaluating and assessing the nexus employ environmental management modeling, economic analysis, and indicators (Albrecht et al. 2018). Indicators are one approach to measure the multi-disciplinary nature of the FEW nexus (Arthur et al. 2019). Indicator sets can be useful for policymakers to have a set of coherent targets to monitor and manage resources, to improve policy development focused on resource security, and to promote the sustainable use of resources (Arthur et al. 2019). Several studies have sought to create indicator sets to assess the FEW nexus. Yuan and Lo (2020) created an integrated FEW nexus indicator, called Linked Indicators for FEW AvailabilitY (LIFEWAY), to measure the food, energy, and water sustainability

of a country. Biggs et al. (2015) integrated the FEW nexus and the Sustainable Livelihoods Framework to create an Environmental Livelihood Security (ELS) index. The ELS indicator set provides an opportunity to understand how environmental indicators for food, energy, and water influence the livelihoods of a community (Biggs et al. 2015). Furthermore, adaptations of the Sustainable Development Goals (SDG) have been modified to combine indicators across the food, energy, and water targets to create subsets of nexus indicators (e.g., Bleischwitz et al. 2018; Fader et al. 2018; Liu et al. 2018). Finally, Venghaus and Dieken (2019) adapt the SDG framework to create a new indicator set to improve on the limited aggregation approaches and the failure to consider all three sectors evenly through a composite indicator of FEW nexus resource security. Despite the increase in FEW nexus indicators, the vast majority only examine the FEW nexus at the national level and only consider the physical resource flows as oppose to governance processes. They also do not address potential impacts from the indicator outputs (Arthur et al. 2019).

Section 2.2: Collaborative Governance

Collaborative governance is an approach to facilitate collaboration within public policy, management, planning, and implementation by engaging multiple actors across scales and sectors in the decision-making process (Emerson et al. 2012). Collaborative governance began in the public administration literature and has since expanded to a wide range of contexts, including natural resource management (Koontz and Thomas 2006). It has been promoted as a paradigm that supports effective resource governance by overcoming challenges of power asymmetries, enhancing accountability of the decision-making entity, increasing transparency of the decision-making process, including

stakeholder directly in knowledge generation, and facilitating cross-sector coordination and planning (Ansell and Gash 2008; Emerson et al. 2012). Collaboration of actors from across scales and disciplines can lead towards greater credibility, legitimacy, and salience in the decision-making process, which can result in reduced vulnerabilities in the natural resource system (Cash et al. 2003).

Prior research on measuring collaborative governance of natural resources has considered approaches to evaluating and assessing how collaboration impacts the process of engagement and the outcomes from it. Authors have considered how collaborative governance impacts the processes of governance in forestry (e.g., Cheng and Sturtevant 2012; Secco et al. 2014; Abrams et al. 2020), renewable energy (e.g., Ulibarri 2015), and water management (e.g., Ferreyra and Beard 2007; Huang et al. 2017). Additionally, authors have considered how collaborative governance impacts the outcomes of watershed management (e.g., Biddle 2017; Ferreyra & Beard 2007), environmental governance (e.g., Biddle & Koontz 2014; Duan et al. 2020), ecosystem health and conservation (e.g., Koontz et al. 2020; Muñoz-Erickson et al. 2007), climate change adaptation (e.g., Kalesnikaite 2019), and community land management (e.g., Cundill & Fabricicus 2010). Though there are arguments for increased scholarship on the correlation between collaboration and environmental outcomes (Koontz and Thomas 2006), assessing the processes of collaboration first is an important step to truly understanding how collaborative governance leads to outcomes. To understand the impact of the process of collaborative governance, studies have used a variety of approaches, including social network analysis (e.g., Huang et al. 2017), literature review (e.g., Cheng and Sturtevant 2012; Secco et al. 2014; Coletti and Landoni 2018),

regression analysis of survey data (e.g., Chen and Manley 2014; Ulibarri 2015), and indicator development (e.g., Abrams et al. 2020). One example approach is the logic model application, designed by Thomas and Koontz (2011). This approach parcels out the components of inputs, processes, outputs, and outcomes. In this way, this framework focuses on linking key components of the system to clearly differentiate between framework concepts (Thomas and Koontz 2011). These studies highlight the diversity of approaches to evaluate and assess collaborative governance, emphasizing the importance of developing such mechanisms to understand the collaborative process and to understand how it correlates with outcomes. However, there is currently limited scholarship on evaluating and assessing collaborative governance of multi-disciplinary systems, such as the FEW nexus.

Understanding how collaborative governance impacts the process of engagement is important for several reasons. First, evaluating and assessing collaborative governance allows for the identification of the potential benefits and limits of collaborative governance and of its impacts on society (Conley and Moote 2003). Additionally, it can help to improve collaborative efforts to meet shared goals, provide guidelines to identify appropriate approaches for different circumstances, and inform appropriate regulations within policy (Conley and Moote 2003; Ferreyra and Beard 2007). Furthermore, tools developed to measure collaborative governance can be used as performance measures to evaluate and assess new governance and management approaches (Abrams et al. 2020). Finally, evaluation and assessment can help determine when the implementation of collaborative governance has benefit in practice, can address criticisms of collaborative

efforts, and can assess and improve efforts at an institutional level (Conley and Moote 2003).

4.2.3 Sustainability Indicators

Approaches to measuring sustainability have centered around developing indicator frameworks. Indicators help move a concept from operationalization to measurement, as they show symptoms or signs of sustainability components, which can be useful for policy making and communication (Singh et al. 2009). The sustainable development literature includes a diversity of indicators from local to global scales across governmental and non-governmental development (Parris and Kates 2003). However, a criticism of sustainability indicators is that there is not a universal set of indicators or standardization to measure sustainability and its components (Parris and Kates 2003; Singh et al. 2009). One of the most wide-reaching indicator sets currently within sustainability is the Sustainable Development Goals (SDG) framework. Created by the United Nations (UN) in 2015 to improve on the 2000 UN Millennium Development Goals, this indicator set provides a structure for countries to measure their progress in various sustainability initiatives and move towards a sustainable future. It includes seventeen goals with a total of 169 targets that lie underneath them. Though the framework was initially designed to operate at the national level, adaptations have been made for use at regional and local scales.

Some scholars have conceptualized the FEW nexus as a pathway for practical integration of the SDG framework to achieve the goals, specifically linking goal 2 (Zero Hunger), goal 6 (Clean Water and Sanitation), and goal 7 (Affordable and Clean Energy).

The FEW nexus has been argued to help improve policy, management, and governance to ensure sustainability within the SDGs (Liu et al. 2018; Pahl-Wostl 2019). Specifically, the FEW nexus can identify synergies, co-benefits, trade-offs, and unexpected consequences between the resources and can lead towards greater coordination, collaboration, and coherence across policy, planning, decision-making, governance, and management (Liu et al. 2018). Some scholars have directly explored the linking of relevant goals within the SDG framework to address the FEW nexus (e.g., Rasul 2016; Bleischwitz et al. 2018; Fader et al. 2018; Liu et al. 2018). However, these frameworks have focused on physical resource flows and have failed to consider trade-offs and co-benefits between governance and stakeholder collaboration across the three sectors.

The SDG framework alone is insufficient for evaluating and assessing collaborative governance. Including goal seventeen, Partnerships for the Goals, in a FEW nexus approach to the SDG framework initially appears to provide opportunity for evaluation of governance and collaboration. Goal 17 itself, however, is insufficient to adequately measure collaboration and governance. For example, for the theme of multi-stakeholder partnerships in goal 17, one target is to "enhance…multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology, and financial resources" (United Nations 2020, p. 21). Yet the indicator to measure this goal is simply the number of countries that report progress towards multi-stakeholder engagement that advances the SDGs, making the target dependent upon national-level perception of collaboration rather than metrics of actual collaborative engagements. This is not a true measure of partnership or collaboration. Additionally, the three other goals directly related to the FEW nexus—goal 2, goal 6, and goal 7—each contain themes for

collaboration and coordination. However, these goals also fail to contain true measures of collaboration. For example, under goal 7 (Affordable and Sustainable Energy for All), the only collaborative goal focuses on "enhancing international cooperation to facilitate access to clean energy research and technology" (United Nations 2020, p. 8). Measured by the amount of financial funding flowing from developed countries to developing countries for renewable energy production, this does not directly capture or measure collaborative engagement. Finally, the SDG framework does not consider the trade-offs and interactions between resources. This has led some scholars to critique the SDG framework for failing to consider trade-offs, where achieving one goal may be at the expense of another (e.g., Fader et al. 2018).

3. CONCEPTUAL FRAMEWORK

This conceptual framework bridges the collaborative governance, FEW nexus governance, and sustainability indicators literatures. It provides an approach that begins to assess collaborative FEW nexus governance. The framework includes a set of indicators for assessment, which were constructed from a systematic literature review. The sections below elaborate on the methods used to create the framework and accompanying indicator set.

4.3.1 Framework Construction

This framework is an adaptation from the Collaborative Governance Regime (CGR) framework in Emerson et al. (2012). The CGR framework provides a comprehensive conceptualization of collaborative governance components and has been

used by other empirical studies (e.g., Ulibarri 2015; Biddle 2017; Abrams et al. 2020). However, other collaborative governance frameworks include aspects that are not explicit in the CGR framework, such as actor inclusivity. Triangulating across multiple literatures therefore allows for a more comprehensive understanding of collaborative governance within environmental management. Additionally, the CGR was created with a singular-disciplinary perspective; considering additional settings of collaborative governance allow for the creation of a framework that can better address multi-disciplinarity. Thus, the CGR framework was used as an initial outline, with several themes added and removed to most adequately represent local FEW nexus systems. Based on a targeted literature review of empirical studies and theoretical construction, I triangulated the literature to uncover the most common concepts of collaborative governance. When these collaborative governance concepts were integrated with the food-energy-water nexus, I produced a framework of FEW nexus collaborative governance, as depictured in figure 6. This conceptual framework consists of three main concepts: structural dimensions, decision-making processes, and organizational values. Each of these three framework concepts contain variables (table 8), which are used to create an indicator set for assessment (table 9).

These three concepts interact together across the three sectors. Structural dimensions are defined as the institutional organization of the sectors and the actors within the sector, similar to capacity for joint action from Emerson et al. (2012). Structural dimensions across the three sectors need to be compatible with one another for collaboration to successfully occur. Structural dimensions include the three indicators of institutions, actor inclusivity, and power. Institutions here refers to the organizational

structures of stakeholder organizations and the rules that govern them (Ostrom 1990). While this is a more limited understanding than that of the larger institutions and institutional analysis literature, my consideration specifically focuses on the compatibility of rules in use and organizational structures across sectors for the advancement of collaborative governance. Actor inclusivity refers to a diversity of actors being included in the collaborative engagement; this includes actors from multiple governance sectors (e.g., public, private, non-profit), from multiple levels and scales, and from across all three sectors. Power refers to a balance of power among stakeholders and sectors or intentional efforts to understand and overcome power differences within the collaborative engagement. Unchecked differentials in power can challenge collaborative engagement, as powerful actors may manipulate the process for their own gain. However, as the process of collaborative governance can overcome challenges of power asymmetries (Ansell and Gash 2008; Emerson et al. 2012), compatible structural dimensions can be achieved when there is institutional compatibility and inclusion of multi-level, cross-sector engagement with all participate in the decision-making and governance.

Decision-making processes are the ways in which stakeholders within each sector evaluate alternatives and outcomes to make informed choices under specific contexts and uncertainties. Successful collaborative governance needs compatibility in this decision-making across sectors. Similar to principled engagement from the CGR framework, this concept refers to the process of and approaches to engagement between the actors for collaborative decision-making. However, principled engagement emphasize building the initial relationship building between actors (Emerson et al. 2012), whereas decision-making processes here focuses on the activity between the sectors throughout the

engagement. Decision-making under uncertainty, specifically, considers the approach to evaluating outcomes and making informed choices within a dynamic system containing uncertainties and risk (Larson et al. 2015). Scholars have begun to consider uncertainties as a given within human-environment systems (Folke et al. 2005; Pahl-Wostl 2009), and complex human-environment systems, such as the FEW nexus, require the consideration of system uncertainties within the decision-making process (Larson et al. 2015). Yet different groups can have different perspectives on uncertainty (Jacobs et al. 2005; McNie 2007), which can present challenges for coordination and collaboration in an uncertain world (White et al. 2015). Complementary decision-making approaches are thus important for successful collaborative governance. While the literature on decision-making under uncertainty is vast, I acknowledge that my conceptualization of it here is limited. In that vein, I focus here on the collaborative governance components of decision-making that I believe lead towards successful collaborative engagements within the context of the FEW nexus system.

Decision-making processes include five indicators: leadership, shared goals, communication, resources, and knowledge. Intentional leadership refers to the act of bringing stakeholders together and moving the process forward. Leadership can be also important for overcoming power asymmetries, for building trust between stakeholders, and facilitating and maintaining institutional rules (Ansell and Gash 2008). I define shared goals as the sectors in the engagement having the same desired outcome from the engagement, which may include having a shared vision, purpose, and/or objective between the sectors. Shared goals allow all the stakeholders across the sectors to be on the same page about the intention of the collaborative engagement and to have a shared

understanding of the potential benefit from collaboration. Effective communication, the open dialogue between stakeholders across sectors, is necessary for successful collaborative governance (Yeboah-Assiamah et al. 2016; Medema et al. 2017; Porter and Birdi 2018). This should include negotiation, discussion, and listening between the stakeholders across sectors (Newig et al. 2017). Share resources refers to the finances, time, skill, personnel, and/or capital that are shared between sectors within the collaborative engagement to advance the mutual goals. Shared knowledge is the information, data, and expertise that sectors bring to the collaborative governance engagement to the benefit of all three sectors (Plummer et al. 2012). Together, leadership and effective communication can move collaborative engagements forward towards a shared goal, where shared resources and knowledge provide support to bolster the engagement and lead toward mutually beneficial outcomes.

Organizational values focus on the needed inherent similarities or agreement for coordination; they provide an essential foundation that must be established before or in the early stages of a collaborative engagement. This is similar to shared motivation in the CGR framework, as it focuses on the interpersonal and relational elements of collaborative governance (Emerson et al. 2012). Organizational values include the three indicators of trust, commitment, and shared values. Trust refers to the condition of having belief in another's goodwill across the sectors and to the process of building increased trust for engagement. Trust has been found to be a foundational component of successful collaborative governance in theoretical and empirical studies (Ansell and Gash 2008; Schoon et al. 2017; Sullivan et al. 2019). It allows stakeholders to move beyond their own perspective and understand the values and interests of others (Emerson et al. 2012).

Commitment to the process refers to stakeholders across sectors choosing to engage in and being dedicated to the process with the belief that collaborative engagement will lead to the best mutual gains (Ansell and Gash 2008). Without this commitment, stakeholders may not invest in the collaborative engagement as they do not see the mutual gains as better than the potential individual benefit. Shared values are having similar perspectives, interests, principles, and ethics between the sectors or the active effort to understand others' different perspectives and interests. While these values do not need to identical across the three sectors, compatibility between them and mutual understanding of the differences in values is needed for successful collaborative engagement.

The three concepts of structural dimensions, decision-making processes, and organizational values are the collaborative dynamics of the system. These three must work together across the sectors in the context of the FEW nexus system for successful collaborative governance to occur. They inherently operate in a cyclical fashion, whereby each concept can influence the others. These concepts make up the collaborative dynamics of the system and are situated within and influenced by the greater system context. The system also includes the influence of prior history, external influences, and impacts. First, prior history, historical instances of conflict or cooperation, underlies the collaborative engagement; previous existence of animosity or of cooperation between sectors can impact the outcome from the collaboration (Ansell and Gash 2008). Second, external influences, components outside of the examined FEW nexus system itself, can influence the collaborative governance process. These may include economic conditions, climate change influences, population dynamics, and political factors. While these influences are only indirectly connected the collaborative process itself, they can still

influence the success or failure of collaborative engagements. For example, in a case where collaborative governance of the FEW nexus could lead to positive benefit for resource security, yet the economic costs to engage in collaborative governance instead of single-sector governance are too great, the economic conditions of this setting may a hinderance for successful collaboration. Third, impacts result from the collaborative process, which may influence either the local nexus system itself or the larger system outside of it. For example, successful collaborative engagement on a specific governance decision may lead to increase food, energy, and water resource security within that system. Finally, the framework should be interpreted as a system of feedbacks, not as a linear process. For example, the outcome and impacts from one collaborative engagement can set the stage for the success or failure of a future engagements.

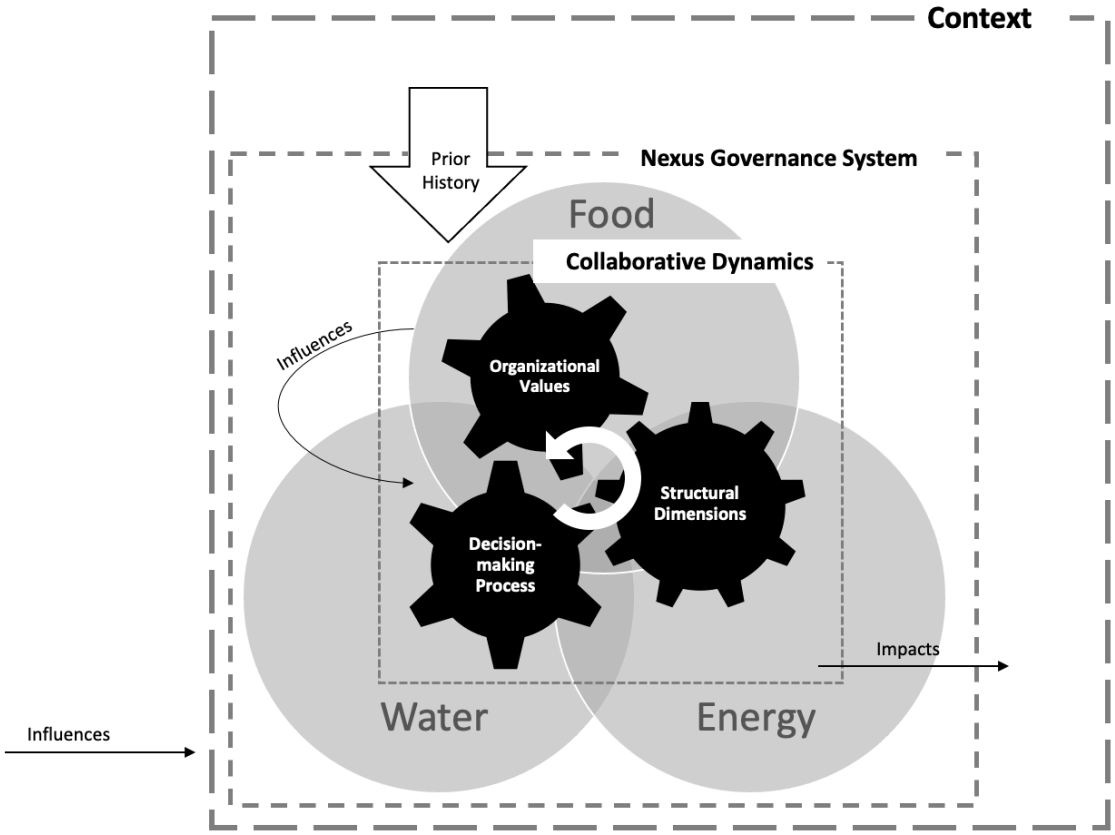

Figure 6: Conceptual framework for assessing collaborative FEW nexus governance.

Table 8: The operationalization of the three key concepts of the conceptual framework.

Concept	**Definition**	**Variables**
Structural dimensions	Complementary organizational structures and rules in use across sectors in engagement	Institutions Actor inclusivity Power
Decision-making processes	Compatibility of the processes of making collaborative informed choices for outcomes across sectors in engagement	Leadership Shared goals Communication Resources Knowledge
Organizational values	Basic foundation of principles that are similar across sectors or an understanding and acceptance of others' different perspectives across sectors	Trust Commitment Shared values

4.3.2 Indicator Set

The three key concepts of the conceptual framework include eleven variables. Each of these variables contain indicators, which together make up the indicator set to assess the concepts of my framework. This indicator set can be applied to a FEW nexus governance system in order to implement the framework in practice. It was developed through a multi-stage literature review of collaborative governance and the FEW nexus, then refined through empirical study of two case cities. An overview of the variables in each of the three framework concepts is provided in table 8. Each variable contains several indicators for assessment of collaborative governance of the FEW nexus. Table 9 provides a description of each variable and the accompanying indicators, measurements, and data. This allows for operationalization of the concepts that compose the conceptual framework.

The creation of this indicator set involved a three-step process. First, I conducted a multi-staged literature review of collaborative governance. A systematic, though not comprehensive, literature review was conducted to identify the main components of collaborative governance. In this stage, I triangulated key literature of collaborative governance theory and practice to identify the most common, relevant, and inclusive components of collaborative governance. This resulted in a comprehensive list of the variables used to conceptualize collaborative governance. While similar to foundational frameworks of collaborative governance (e.g., Ansell and Gash 2008; Emerson et al. 2012), this variable set improves on these by explicitly considering components more important in multi-disciplinary collaborative governance over the single-sector governance these foundational frameworks were based on. Then, I conducted a

comprehensive literature review of collaborative governance measurement, evaluation, and assessment. I then focused specifically on literature that assesses collaborative processes using indicators. From this scholarship, I created a list of indicators to assess the variables of interest.

Second, I conducted an additional targeted literature review on food-energy-water nexus governance. Reviewing this literature, I selected publications specifically on FEW nexus indicators and matched the indicators from the FEW nexus literature onto the variables identified from the collaborative governance literature review. This resulted in a set of indicators from both the collaborative governance and the FEW nexus literatures matched onto the identified variables. For each of the identified indicators, the accompanying measurement approach and data source were considered. Finally, I considered the targets within the relevant Sustainable Development Goals (SDGs)—goals 2, 6, 7, and 17—to determine any relevant indicators from this framework for FEW nexus collaborative governance. In the end, this resulted in a set of ad-hoc indicators for each of the identified variables. These include primarily the measurement approaches of secondary data analysis, social network analysis, surveys, and interview methods. Secondary data analysis includes document analysis, media analysis, and data from national and state databases. Social network analysis (SNA) is an approach to quantify and measure the information flows, collaboration, and communication between actors in a system (Borgatti et al. 2009); scholars have used it as an indication of collaborative governance within a network (e.g., Secco et al. 2014). Survey design and interviews are used to capture values and perspectives of actors in the system, as proxy measures for values cannot be captured by secondary analysis (Abrams et al. 2020). The complete

indicator set, including the eleven selected variables for the framework, is presented in table 9.

Finally, through empirical studies of FEW nexus governance in Cape Town, South Africa and Phoenix, Arizona, USA, I matched the variables from my theoretical framework onto those uncovered from case analysis. To do this, I used a grounded approach to empirically identify instances of collaborative governance between food, energy, and water stakeholders through the open coding process (Bernard et al. 2017). These codes were grouped into categories through the process of axial coding (Bernard et al. 2017) and then compared to the variables identified from the literature here through the process of pattern matching (Yin 2018). In this way, I examined how the variables from the literature were demonstrated within integrated FEW nexus governance. Figure 7 provides an overview of the complete process of indicator creation.

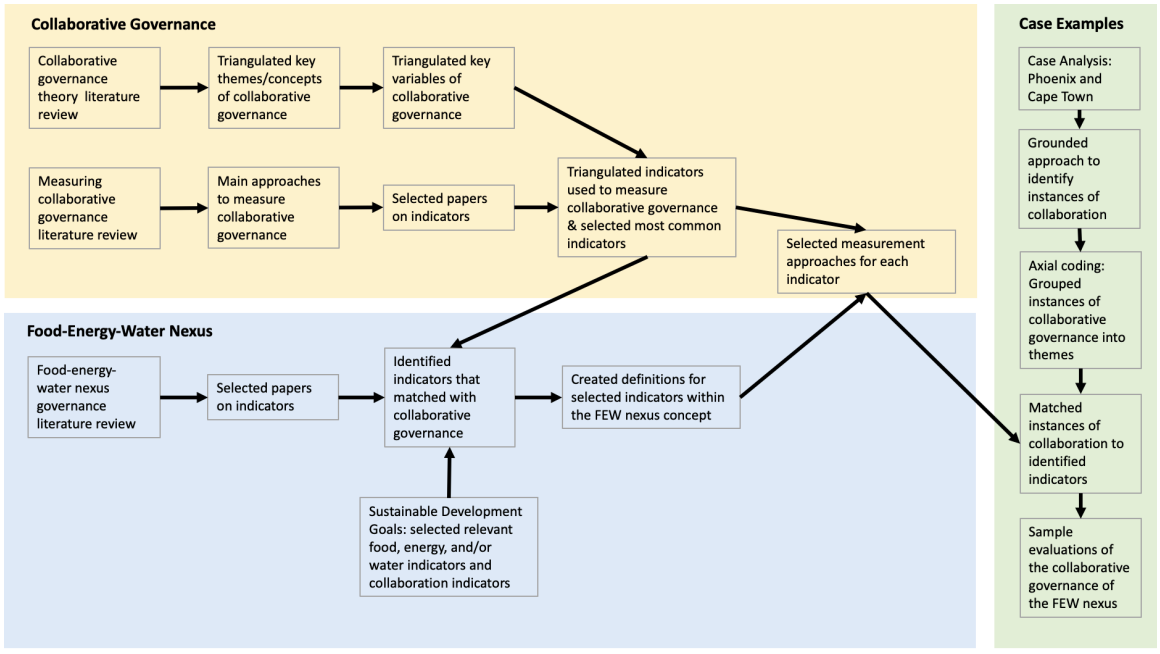

Figure 7: Diagram of the process for creating the indicator set.

Table 9: Eleven variables considered for assessing collaborative governance of the FEW nexus. Each variable includes a definition, identified indicator(s), measurement of those indicators, the type of data, and an example source using this indicator

Variable	Definition	Indicator	Measurement	Data Source	Source
Institutions	Organizational structures or roles of actors or sectors that encourage cross-sector collaboration	Rule compliance	Stakeholder perspective on whether there are management plans and rules for cross sector resource use AND on how stakeholders respect and adhere to existing rules	Survey	Cundil & Fabricius 2010
		Contracts	Number of formal contracts between at least two of the three sectors	Secondary data	--
Actor Inclusivity	Inclusion of different actors from food, energy, and water sectors in engagement	Network size	Number of total actors and in each food, energy, and water sector in the study area	SNA	Abrams et al. 2020
		Sub-network proportion	Multiplication of the three times the proportions of actors in each resource subgroup [see equations below, Sub-Network Proportion=27(f*w*e)] (0-1)	SNA	--
		Actors in the center of the network	Percent of actors in the center of the information network (0-100), based on core/periphery analysis (flow of information)	SNA	Secco et al. 2014

Power	Efforts to overcome or understand power dynamics between sectors	Centrality of power	Centralization of the network (0-1)	SNA	Kharanagh et al. 2020
		Empowerment	Stakeholder perspective on the level of power they have in cross-sector engagements	Survey (or interview/case study)	Secco et al. 2014
		Influence	Percentage of stakeholders who think their comments have capacity to influence collaborative decision-making	Survey	Secco et al. 2014
Leadership	Intentional leadership by an actor or sector to bring actors to the table or keep the process moving	Leadership	Stakeholder perspective of the presence of leadership in advancing the collaborative effort	Survey (or interview/case study)	Cundil & Fabricius 2010
Shared Goals	Shared purpose, vision, or goals between the food, energy, and water sectors	Consensus of missions	Content analysis of mission statements for the actors in the system to find consensus of themes	Content analysis	--
		Goals' perspectives	Stakeholder perspective of shared goals between other sectors	Survey	--
Communication	Effective and open communication or dialogue across food, energy, and water sectors	Network communication	Density of the local network (0-1)	SNA	Bodin & Crona 2009

		Communication perspectives	Stakeholder perspective of ease and frequency of communication	Survey	--
Resources	Finances, time, skills, personnel, or capital resources shared in engagement	Funding	Amount of state and federal funding awarded towards collaborative engagements with food, energy, and/or water stakeholders	Secondary data	Abrams et al. 2020
		Use of time	Quickness in informing stakeholders, in-closeness centrality (flow of information) (0-100)	SNA (only for bidirectional network)	Secco et al. 2014
		Personnel	Stakeholder perspective of the availability of personnel specific for cross-sector collaboration	Survey	--
Knowledge	Knowledge, data, or information shared between sectors	Knowledge flows	Percent of bidirectional flows of collaboration (0-100)	SNA (only for bidirectional network)	Secco et al. 2014
		Learning opportunities	Number of cross-sector learning opportunities (workshops, meetings, etc)	Secondary data	Ferreyra & Beard 2007
		Data access perspective	Stakeholder perspective on the access to credible data from other organizations	Survey	Ferreyra & Beard 2007
Trust	Presence of trust or belief that all actors are acting in good faith or with good intentions	Trust perspectives	Stakeholder perspective on the level of trust across food, energy, and water sectors	Survey	--

Commitment	Shared commitment or dedication to the cross-sector collaborative process and a willingness to participate	Willingness	Stakeholder perspective of the willingness of self and perceived willingness of others to engage in collaboration	Survey (or interview/case study)	Cundil & Fabricius 2010
		Time	Length of collaborative engagement	Survey or secondary data	--
Shared Values	Shared interests, values, or perspectives between sectors	Values perspectives	Stakeholder perspective on how their values align with other across sectors	Survey (or interview/case study)	--

4.4 CASE APPLICATIONS

Two cases of urban FEW nexus governance under conditions of water stress were examined to understand how the framework and indicator set may be exemplified through empirical study. Each of the two cases include a brief case description, followed by examinations of collaborative governance in practice as based on the conceptual framework and accompanying indicators. While these cases do not provide full measurement for all of the variables, they exemplify the usefulness of the framework and indicate the level of urban FEW nexus collaborative governance.

4.4.1 Phoenix, Arizona, USA

The Phoenix metropolitan area is in the Southwestern region of the United States. The metropolitan area contains a population of about 4.5 million people and is one of the fastest growing cities in the nation. Located in the Sonoran Desert, the area has a semi-arid climate with an annual rainfall of approximately 9 inches (23 centimeters). Water to support the urban metropole comes from four main sources: local surface water, imported surface water from the Colorado river, groundwater, and reclaimed water (Larson et al. 2013). There are strong interlinkages between the three FEW nexus resources. As a desert city, water is a central resource in the management of food and energy resources (White et al. 2017). Agriculture is important to the history and culture of Arizona, resulting in heavy irrigation even within the metropolitan area; approximately 30% of water used within the urban area in 2017 was for irrigation (Arizona Department of Water Resources 2020). Energy is crucial for water procurement, distribution, and treatment. For example, energy is needed to pump water from the Colorado River to

central and southern Arizona through the Central Arizona Project (CAP) canal, which brings water 336 miles over nearly 3000 feet in elevation change (Bartos and Chester 2014). CAP is the single largest user of electricity in the state of Arizona (Bartos and Chester 2014). Additionally, water is needed to cool the Palo Verde Nuclear Power Plant, the largest nuclear plant in the United States (Bartos and Chester 2014). With such strong interlinkages between food, energy, and water resources, governance collaboration between the three sectors provides opportunity for improved management approaches to reduce unintended consequences and increase resource security.

Structural dimensions: The three sectors of food, energy, and water have governance structures that operate at different levels. Energy governance is highly centralized around a few sub-regional actors, including utility companies and the AZ Corporation Commission. Agriculture and food governance is generally decentralized, with most decisions made at the farm level. However, collaborative organizations such as irrigation districts and lobbying associations influence agriculture decision-making, and state and national Departments of Agriculture set some regulations (Eakin et al. 2016). Governance of water resources consists of a diversity of actors from various levels and scales to manage the supply and demand of water resources (Larson et al. 2013). With food, energy, and water governance operating at different scales, there is not full organizational governance alignment between the three. Yet with some cross-sector institutions (e.g., irrigation districts) and formal contracts between cross-sector and boundary organizations, there is some positive support for institutional collaborative governance; thus, institutional alignment is considered moderate. A social network analysis of the region reveals a large number of actors across all three FEW nexus sectors

are included within the collaborative governance network (Jones & White *in review*). This indicates the high level of actor inclusivity within the network. Additionally, the same social network analysis contains moderately low level of network centralization, which suggests a distributed power-sharing in collaboration (Jones & White *in review*). This indicators that there may not be strong power asymmetry that could inhibit collaborative governance. Thus, with high actor inclusivity and power sharing, even with moderate indication of institutional alignment, the Phoenix area has structural dimensions that would support collaborative FEW nexus governance.

Decision-making processes: A social network analysis shows a low density between the actors in the network, which suggests limited communication between actors (Jones & White *in review*). In semi-structured interviews with FEW nexus stakeholders, water actors emphasized their desire to collaborate across all three sectors, however energy and food actors expressed that they often felt excluded from water decision-making (Chapter 3). This shows mixed perspectives on leadership; the water sector sees themselves as moving engagements forward, but the food and energy sectors seem them as failing to include others in collaborative decision-making. The interviewees also discussed the limited personnel resources they had to intentionally engage in collaboration and limited timeframes to make decisions, where there was not always sufficient time for collaboration and data-gathering across sectors (Chapter 3). This suggests a low level of resource sharing for collaborative governance success. Finally, participants noted the importance of having a shared goal, and they emphasized the great advantage of the engagement if that goal could lead towards beneficial outcomes that no single organization could achieve on its own (Chapter 3). This suggests that shared goals

may be present within collaborative FEW nexus engagements. In sum, these findings highlight that there are challenges to engaging in collaborative decision-making processes, but they can be overcome with clear, shared goals and effective leadership.

Organizational values: Through semi-structured interviews, trust was identified as a key component for successful collaboration, though many actors noted a lack of trust in previous engagements that prevented prior success (Chapter 3). This suggests that actors may be willing to work to build trust across sectors, but that trust may not be present already. However, most stakeholders noted the value of reducing risk in decision-making (Chapter 3). Thus, a focus on risk reduction as an avenue of shared values across the organizations could provide an opportunity for collaboration. Overall, this suggests a moderate level of organizational value coherence between the three FEW nexus sectors, and this could be improved with intentional efforts to build trust between them.

In the Phoenix metropolitan area, overall, there is currently moderate collaborative governance between food, energy, and water governance sectors, and there is promise for future collaboration. Integrated FEW nexus governance in Phoenix is challenged by structural mismatch between the three sectors and by limited communication across them. Additionally, with a prior history of conflict between some stakeholders, collaborative engagement may be further hindered. For example, interview respondents noted that attempts to collaborate on water and agricultural governance with a Native American tribe failed because of centuries of tension between Native and non-Native communities (Chapter 3). However, with many actors being connected to others, even indirectly, the structure of the social network provides opportunity for greater collaboration. Additionally, water actors have expressed a willingness to initiate and lead

collaborative engagements across sectoral boundaries to reduce risk and unintended consequences. However, this leadership needs to be better coordinated to uphold the shared power and actor inclusivity of the network in the governance process. Thus, with increased trust and communication channels and with leadership that better engages food and energy actors, full collaborative FEW nexus governance may be possible. Figure 8 provides an overview of the variables considered in the analysis.

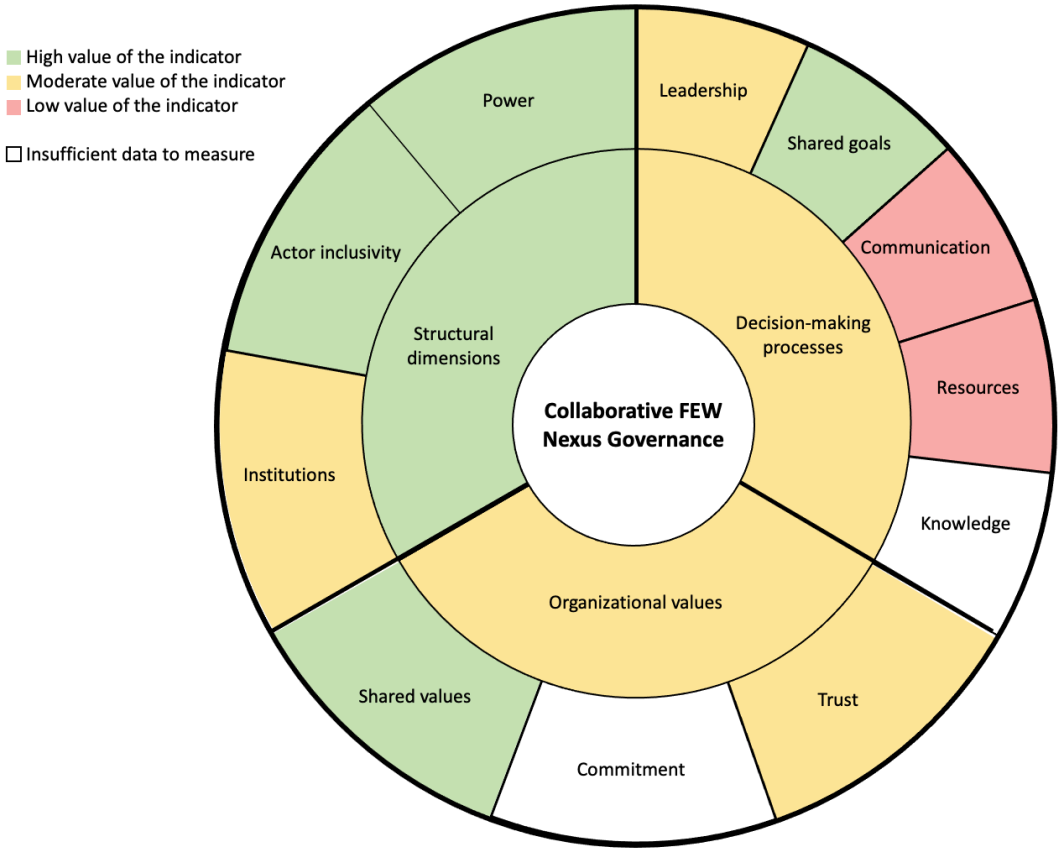

Figure 8: Assessment wheel for Phoenix for the assessment of the eleven variables and three concepts based on the indicator set and framework for collaborative FEW nexus governance.

4.4.2 Cape Town, South Africa

Cape Town is located in the Southwestern tip of South Africa, where the metropolitan area has a population of approximately 4 million people. The area is characterized by a Mediterranean climate with warm, dry summers and mild, wet winters (Sousa et al. 2018). Surface water composes most of the water supply in the region, with some augmentation from groundwater and desalination. Demand increases in the summer with increased outdoor water use, though summer also has low rainfall leading to lower surface water reserves and results in a temporal imbalance between supply and demand (Wright and Jacobs 2016). This is a further challenge due to limited water storage capacity (Herrfahrdt-Pähle 2013) and uneven spatial distribution of water resources (Ololade 2018). Interlinkages within the FEW nexus were highlighted through the impacts of the 2018 Cape Town water crisis, where a three-year drought between 2015-2017 put major strains on the city's and region's water supply. While the crisis was averted with heavy rains and high urban water conservation, with the increasing impacts of climate change, droughts are expected to become more common in the region (Pascale et al. 2020). Agriculture surrounds the city, sharing the water that feeds into the city's reservoirs. These agricultural regions are key for the provision of food throughout the country and include the world-renowned wine regions of Stellenbosch and Franschhoek. Cuts to agricultural water thus can impact the food sector by reducing agricultural yields that can disrupt supply chains, by forcing layoffs of agricultural workers, and by leading to restaurant closures (Chapter 2). The water crisis led to many proposals for increased water augmentation approaches such as desalination, groundwater pumping, and water reuse (Chapter 2). As energy-intensive approaches to water augmentation, this can strain

the city's electrical grid, which already faces capacity issues; the city faced an energy crisis in the past (Jaglin 2014), and still has occasional load-shedding. Thus, plans to increase water capacity in the city should consider the potential influence on energy resources for increased security across both sectors.

Structural dimensions: The three sectors of food, energy, and water have institutional structures that operate in different ways. Governance of the agriculture sector is highly decentralized, with most decisions managed at the local level either by individual farms or through local Water User Associations (Termeer et al. 2018). Energy governance, on the other hand, is highly centralized at the national level, where a single utility company, Eskom, provides 95% of the country's electricity (Inguscio 2017) and where regulation and tariff-setting are done through the national government (Kelly and Geyer 2018). Water governance is multi-leveled with much governance occurring at the regional and basin levels, though some power is held at the national level and by municipalities (Beck et al. 2016). This includes the Department of Water and Sanitation providing water-related policy and regulation from the national level, Catchment Management Agencies and regional water utilities provide watershed management and water-related infrastructure at the provincial and regional levels, and municipalities and water service providers ensuring water services at the local level (Beck et al. 2016). Furthermore, these institutional mismatches are compounded by a prior history of political challenges in the country that exacerbate natural resource management, such as the reconstruction post-Apartheid and the tension between the minority party (that controls the Western Cape provincial government) and the majority party (that currently controls the national government), A media analysis of news articles surrounding the

Cape Town water crisis also showed a high number of frames blaming the water crisis on government and management decision-making (Chapter 2). Overall, with organizational structures operating at different institutional levels and influences from prior history straining collaborative engagement, there is limited coordination and low support for collaborative FEW nexus governance from the structural dimensions.

Decision-making processes: Based on a media analysis, communication does exist between different levels of governance and between different FEW nexus sectors (Chapter 2). However, media frames also noted the need for increased communication to successfully respond to the water crisis. This suggests a moderate level of communication for collaborative governance of the FEW nexus. Additionally, in the context of the water crisis, there were shared goals between food, energy, and water actors to avert the crisis and restore water security. This suggests complementary shared goals, which support collaborative governance. Finally, physical water and financial resources were shared between different organizations and sectors to address water crisis challenges (Chapter 2). Though most of this resource sharing was at the grassroots level, instead of in the decision-making space, it suggests an opportunity for bottom-up efforts of resource governance. Thus, with a high level of resource sharing for grassroots resource governance, shared goals between sectors, and a moderate level of communication, the evidence suggests a high level of support for FEW nexus collaborative governance from decision-making processes.

Organizational values: Media analysis revealed a strong distrust of elected officials, the government, and resource management departments. In fact, trust was almost never mentioned in the positive but only to express distrust of actors (Chapter 2).

Additionally, instances of shared values were limited (Chapter 2). This finding may suggest that the food, energy, and water organizations combating the water crisis may not have similar foundational values, though further investigation through survey or interviews of stakeholders is needed. In sum, low levels of apparent shared values and trust between FEW nexus sectors suggests minimal support of collaborative FERW nexus governance from organizational values.

In the Cape Town metropolitan area, there is limited apparent collaborative governance between food, energy, and water stakeholders. With structural mismatches between the three sectors, distrust of water management and political leaders, limited shared values, and a history of conflict with the government, there is not a strong foundation for collaborative governance to occur. The metropolitan area would need to overcome these challenges for successful collaborative FEW nexus governance. However, the shared goal among all actors of combating the water crisis and making the city resilient to future drought shocks and stressors, along with coordination in the decision-making across sectors in light of the water crisis, provides an opportunity to motivate stakeholders to work through these and future challenges, engage in collaboration, and strive toward cross-sector governance for mutual benefit. Figure 9 provides an overview of the variables considered in the analysis.

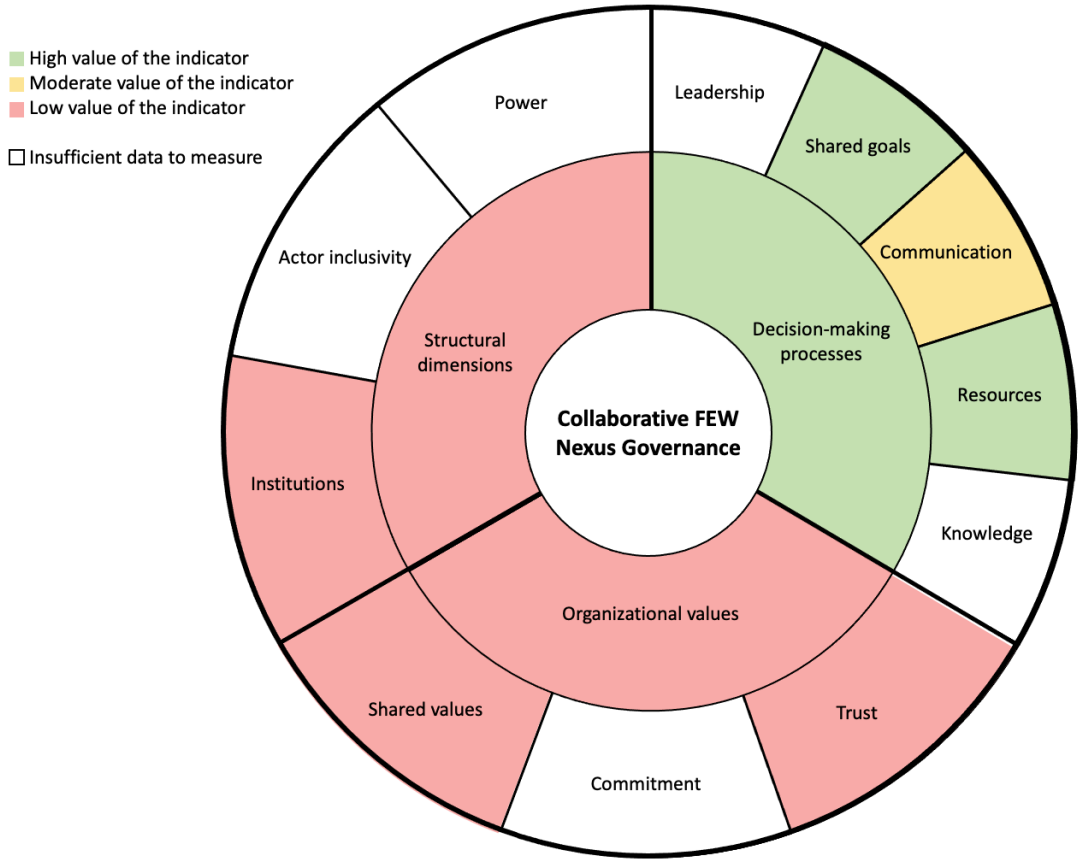

Figure 9: Assessment wheel for Cape Town for the assessment of the eleven variables and three concepts based on the indicator set and framework for collaborative FEW nexus governance.

4.5 DISCUSSION

This framework has several key contributions for FEW nexus governance in practice. First, there are currently no frameworks to evaluate or assess FEW nexus governance. The indicator set presented here can provides an avenue toward overcoming this knowledge gap as it creates an approach to understand and assess the landscape of collaborative local FEW nexus governance. This is an important foundation for any study of FEW nexus governance at the local level, as it provides a starting point from which to argue for increased collaboration or from which to find examples of successful

collaboration in practice. Additionally, it can be used to validate or challenge the claim that collaborative governance leads to increased resource security and improved management outcomes. While FEW nexus governance claims to lead towards positive outcomes (Finley and Seiber 2014; Leck et al. 2015), studies have not yet drawn empirical relationships between FEW nexus integrated governance and improved outcomes, and scholars have critiqued the ability of collaborative governance to improve environmental outcomes (Koontz and Thomas 2006). This framework provides an opportunity to address this claim, with additional research, to correlate collaborative nexus engagement with resource security and environmental outcomes.

This framework also contributes to the literature of collaborative governance. Measurement, evaluation, and assessment approaches for collaborative governance of natural resource systems focus mostly on single-sector resource management (e.g., Cundill and Fabricius 2010; Secco et al. 2014; Abrams et al. 2020), as traditional collaborative governance frameworks do not have interdisciplinarity built into them. The framework presented here, while specific to the FEW nexus, seeks to overcome this gap and it can provide support for assessment approaches of other cross-sector resource systems. Additionally, much of the foundational components of key collaborative governance literature from single-disciplinary study (Ansell and Gash 2008; Emerson et al. 2012) holds true in the application of collaborative governance to the multi-disciplinary resource system of the FEW nexus. This suggest that, though modifications may be needed, conventional collaborative governance is still relevant and useful in application of multi-disciplinary sustainable governance systems.

Finally, in analyzing the cases of Phoenix and Cape Town, the application of this framework provides an opportunity to understand the collaborative governance between the three resource sectors. The Phoenix case shows a moderate level of collaborative FEW nexus governance, while the Cape Town case shows limited collaborative governance. Without significant collaboration between the three governance sectors, these findings are in line with the claim of theoretical literature that there is limited collaboration between the three sectors in decision-making in practice (e.g., Finley and Seiber 2014; Leck et al. 2015). Additionally, the application of the framework also allows us to identify specific areas where collaboration is weakest and to make recommendations for increased collaboration moving forward. This provides opportunity for the use of this framework to encourage FEW nexus decision-makers, stakeholders, and governance actors in practice to collaborate in governance.

4.5.1 Limitations

The research presented here includes several limitations. First, the framework is based on only two cases of urban FEW nexus governance. Additional cases would provide greater support for the structure of the framework and generalizability to increase its utility. Second, the cases were based on limited data. Increased data through in-person engagements and additional sources for secondary data would enhance the application of the framework. Despite these limitations, this framework still provides a needed step towards assessment of collaborative governance of the FEW nexus, creating a pathway towards measurement of FEW nexus governance. Future work with additional cases to increase the generalizability of the framework and to validate the indicator set will

provide support to overcome these limitations and increase the utility of the framework and indicator set created here.

4.5.2 Future Work

This research provides several opportunities for future research. First, additional cases can be examined to provide greater support for and refinement of the indicators and measures. This will increase the generalizability of the conceptual framework and indicator set. Additional cases can include other water stressed cities with strong food-energy-water linkages, such as Sao Paulo, Brazil and Chennai, India. This would create a database of cases that could be used in comparative case analysis to create theoretical propositions for FEW nexus governance based on empirical findings. Additionally, with these new cases, the indicator set can also be validated to ensure the usability and salience of the framework. This would move the framework and indicator set from assessment to measurement. Second, the indicator set can be used to assess the level of collaborative governance of FEW nexus sectors and compare those assessments to measures of resource security or environmental outcomes. More research is needed to empirically investigate how the presence of collaborative governance influences outcomes (Porter and Birdi 2018). This could be used to assess the quantity or quality of the outcomes themselves that come from collaborative FEW nexus engagements *or* to measure the impact of collaborative FEW nexus governance on existing outcomes as compared to similar projects without collaborative governance of the FEW nexus. Connecting FEW nexus governance to outcomes could provide empirical evidence to support or challenge the theoretical claims of FEW nexus governance scholarship that

collaboration between the three sectors increases security of food, energy, and water resources. Finally, additional methods could be used to consider interventions to increase collaborative governance between the three resources. For example, agent-based modeling can be used to simulate collaborative interactions between stakeholders across FEW sectors (e.g., Ding et al. 2019), where interventions can be simulated to understand whether they might increase or decrease collaboration. Additionally, a survey of collaborative FEW nexus projects or a thorough in-depth case study of one specific collaborative FEW nexus engagement can be used to understand the details of successful collaborative governance between the three FEW nexus sectors.

4.6 CONCLUSION

With the strong interrelationships between the food-energy-water nexus resources, collaborative governance across the three can provide opportunities to reduce unintended consequences in decision-making and increase resource security. Effective implementation of collaborative FEW nexus governance can be enhanced by the assessment of existing FEW nexus systems. Assessment is important to understand the strengths and weakness of the integrated governance system, to consider the benefit of specific governance approaches in practice, to address criticisms of integrated FEW nexus approaches, and to assess and improve such approaches (Conley and Moote 2003). However, there are currently no methods to assess FEW nexus governance in the literature. The conceptual framework and assessment indicator set presented here provides an opportunity to address this research gap. This framework considers the interplay between the structural dimensions, decision-making processes, and

organizational values across food, energy, and water sectors that facilitate or hinder collaborative governance. Application of this framework involves the assessment of eleven variables, which form the backbone of an indicator set. This indicator set provides an opportunity to better understand and assess FEW nexus governance, a major call in the literature for further research (e.g., Albrecht et al. 2018; Opejin et al. 2020). Future research will involve the consideration of additional cases to create a database of FEW nexus governance case studies, the validation of the indicator set and framework, and the refinement of the framework to move from assessment to comprehensive evaluation and measurement. Furthermore, this framework and accompanying indicator set may also be applied to specific FEW nexus governance interventions to determine how collaborative governance of food, energy, and water resource security outcomes improve with increased collaborative governance. Finally, the framework can be used to propose realistic changes that can increase the level of collaboration within FEW nexus governance in practice.

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

With strong interrelationships between the three resources of food, energy, and water, integrated governance across the three sectors offers opportunity to reduce unintended consequences and increase resource security. Yet with limited governance engagement happening across this food-energy-water (FEW) nexus, it is important to understand the limitations to FEW nexus governance in practice, to examine why these barriers exist, and to identify opportunities to overcome these challenges. Integrating the theory of collaborative governance and the concept of the FEW nexus provides an opportunity to better understand the structure of and approaches to FEW nexus governance. The purpose of this research was (i) to better understand the landscape of governance within the food-energy water nexus, (ii) to identify and examine barriers to this integrated governance and propose approaches to overcome those barriers, and (iii) to develop an approach to assess FEW nexus collaborative governance to move from theoretical conceptualization towards assessment. To achieve this goal, I conducted two case analyses in Cape Town, South Africa and in Phoenix, Arizona, USA. I then created a conceptual framework and accompanying indicator set to begin to assess the collaborative governance of FEW nexus governance in practice. In this vein, the remainder of the conclusion proceeds as follows. First, I present a summary of the results and key findings from chapters two, three, and four. Second, I provide a synthesis of the findings, key takeaway points, and policy recommendations that emerged from the research. Finally, I conclude with limitations of the study and a discussion of future work.

5.2 CHAPTER CONCLUSIONS

5.2.1 Chapter 2 Conclusions: Media Framing of the Cape Town Water Crisis

In the second chapter, I conducted a media analysis of the framing of news articles surrounding the 2018 water crisis in Cape Town, South Africa. International media captured the water crisis, as the metropolitan area of Cape Town came within 100 days of running out of water while the city faced severe water stress. The city limited residents to 50 liters of water per person per day and heavily reduced the water allocated for surrounding agriculture. Thankfully, with plentiful winter rains, Cape Town was able to avoid complete depletion of their reservoirs and relax water restrictions. However, in the face of climate change, the city is expected to face future drought (Pascale et al. 2020) and many city water managers internationally are looking to lessons learned from Cape Town to improve their own water management approaches. Thus, investigating the case of the Cape Town water crisis provides a unique and relevant exemplar of a response to water crisis that may have implications for other cities, and the media surrounding the crisis provides an opportunity to understand the perspectives of the crisis. Media can shape public opinion (Slater 2007) and has been shown to influence public policy (Birkland 1996), thus reflecting and shaping the public discourse (Althaus and Tewksbury 2002). This is because frames presented can resonate through society, and frames that are perceived to align well with events are often repeated and emphasized in the media (Benford and Snow 2000). Thus, analyzing media framing provides an important perspective of the water crisis phenomenon. The purpose of this paper was to explore the role of media discourse surrounding the water crisis to understand the

collective action framing, the collaborative governance to address the crisis, and the impact of the crisis on the interconnected FEW nexus. To conduct this media analysis, I extracted all news articles about the Cape Town water crisis within the defined search criteria for analysis. I then created a codebook of key constructs for collective action frames, collaborative governance, and the FEW nexus components as based on previous literature. Through the process of content analysis (Bernard et al. 2017; Krippendorff 2018), I coded the news articles with the codes from the codebook and examined the resulting segments of those codes. The results of this research provide four key insights.

First, this chapter investigates the collective action frames of diagnostic, prognostic, and motivational frames to provide insight into the causes, proposed solutions, and calls to action surrounding the water crisis, respectively. Drought, politics, poor management, and overuse of surface water supplies were blamed for causing the water crisis through diagnostic frames. This suggests that, in addition to physical drought, governance itself may have exacerbated the water stress in Cape Town, as suggested by previous scholarship (Enqvist and Ziervogel 2019; Taing et al. 2019). Reducing water use through domestic and agriculture restrictions and by increasing water supply through large-scale technological infrastructure were presented as potential solutions, or prognostic frames, to combat the water crisis. While this addresses the issues surrounding physical deficits in water, and provides solutions regarding diversifying water sources that have been encouraged by previous literature (LaVanchy et al. 2019; Olivier and Xu 2019), the primary solutions presented in the media do not state the need for improved governance approaches. This suggests a potential mismatch between identified problems and proposed solutions, which could be problematic for preventing another water crisis in

the future. Finally, despite these challenges, the motivational frames, or calls to action, provide encouragement for the future of water management as they focused on residents coming together to defeat the crisis collectively.

Second, this media analysis sheds light onto the role of collaborative governance in addressing the water crisis. The results of the codes for collaborative governance indicate that some collaboration did occur in the response to the water crisis and was provided as a potential, though not the primary, solution to address the crisis. These instances of collaborative governance primarily included shared resources, suggesting that opportunities to share supplies or services encouraged collaborative engagement. Communication, actor inclusivity, and shared knowledge were also identified occurrences of collaborative engagement. However, with limited instances of collaborative governance overall, the analysis suggest that increased collaboration is still needed for integrated governance. With limited code occurrences of shared values, trust, and history, the results suggest that overcoming barriers to collaborative governance should focus specifically on improving these factors. These have also been the suggestions of previous literature (Visser 2018; Rodina 2019; Ziervogel 2019), which have called for successful water management and governance to focus on building trust and addressing a history of conflict and tension between governance stakeholders.

Third, the water crisis had major impacts on and implications for the food and energy sectors. In the food sector, with decreased surface water supplies and with increased restrictions placed on water use in the surrounding agricultural districts, there were reduced crop yields and greater economic strain for farmers. This led to fears about disruptions in food distribution, about exports from the world-renounced wine regions

surrounding the area, and about closures of restaurants unable to operate. In the energy sector, the water crisis had a more indirect impact. As many proposed solutions to the water crisis included large-scale water augmentation approaches, such as desalination and water reuse, solutions to the water crisis could lead to strains on the energy crisis. Cape Town experienced an energy crisis in 2008 (Jaglin 2014), and the electrical grid is already at capacity with planned load shedding continuing to occur as recently as 2020. Implementing these proposed solutions without additional capacity added to the electrical grid would only address the water crisis at the expense of the energy sector. These interconnections between the water crisis and the food and energy sectors highlight the complexity of the FEW nexus in Cape Town and point to the need for collaborative governance in response to the crisis to minimize unintended consequences and feedbacks.

Finally, in examining the intersection between collaborative governance and the FEW nexus, the results show limited instances of collaborative governance between food, energy, and water stakeholders. This suggests that there may be limited collaboration between the three governance sectors. However, with the strong impact of the water crisis on the related FEW nexus sectors, and the strong possibility for future drought to occur again in Cape Town (Pascale et al. 2020), collaborative governance across the FEW nexus sectors is critical for holistic resource management and security. This call for greater integrated governance and systems thinking in response is in line with other studies examining the Cape Town water crisis (Enqvist and Ziervogel 2019; Taing et al. 2019; Ziervogel 2019).

In conclusion, this media analysis on the Cape Town water crisis provides insight into the political and societal perspectives of the water crisis, as media framing can

reflect and shape the broader discourse of a phenomenon (Althaus and Tewksbury 2002). The analysis highlights the causes, proposed solutions, and calls to action surrounding the water crisis; these findings suggest that politics and poor management may have partly caused the crisis, yet the discourse provides minimal recommendations for improvements to governance. Additionally, though some instances of collaborative governance were present, these were few in number. With the strong impact of the water crisis on the food and energy sectors, then, collaborative governance, specifically between food, energy, and water sectors, provides an opportunity to reduce unintended consequences and lead towards greater resource security. However, current collaboration between these sectors appears to be limited; I suggest that future water management in Cape Town should consider a FEW nexus approach to governance to protect against future shocks and stressors.

5.2.2 Chapter 3 Conclusions: Understanding Barriers to Collaborative Governance for the FEW Nexus

In the third chapter, I presented a case study analysis of FEW nexus governance in the Phoenix, Arizona metropolitan area to examine the structure of barriers to collaborative governance. To achieve this goal, I identified the key barriers to collaborative FEW nexus governance, examined how stakeholders experienced these barriers to understand why they exist, and provided recommendations for how to overcome these barriers. Using a qualitative case study approach (Yin 2018), I presented three theoretical propositions to address each of these research objectives, and I addressed them through the case study design. First, I used social network analysis to

identify which stakeholders had the highest level of centrality and were most important within the FEW nexus (Freeman 1978; Borgatti et al. 2009). Then, these stakeholders were mapped on an interest-influence diagram, and those considered to have high interest and/or high influence over FEW nexus governance were included in the participant selection. From these identified stakeholders, I conducted interviews to understand their perspectives and experiences on collaboration and governance across the FEW nexus. Additionally, I conducted participant observation of public meetings for several important stakeholder organizations. These data were analyzed using qualitative coding to capture the key constructs related to barriers to collaborative governance of the FEW nexus. The results of this study provide three contributions towards scholarship of collaborative governance of the FEW nexus.

First, this chapter identifies the barriers to collaborative FEW nexus governance. The identified barriers from the empirical results are conceptualized into four categories of barriers to FEW nexus governance: structural asymmetries, process asymmetries, communication and coordination, and external influences. While the first three of these categories are consistent with previous scholarship (Howarth and Monasterolo 2016; Liu et al. 2018; Pahl-Wostl 2019), the category of external influences had not yet been noted by the literature. External influences include the context in which the FEW nexus governance system is situated, and thus are critical considerations for collaborative governance. While a favorable context can encourage collaborative governance, an unfavorable one can inhibit it. Understanding the nature of the surrounding context of the governance system is crucial for successfully implementing collaborative FEW nexus governance in practice.

Second, this case study seeks to understand how stakeholders experience barriers to collaborative governance for the FEW nexus and why these barriers exist. The results showed that, while stakeholders across sectors have similar goals, there approaches to decision-making and management vary. This results in *sector mismatch*, the differences in processes and structures between food, energy, and water governance systems, and this can provide challenges for stakeholders to collaborate across sectors. Because of these mismatches, each sector experiences barriers to collaborative FEW nexus governance differently. The water sector has begun to overcome existing barriers to initiate cross-sector governance. With the multi-level structure to water governance, and with water being the limited resource within the Phoenix metropolitan area, the sector has the ability and incentive to coordinate with different stakeholders across food and energy. In the food sector, there is great collaborative governance with other food and agriculture actors, though more limited collaboration across sectors. Based on participant responses, this may stem from perceived power differences with major water actors and from previous negative experiences collaborating with other non-food actors. Finally, in the energy sector, there is a diversity of collaborative governance approaches; some energy actors collaborate across sectors while others collaborate mostly with organizations similar to them. This may be mostly due to the limited number of energy stakeholders within the Phoenix metropolitan area (Jones & White *in review*). In sum, barriers to collaborative FEW nexus governance exist in the Phoenix area because of *sector mismatch*, and each sector thus has different approaches to governance collaborations. Scholars have called for an increased consideration of the importance of scale within FEW nexus governance (Pahl-Wostl et al. 2020), and understanding existing mismatch

between stakeholders is needed for collaborative governance to occur in practice (Plummer et al. 2013).

Third, this study provided recommendations on how to overcome the identified barriers, based on stakeholder perspectives and collaborative governance concepts. Based on stakeholder responses, seven strategies were identified for overcoming barriers to FEW nexus governance: building trust, shifting mindsets, finding common ground, improving transparency, increasing resources for collaboration, establishing win-win solutions, and supporting each other in times of crisis. When considering the collaborative governance literature, this suggests that improvements towards collaborative governance throughout the FEW nexus should focus on the theme of increasing shared motivation (Emerson et al. 2012). This shared motivation includes the recommendations from stakeholders to improve transparency, build trust, and have shared goals and their values of shifting mindsets, finding common ground, and establishing win-win solutions (Ansell and Gash 2008; Emerson et al. 2012). Once this foundation of shared motivation for collaborative FEW nexus engagement has been established, addressing differences in organizations structures and procedures that cause *sector mismatch* can be addressed.

In conclusion, the case study of the Phoenix, Arizona metropolitan area identifies the key barriers of structural asymmetries, process asymmetries, communication and coordination, and external influences as challenges to implementation of collaborative FEW nexus governance. While each sector experiences these barriers differently, they occur because of *sector mismatch* between food, energy, and water stakeholders. Overcoming these barriers will require a focus on establishing a shared motivation for

collaborative governance between food, energy, and water actors, establishing a foundation for collaborative success. Though this case study produces evidence from only one system, the findings from the study are similar to those of other FEW nexus governance systems (e.g., Howarth and Monasterolo 2016; Daher et al. 2019). It thus provides an opportunity to generalize the results to other urban FEW nexus systems and provides important insights for the implementation of collaborative FEW nexus governance in practice.

5.2.3 Chapter 4 Conclusions: Assessment of Food-Energy-Water Nexus Governance

In the fourth chapter, I provided a framework for the assessment of collaborative FEW nexus governance. Integrating the theory of collaborative governance, the concept of FEW nexus governance, and the approach to sustainability indicators, I then present a framework for assessing collaborative governance within the FEW nexus. This framework, building on the Collaborative Governance Regime by Emerson et al. (2012), includes three central concepts—structural dimensions, decision-making processes, and organizational values—that interact cyclically to facilitate collaborative governance between FEW nexus sectors. Structural dimensions are the institutional components of the sectors and their actors, which need to be compatible with one another for collaboration to occur. Decision-making processes include the ways in which sectors and stakeholders evaluate actions and outcomes to make informed choices within the context of the system. While the processes need not be the same across the sectors, the approaches to decision-making must complement one another to facilitate action from collaborative engagement. Organizational values focus on the inherent principles of the

sectors and their engagements, which should be in agreement for engagements to be initiated and moved forward. These central interactions are also influenced by external influences. External influences can include components of the collaborative process, such as a prior history of antagonism or cooperation between stakeholders, and those outside the collaboration itself, such as political, environmental, and economic shocks and stressors.

Within these three concepts, I identified eleven variables: institutions, actor inclusivity, power, leadership, shared goals, communication, resources, knowledge, trust, commitment, and shared values. Each variable contains one to three indicators that encapsulate the definition the variable. Each indicator is accompanied with an associated approach to measurement and potential data source, including secondary data analysis, social network analysis, interview and case study research, surveys, and media analysis. To create this variable list and associated indicator set, I conducted a systematic literature review of collaborative governance measurement and evaluation approaches, identifying variables that occurred across the literature and encompassed the full scope of collaborative governance. Then, I conducted a targeted literature review of FEW nexus indicators to identify those that most related to FEW nexus governance and that intersected with the identified collaborative governance variables. Finally, I examined the targets under the most relevant Sustainable Development Goals—goals 2, 6, 7, and 17—to determine additional relevant indicators and measures for the variables.

With the creation of the conceptual framework and accompanying indicator set, I then applied this framework to the two case cities in the dissertation: Phoenix and Cape Town. In Phoenix, structural dimensions benefit from the inclusion of a diversity of

actors in FEW nexus governance and from power sharing within engagements. Decision-making processes are moderately coordinated across sectors, with clear shared goals between the sectors, but there are challenges to communication approaches and to resource sharing. Organizational values are also moderately coordinated, with moderate trust and many shared values across the sectors. Overall, the indicators of the framework highlight that there is moderate collaborative governance between food, energy, and water sectors in Phoenix. However, collaborative governance could be increased through a focus on improving communication channels and increasing shared resources between FEW nexus sectors. In Cape Town, structural dimensions are not coordinated across the FEW nexus sectors as institutions operate at different scales and with different rules and regulations. Decision-making processes, however, are strongly coordinated, as the sectors had the shared goal of overcoming the water crisis and increased resource sharing to achieve their goal. Organizational values, though, are also low; there is limited trust between governance sectors, which may be exacerbated by existing political tensions, and there are few instances of shared values and perspectives being held across sectors. Thus, the framework and indicators highlight that there is limited apparent collaborative governance of FEW nexus sectors. Moving towards collaborative governance of FEW nexus in Cape Town should focus on building trust, developing an understanding of others' values and perspectives, and actively working to overcome the differences in institutional structures between the sectors. These two cases provide preliminary examples of the application of the indicator set to urban systems of FEW nexus collaborative governance.

This assessment framework provides several key contributions to the literature. First, it advances the concept of FEW nexus governance by moving from merely theoretical conceptualization towards assessment. This is important because assessment can identify specific strengths and weaknesses of the FEW nexus collaborative governance system, provide guidance on improving collaborative engagements, and inform our understanding of the potential benefits and limitations of collaborative governance (Conley and Moote 2003). Second, these findings also contribute toward the collaborative governance literature. As the theory of collaborative governance generally focuses on single-sector resource governance, especially in assessment frameworks for collaborative governance, this research provides an example of a framework for assessing multi-disciplinary collaborative governance, which could be useful for other integrated resource systems. Finally, it provides an opportunity to understand and compare the collaborative FEW nexus governance within and between cities. Understanding the collaborative governance in this way provides an opportunity to move towards increased collaborative FEW nexus in practice as it identifies specific places within the system where greater focus is needed to move towards successful collaborative approaches.

5.3 SYNTHESIS AND TAKEAWAYS

Chapters two, three, and four integrate the literatures of collaborative governance theory and the concept of the FEW nexus. This integration allows for better understanding of collaborative FEW nexus governance in practice, including the barriers to collaborative engagements and the opportunities to overcome these barriers. The backbone between the chapters consists of twelve variables—the eleven used in the

indicator set and the underlying variable of prior history that influences the others. These variables were developed from extensive literature review and conceptual framework construction and weave their way through the dissertation. As the connecting thread between the chapters, they provide opportunity to dissect the nature of collaborative FEW nexus governance, showcase different perspectives of this governance through multiple methods, and compare the governance across the two case cities.

In summary, I have several overarching conclusions from this research. First, siloed decision-making in response to water stress can present challenges for other resource sectors such as food and water. While theoretical scholarship has discussed this proposition (Leck et al. 2015; Rasul and Sharma 2016), the findings provide empirical evidence of how water-focused decision-making can lead to negative impacts in the food and energy sectors. Second, with numerous barriers to collaborative FEW nexus governance, many of these barriers exist because of *sector mismatch*. Similar to scale mismatch (Cash et al. 2006; Pahl-Wostl et al. 2020), this refers to the differences in structures and processes between the three governance sectors of food, energy, and water that create challenges for coordination as the sectors are disjointed from one another. Third, an approach to assessing FEW nexus collaborative governance is valuable to identify the components of the governance process that support collaborative engagement. This provides an opportunity to overcome barriers to FEW nexus governance in practice by identifying specific variables within the collaborative governance system to focus on improving in order to move towards collaborative FEW nexus governance. Additionally, such a process allows for the comparison of different FEW nexus governance systems to one another, as the framework moves towards

assessment of this governance. This is important to understand the nuances of the nature of collaborative FEW nexus governance, to encourage this governance in practice, and to learn from urban cases that are successfully engaging in collaborative governance across the FEW nexus.

5.3.1 Intellectual Contribution

This scholarship advances the literature of FEW nexus governance in several ways. First, this dissertation addresses the calls for FEW nexus literature to include increased scholarship on governance (Opejin et al. 2020; Urbinatti et al. 2020), increased empirical studies of FEW nexus governance (Ringler et al. 2013; Liu et al. 2018), increased engagement of stakeholders using participatory approaches (Urbinatti et al. 2020; Wahl et al. 2021), and increased use of qualitative methods (Endo et al. 2017; Albrecht et al. 2018; Newell et al. 2019). Additionally, this research responds to the calls for empirical studies to focus on the local and urban level (Mounir et al. 2019; Simpson et al. 2019a; Zhu et al. 2020). Second, as there are no known frameworks or approaches for measurement, evaluation, or assessment of FEW nexus governance, this dissertation moves FEW nexus governance from merely theoretical conceptualization towards assessment. While scholars have developed tools to engage stakeholders and have created frameworks and indicator systems for measurement of FEW nexus resources, the framework and indicator set presented here are the first known attempts to assess FEW nexus governance itself.

This dissertation also advances the literature of collaborative governance. It provides an assessment framework of multidisciplinary collaborative governance. Most

scholarship on measurement, evaluation, or assessment of collaborative governance focuses on singular resource sectors or systems; exemplar multidisciplinary approaches have not yet been designed. The framework presented here provides an opportunity for collaborative governance assessment frameworks of other multi-disciplinary systems. Finally, this research advances scholarship of sustainability science. By responding to calls for increased scholarship for solutions-based approaches and on stakeholder-focused research (Miller et al. 2014), it contributes towards the advancing the literature of sustainability science in practice. Through the creation of an indicator set, this dissertation designed a tool that can begin to lead towards increased collaborative governance in practice between FEW nexus sectors. Additionally, with the engagement of stakeholders throughout the dissertation, this research provides an opportunity for them to consider implementing collaborative FEW nexus approaches into their work, as stakeholder engagement processes can lead towards outcomes that support sustainability (Lubchenco 1998). In these ways, this dissertation contributes towards advancing the literatures of FEW nexus governance, collaborative governance, and sustainability science.

5.3.2 Policy Insights

Decision-making and governance in water-stressed cities should move towards a collaborative FEW nexus approach that engages the three sectors to reduce knock-on effects in other resources. Especially in areas expected to be hardest hit by climate change, drought and water stress can have increasing direct and indirect impacts on the connected food and energy sectors. Based on the findings and conclusions of this

research, I provide four policy insights for moving collaborative FEW nexus governance into practice. These insights should be considered in the creation of future policies to lead towards successful collaborative FEW nexus governance in practice:

(1) *Sector mismatch* is why barriers to collaborative governance exist, thus overcoming this mismatch is key for successful collaborative engagement. Scholars have begun to study how the role of scale can influence how food, energy, and water sectors interact with one another (Pahl-Wostl et al. 2020). This is likely to also exist not just across scales or levels, but through different sectors that were designed independently with different goals, processes, and structures. For collaborative engagement to be successful, stakeholders must acknowledge these mismatches and intentionally focus on engaging in ways that directly address these differences.

(2) Overcoming barriers to FEW nexus governance requires a focus on addressing fundamental components of collaborative governance. The key variables identified as intersections between the FEW nexus and collaborative governance provide an opportunity to examine specific components of the system, identify which ones need improvement, and work to address these specific weaknesses. Doing so will help to facilitate collaborative FEW nexus governance in practice. By determining which variables are weakest, FEW nexus sectors and stakeholders can focus on strengthening specific weaknesses in their engagements. This could be done by integrating congressional committees between food, energy, and water resources to better encourage collaborative governance across the three sectors.

(3) There should be incentives and support for collaborative FEW nexus governance. As collaborative engagements can take more time, resources, and commitment (Liu et al. 2018), stakeholders and sectors need to be assisted to engage in these collaborative engagements. Additionally, stakeholders must be motivated to invest more effort into collaborative over siloed engagement. They need to establish win-win solutions across the sectors and see the potential outcomes from collaborative FEW nexus governance as greater than those that would come from single-sector governance. For example, policy can encourage this collaborative governance in practice by providing specific funding for collaborative FEW nexus engagements.

(4) Addressing any prior history of antagonism or cooperation is necessary for successful collaborative engagement. Any historical tensions between stakeholders can create an additional layer of complexity for collaborative engagement, even when other variables of successful collaborative governance are in place. Stakeholders may need to first work on these historical instances of conflict and animosity before successfully engaging in FEW nexus collaborative governance.

These policy recommendations provide support for the implementation of collaborative approaches in practice. They also suggest that implementing collaborative FEW nexus governance is complex and challenging. While it can provide opportunity for greater resource security across all three sectors, it also requires significant investment to identify barriers and overcome them. However, the successful implementation of collaborative FEW nexus governance in practice provides opportunity to improve

resource management, and these policy recommendations provide guidance for successful implementation, even beyond the case cities examined here.

5.3.3 Broader Impacts

This research will have implications for other cities within the United States and globally that are facing increasing and more frequent water stress. The Cape Town water crisis and multi-decadal megadrought in Phoenix present relevant cases of extreme water challenges and subsequent consequences. As the impacts of climate change continue to increase the risks of cities becoming more water stressed and threaten the resource security of energy and food, this dissertation will present an opportunity to learn best-practices of water crises responses and expected impacts on related FEW nexus sectors. Additionally, the outcomes from this research provide recommendations for examining local FEW nexus governance to overcome existing barriers and lead towards collaborative governance in practice. Understanding the food, energy, and water interdependencies and working towards collaborative governance across these three sectors can lead towards decision-making with reduced uncertainty to increase resource security and system sustainability.

5.4 LIMITATIONS AND FUTURE RESEARCH

5.4.1 Limitations

While this dissertation provides insight into collaborative FEW nexus governance in practice, there are some limitations of this study. First, the use of secondary data for media analysis in chapter 2 provides a limited perspective on FEW nexus governance.

While it offers insight into the perceptions of the public and into the potential influence on public policy, direct stakeholder engagement would be needed to fully understand the nuances of the FEW nexus governance system. Second, in chapter 4, the indicators developed in the assessment framework were not examined directly within the two case cities. While the variables used to develop the indicators made up the backbone across the case analyses, the investigation of the two cases themselves were not designed around the indicators and their associated measurement approaches. However, existing assessments do supply an understanding of the collaborative FEW nexus governance and provide a preliminary application of the framework and indicator set. Through my proposal for future research, I intend to address these limitations to enhance the outcomes of this dissertation and to continue to advance the discourse of FEW nexus governance and collaborative governance.

5.4.2 Future Research

There are several opportunities for future research that emerge from this dissertation. First, while the Cape Town media framing provides a preliminary understanding of the role of collaborative governance of the food-energy-water nexus, stakeholder engagement research would enhance these findings. Stakeholder engagement through interviews, participant observation, and focus groups through empirical data collection would provide greater depth of understanding collaborative governance in practice in Cape Town. These results would provide support for or a refute to the findings of my research here, which could provide greater support for the usefulness of media framing in understanding governance landscapes. Additionally, following a structured

case study approach (Yin 2018) would provide an opportunity to capture the perspectives of the governance stakeholders involved in the decision-making, to investigate the nuances of that governance and the impacts of the water crisis on the FEW nexus, and to more directly compare the case analyses from Cape Town and Phoenix. Finally, this would address some of the limitations of the interpretations from media framing by providing additional data and analysis from other perspectives.

Second, a database of urban cases of FEW nexus collaborative governance should be created. Increasing the number of case cities of urban FEW nexus collaborative governance could lead to the development of more generalizable understandings about FEW nexus collaborative governance in practice. This would allow me to analyze patterns of barriers and opportunities for greater implementation of collaborative FEW nexus governance. It could also lead to theoretical propositions that could be generalized across and transferred to other cities, resulting in greater generalizability of the results and in potential generation of new theory. Furthermore, these additional cases would provide an opportunity to implement, validate, and revise the assessment framework and indicator set. Validation of the framework with the database of cases would provide an opportunity to move the framework toward full evaluation and measurement of collaborative FEW nexus governance. This would increase the usability of the assessment tool and allow for greater application and generalizability of the indicator set.

Finally, once the framework has been established as an approach to measure collaborative FEW nexus governance, this can be implemented to consider how the level of FEW nexus governance in practice relates to desired sustainability outcomes. While the FEW nexus approach to governance purports to reduce unintended consequences and

lead towards greater sustainability of the three resource systems (Lele et al. 2013), there is not yet empirical study that directly links collaborative FEW governance approaches to outcomes. Some scholars of collaborative governance have questioned how directly the collaborative process leads to environmental outcomes (Koontz and Thomas 2006). By establishing an approach to measure FEW nexus governance, I can then consider how the level of governance relates to system outcomes, such as water conservation, food and energy access, and environmental conservation. This could be done by evaluating and assessing the collaborative FEW nexus governance of an engagement and correlating it with established environmental outcome measures or resource security measures.

5.5 CONCLUSION

In conclusion, this dissertation integrates the literatures of collaborative governance theory and the food-energy-water nexus to investigate how this theory can improve FEW nexus governance in practice. The goal of this research is to (1) understand the nature of collaborative FEW nexus governance under conditions of water stress, (2) identify barriers to collaborative FEW nexus governance and examine why the barriers exist, and (3) develop an assessment framework to move FEW nexus governance from conceptualization towards evaluation and measurement. The dissertation addresses several gaps in the literature, responding to calls for increased empirical scholarship on FEW nexus governance and addressing the lack of approaches to assess this governance. In chapter 2, I employ media framing analysis of news articles about the Cape Town, South Africa water crisis to understand the role of collaborative governance for management of integrated FEW nexus resources. In chapter 3, I conduct a systematic

case study with stakeholder engagement in Phoenix, AZ, USA to understand the nature of and barriers to FEW nexus governance. In chapter 4, incorporating the sustainability indicators scholarship, I create an assessment framework of collaborative FEW nexus governance and provide an accompanying indicator set. This provides an opportunity to move FEW nexus governance from merely theoretical conceptualization towards assessment. Ultimately, this research concludes that (1) siloed decision-making in response to water stress can indeed have negative impacts on other FEW nexus sectors, as evidenced by empirical findings, (2) mismatch in processes and structures between FEW nexus governance sectors exacerbates opportunities for collaborative governance and upholds existing barriers, and (3) assessment of collaborative FEW nexus governance provides an opportunity for more nuanced understandings of individual governance systems and for identification of specific variables for improvement. This can encourage collaborative FEW nexus governance in practice. This dissertation will be useful for other urban contexts to examine and implement collaborative FEW nexus governance.

REFERENCES

Abrams J, Huber-Stearns H, Gosnell H, et al (2020) Tracking a Governance Transition: Identifying and Measuring Indicators of Social Forestry on the Willamette National Forest. Soc Nat Resour 33:504–523. https://doi.org/10.1080/08941920.2019.1605434

Agranoff R, McGuire M (1998) Multinetwork management: Collaboration and the hollow state in local economic policy. J Public Adm Res Theory 8:67–91. https://doi.org/10.1093/oxfordjournals.jpart.a024374

Albrecht TR, Crootof A, Scott CA (2018) The Water-Energy-Food Nexus : A systematic review of methods for nexus assessment. Environ Res Lett 13:1–26. https://doi.org/10.1088/1748-9326/aaa9c6

Allan T, Keulertz M, Woertz E (2015) The water–food–energy nexus: an introduction to nexus concepts and some conceptual and operational problems. Int J Water Resour Dev 31:301–311

Allouche J, Middleton C (2015) Technical Veil , Hidden Politics : Interrogating the Power Linkages behind the Nexus. 8:610–626

Althaus SL, Tewksbury D (2002) Agenda Setting and the "New" News. Communic Res 29:180–207. https://doi.org/10.1177/0093650202029002004

Anderies JM, Folke C, Walker B, Ostrom E (2013) Aligning Key Concepts for Global Change Policy: Robustness, Resilience, and Sustainability. Ecol Soc 18:8–21

Ansell C, Gash A (2008) Collaborative governance in theory and practice. J Public Adm Res Theory 18:543–571. https://doi.org/10.1093/jopart/mum032

Arthur M, Liu G, Hao Y, et al (2019) Urban food-energy-water nexus indicators: A review. Resour Conserv Recycl 151:104481. https://doi.org/10.1016/j.resconrec.2019.104481

Baird J, Plummer R, Bodin Ö (2016) Collaborative governance for climate change adaptation in Canada: experimenting with adaptive co-management. Reg Environ Chang 16:747–758. https://doi.org/10.1007/s10113-015-0790-5

Barthel S, Parker J, Ernstson H (2015) Food and Green Space in Cities: A Resilience Lens on Gardens and Urban Environmental Movements. Urban Stud 52:1321–1338. https://doi.org/10.1177/0042098012472744

Bartik TJ, Bingham RD (1997) Can Economic Development Programs Be Evaluated? In: Bingham RD, Mier R (eds) Dilemmas of Urban Economic Development: Issues in Theory and Practice. Sage, Thousand Oaks, CA, pp 246–290

Bartos MD, Chester M V. (2014) The conservation nexus: Valuing interdependent water and energy savings in Arizona. Environ Sci Technol. https://doi.org/10.1021/es4033343

Bazilian M, Rogner H, Howells M, et al (2011) Considering the energy, water and food nexus: Towards an integrated modelling approach. Energy Policy 39:7896–7906. https://doi.org/10.1016/j.enpol.2011.09.039

Beck TL, Rodina E, Luker L, Harris L (2016) Institutional and policy mapping of the water sector in South Africa. 1–12

Bell A, Matthews N, Zhang W (2016) Opportunities for improved promotion of ecosystem services in agriculture under the Water-Energy-Food Nexus. J Environ Stud Sci 6:183–191. https://doi.org/10.1007/s13412-016-0366-9

Benford RD, Snow DA (2000) Framing Processes and Social Movements: An Overview and Assessment. Annu Rev Sociol 26:611–639

Berardy A, Chester M V. (2017) Climate change vulnerability in the food, energy, and water nexus: Concerns for agricultural production in Arizona and its urban export supply. Environ Res Lett 12:. https://doi.org/10.1088/1748-9326/aa5e6d

Bernard HR, Wutich A, Ryan GW (2017) Analyzing qualitative data: Systematic approaches. Sage Publications

Biddle JC (2017) Improving the effectiveness of collaborative governance regimes: Lessons from watershed partnerships. J Water Resour Plan Manag 143:1–12. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000802

Bielicki JM, Beetstra MA, Kast JB, Wang Y (2019) Stakeholder Perspectives on Sustainability in the Food-Energy-Water Nexus. Front Environ Sci 7:1–18. https://doi.org/10.3389/fenvs.2019.00007

Biggs EM, Bruce E, Boruff B, et al (2015) Sustainable development and the water-energy-food nexus: A perspective on livelihoods. Environ Sci Policy 54:389–397. https://doi.org/10.1016/j.envsci.2015.08.002

Birkland TA (1996) Natural disasters as focusing events: Policy communities and political response. Int J Mass Emerg Disasters 14:221–243

Bleischwitz R, Spataru C, Vandeveer SD, et al (2018) Resource nexus perspectives towards the United Nations Sustainable Development Goals. Nat Sustain 1:737–743. https://doi.org/10.1038/s41893-018-0173-2

Bodin Ö (2017) Collaborative environmental governance: Achieving collective action in social-ecological systems. Science (80-) 357:. https://doi.org/10.1126/science.aan1114

Bodin Ö, Crona BI (2009) The role of social networks in natural resource governance: What relational patterns make a difference? Glob Environ Chang 19:366–374. https://doi.org/10.1016/j.gloenvcha.2009.05.002

Böhringer C, Jochem PEP (2007) Measuring the immeasurable — A survey of sustainability indices. Ecol Econ 63:1–8. https://doi.org/10.1016/j.ecolecon.2007.03.008

Bollino CA, Anbumozhi V, Babu S, et al (2020) Integrated policies to improve the Energy–Water–Food system nexus to achieve the SDGs. 1–13

Borgatti SP, Mehra A, Brass DJ, Labianca G (2009) Network Analysis in the Social Sciences. Science (80-) 323:892–896. https://doi.org/10.1126/science.1165821

Bradshaw TK (1999) Communities not fazed: Why military base closures may not be

catastrophic. J Am Plan Assoc 65:193–206. https://doi.org/10.1080/01944369908976047

Brisbois MC, de Loë RC (2016) Power in Collaborative Approaches to Governance for Water: A Systematic Review. Soc Nat Resour 29:775–790. https://doi.org/10.1080/08941920.2015.1080339

Brueckner JK, Lall S V. (2015) Cities in Developing Countries. Fueled by Rural-Urban Migration, Lacking in Tenure Security, and Short of Affordable Housing., 1st edn. Elsevier B.V.

Cairns R, Krzywoszynska A (2016) Environmental Science & Policy Anatomy of a buzzword : The emergence of ' the water-energy-food nexus ' in UK natural resource debates. Environ Sci Policy 64:164–170. https://doi.org/10.1016/j.envsci.2016.07.007

Cash DW, Adger WN, Berkes F, et al (2006) Scale and cross-scale dynamics: Governance and information in a multilevel world. Ecol Soc 11:8

Cash DW, Clark WC, Alcock F, et al (2003) Knowledge systems for sustainable development. Proc Natl Acad Sci U S A 100:8086–8091. https://doi.org/10.1073/pnas.1231332100

Cash DW, Moser SC (2000) Linking global and local scales: Designing dynamic assessment and management processes. Glob Environ Chang 10:109–120. https://doi.org/10.1016/S0959-3780(00)00017-0

Chang Y, Li G, Yao Y, et al (2016) Quantifying the water-energy-food nexus: Current status and trends. Energies 9:1–17. https://doi.org/10.3390/en9020065

Chen L, Manley K (2014) Validation of an instrument to measure governance and performance on collaborative infrastructure projects. J Constr Eng Manag 140:1–13. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000834

Cheng AS, Sturtevant VE (2012) A framework for assessing collaborative capacity in community-based public forest management. Environ Manage 49:675–689. https://doi.org/10.1007/s00267-011-9801-6

Clark SS, Chester M V., Seager TP, Eisenberg DA (2019) The vulnerability of interdependent urban infrastructure systems to climate change: could Phoenix experience a Katrina of extreme heat? Sustain Resilient Infrastruct 4:21–35. https://doi.org/10.1080/23789689.2018.1448668

Clark WC (2007) Sustainability science: A room of its own. Proc Natl Acad Sci U S A 104:1737–1738. https://doi.org/10.1073/pnas.0611291104

Clark WC, Dickson NM (2003) Sustainability science: The emerging research program. Proc Natl Acad Sci U S A 100:8059–8061. https://doi.org/10.1073/pnas.1231333100

Cobb C, Halstead T, Rowe J (1995) The genuine progress indicator: summary of data and methodology. Redefining Progress, San Francisco

Cohen JA (1960) A coefficient of agreement for nominal scales. Educ Psychol Meas 37–46

Cohen SJ, Allsopp TR (1988) The potential impacts of a scenario of CO2-induced climate change on Ontario, Canada. J Clim 1:669–681

Coletti M, Landoni P (2018) Collaborations for innovation: A meta-study of relevant typologies, governance and policies. Econ Innov New Technol 27:493–509

Conley A, Moote MA (2003) Evaluating collaborative natural resource management. Soc Nat Resour 16:371–386. https://doi.org/10.1080/08941920309181

Cook ER, Seager R, Cane MA, Stahle DW (2007) North American drought: Reconstructions, causes, and consequences. Earth-Science Rev 81:93–134. https://doi.org/10.1016/j.earscirev.2006.12.002

Cordella A, Paletti A (2019) Government as a platform, orchestration, and public value creation: The Italian case. Gov Inf Q 36:101409. https://doi.org/10.1016/j.giq.2019.101409

Creswell JW, Poth CN (2017) Quality inquiry and research design: Choosing among five approaches. Sage Publications

Cumming GS, Cumming DHM, Redman CL (2006) Scale mismatches in social-ecological systems: Causes, consequences, and solutions. Ecol Soc 11:. https://doi.org/10.5751/ES-01569-110114

Cundill G, Fabricius C (2010) Monitoring the governance dimension of natural resource co-management. Ecol Soc 15:. https://doi.org/10.5751/ES-03346-150115

Currie PK, Musango JK, May ND, Town C (2017) Urban metabolism : A review with reference to Cape Town. Cities 70:91–110. https://doi.org/10.1016/j.cities.2017.06.005

Daher B, Hannibal B, Mohtar RH, Portney K (2020) Toward understanding the convergence of researcher and stakeholder perspectives related to water-energy-food (WEF) challenges : The case of San. Environ Sci Policy 104:20–35. https://doi.org/10.1016/j.envsci.2019.10.020

Daher B, Hannibal B, Portney KE, Mohtar RH (2019) Toward creating an environment of cooperation between water, energy, and food stakeholders in San Antonio. Sci Total Environ 651:2913–2926. https://doi.org/10.1016/j.scitotenv.2018.09.395

Daher B, Mohtar RH (2015) Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. Water Int 40:748–771

Daher B, Mohtar RH, Pistikopoulos EN, et al (2018) Developing socio-techno-economic-political (STEP) solutions for addressing resource nexus hotspots. Sustain 10:. https://doi.org/10.3390/su10020512

Dewulf A, François G, Pahl-Wostl C, Taillieu T (2007) A framing approach to cross-disciplinary research collaboration: Experiences from a large-scale research project on adaptive water management. Ecol Soc 12:. https://doi.org/10.5751/ES-02142-120214

Ding K, Gilligan JM, Hornberger GM (2019) Avoiding “Day-Zero”: A testbed for evaluating integrated food-energy-water management in Cape Town, South Africa.

Proc 2019 Winter Simul Conf

Du Pisani JA (2006) Sustainable development – historical roots of the concept. Environ Sci 3:83–96. https://doi.org/10.1080/15693430600688831

Eakin H, York A, Aggarwal R, et al (2016) Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona. Reg Environ Chang 16:801–814. https://doi.org/10.1007/s10113-015-0789-y

Eberhard R, Margerum R, Vella K, et al (2017) The Practice of Water Policy Governance Networks: An International Comparative Case Study Analysis. Soc Nat Resour 30:453–470. https://doi.org/10.1080/08941920.2016.1272728

Ember CR, Ember M (2009) Cross-Cultural Research Methods, 2nd edn. AltaMira Press, Plymouth

Emerson K, Nabatchi T, Balogh S (2012) An integrative framework for collaborative governance. J Public Adm Res Theory 22:1–29. https://doi.org/10.1093/jopart/mur011

Endo A, Tsurita I, Burnett K, Orencio PM (2017) A review of the current state of research on the water, energy, and food nexus. J Hydrol Reg Stud 11:20–30. https://doi.org/10.1016/j.ejrh.2015.11.010

Enqvist JP, Ziervogel G (2019) Water governance and justice in Cape Town: An overview. Wiley Interdiscip Rev Water e1354. https://doi.org/10.1002/wat2.1354

Fader M, Cranmer C, Lawford R, Engel-Cox J (2018) Toward an Understanding of Synergies and Trade-Offs Between Water, Energy, and Food SDG Targets. Front Environ Sci 6:1–11. https://doi.org/10.3389/fenvs.2018.00112

Ferreyra C, Beard P (2007) Participatory evaluation of collaborative and integrated water management: Insights from the field. J Environ Plan Manag 50:271–296. https://doi.org/10.1080/09640560601156532

Finley JW, Seiber JN (2014) The Nexus of Food, Energy, and Water. J Agric Food Chem 62:6255–6262. https://doi.org/10.1021/jf501496r

Fliervoet JM, Geerling GW, Mostert E, Smits AJM (2016) Analyzing Collaborative Governance Through Social Network Analysis: A Case Study of River Management Along the Waal River in The Netherlands. Environ Manage 57:355–367. https://doi.org/10.1007/s00267-015-0606-x

Folke C, Carpenter SR, Walker B, et al (2010) Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecol Soc 15:20

Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive Governance of Social-Ecological Systems. Annu Rev Environ Resour 441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511

Freeman J (1997) Collaborative governance in the administrative state. UCLA Law Rev 45:

Freeman LC (1978) Cenrality in Social Networks Conceptual Clarification. Soc

Networks 1:215–239

Gamson WA, Wolfsfeld G (1993) Movements and Media as Interacting Systems. Ann Am Acad Pol Soc Sci 528:114–125

Gibson CC, Ostrom E, Ahn TK (2000) The concept of scale and the human dimensions of global change: A survey. Ecol Econ 32:217–239. https://doi.org/10.1016/S0921-8009(99)00092-0

Gober P (2018) Building resilience for uncertain water futures. Springer, Cham, Switzerland

Gonzalez P, Garfin GM, Breshears DD, et al (2018) Southwest. In: Reidmiller DR, Avery CW, Easterling DR, et al. (eds) In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment. U.S. Global Change Research Program, Washington, DC, USA, pp 1101–1184

Grammer HD (2018) Framing the Western Cape water crisis : An analysis of the reporting of five South African publications in 2017 and 2018 by

Guan X, Mascaro G, Sampson D, Maciejewski R (2020) A metropolitan scale water management analysis of the food-energy-water nexus. Sci Total Environ 701:134478. https://doi.org/10.1016/j.scitotenv.2019.134478

Guest G, Bunce A, Johnson L (2006) How Many Interviews Are Enough?: An Experiment with Data Saturation and Variability. Field methods 18:59–82. https://doi.org/10.1177/1525822X05279903

Hajer M, Versteeg W (2005) A decade of discourse analysis of environmental politics: Achievements, challenges, perspectives. J Environ Policy Plan 7:175–184. https://doi.org/10.1080/15239080500339646

Hall TE, White DD (2008) Society for Human Ecology Representing Recovery : Science and Local Control in the Framing of U . S . Pacific Northwest Salmon Policy. Soc Hum Ecol 15:32–45

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

Herrfahrdt-Pähle E (2013) Integrated and adaptive governance of water resources: The case of South Africa. Reg Environ Chang 13:551–561. https://doi.org/10.1007/s10113-012-0322-5

Hoff H (2011) Understanding the Nexus. Backgr Pap Bonn2011 Conf Water, Energy Food Secur Nexus 1–52

Hopwood B, Mellor M, O'Brien G (2005) Sustainable development: mapping different approaches. Sustain Dev 13:38–52

Hörisch J (2018) How business actors can contribute to sustainability transitions: A case study on the ongoing animal welfare transition in the German egg industry. J Clean Prod 201:1155–1165. https://doi.org/10.1016/j.jclepro.2018.08.031

Howarth C, Monasterolo I (2016) Understanding barriers to decision making in the UK

energy-food-water nexus: The added value of interdisciplinary approaches. Environ Sci Policy 61:53–60. https://doi.org/10.1016/j.envsci.2016.03.014

Huang C, Chen T, Yi H, et al (2017) Collaborative environmental governance, inter-agency cooperation and localwater sustainability in China. Sustain 9:. https://doi.org/10.3390/su9122305

Huckleberry JK, Potts MD (2019) Constraints to implementing the food-energy-water nexus concept: Governance in the Lower Colorado River Basin. Environ Sci Policy 92:289–298. https://doi.org/10.1016/j.envsci.2018.11.027

Hussien WA, Memon FA, Savic DA (2017) An integrated model to evaluate water-energy-food nexus at a household scale. Environ Model Softw 93:366–380. https://doi.org/10.1016/j.envsoft.2017.03.034

Inguscio A (2017) Historical path dependencies and energy governance in post-Apartheid South Africa. In: Pereira LM, McElroy CA, Littaye A, Girard AM (eds) Food, energy and water sustainability : Emergent governance strategies. pp 53–66

Jacobs K, Garfin G, Lenart M (2005) More than just talk: Connecting science and decisionmaking. Environment 47:6–21. https://doi.org/10.3200/ENVT.47.9.6-21

Jaglin S (2014) Urban Energy Policies and the Governance of Multilevel Issues in Cape Town. Urban Stud 51:1394–1414. https://doi.org/10.1177/0042098013500091

Kates RW (2011) What kind of a science is sustainability science? PNAS 108:19449–19450. https://doi.org/10.1073/pnas.1116097108

Kates RW, Clark WC, Corell R, et al (2001) Sustainability Science. Science (80-) 292:641–642

Kates RW, Parris TM, Leiserowitz AA (2005) What is sustainable development? Goals, indicators, values, and practice. Environ DC) 47:8–21

Kelly PJ, Geyer HS (2018) The regulatory governance of retail electricity tariff setting in South Africa. Reg Sci Policy Pract 10:203–220. https://doi.org/10.1111/rsp3.12126

Kliskey A, Williams P, Griffith DL, et al (2021) Thinking Big and Thinking Small : A Conceptual Framework for Best Practices in Community and Stakeholder Engagement in Food , Energy , and Water Systems

Koontz TM, Thomas CW (2006) What do we know and need to know about the environmental outcomes of collaborative management? Public Adm Rev 66:111–121. https://doi.org/10.1111/j.1540-6210.2006.00671.x

Krippendorff K (2018) Content analysis: An introduction to its methodology, 4th edn. Sage publications4t

Kurian M (2017) The water-energy-food nexus: Trade-offs, thresholds and transdisciplinary approaches to sustainable development. Environ Sci Policy 68:97–106. https://doi.org/10.1016/j.envsci.2016.11.006

Kurian M, Portney KE, Rappaold G, et al (2018) Governance of water-energy-food Nexus: a social network analysis approach to understanding agency behaviour. In: Managing Water, Soil and Waste Resources to Acheive Sustainable Development

Goals. pp 125–147

Kurian M, Scott C, Reddy VR, et al (2019) One Swallow Does Not Make a Summer: Siloes, Trade-Offs and Synergies in the Water-Energy-Food Nexus. Front Environ Sci 7:1–17. https://doi.org/10.3389/fenvs.2019.00032

Lang DJ, Stauffacher M, Swilling M, et al (2012) Transdisciplinary research in sustainability science: practice, principles, and challenges. Sustain Sci 7:25–43. https://doi.org/10.1007/s11625-011-0149-x

Larson KL, White DD, Gober P, Wutich A (2015) Decision-Making under Uncertainty for Water Sustainability and Urban Climate Change Adaptation. 14761–14784. https://doi.org/10.3390/su71114761

Larson KL, Wiek A, Withycombe Keeler L (2013) A comprehensive sustainability appraisal of water governance in Phoenix, AZ. J Environ Manage 116:58–71. https://doi.org/10.1016/j.jenvman.2012.11.016

LaVanchy GT, Kerwin MW, Adamson JK (2019) Beyond 'Day Zero': insights and lessons from Cape Town (South Africa). Hydrogeol J 27:1537–1540. https://doi.org/10.1007/s10040-019-01979-0

Lebel L, Haefner A, Pahl-Wostl C, Baduri A (2020) Governance of the water-energy-food nexus: insights from four infrastructure projects in the Lower Mekong Basin. Sustain Sci 15:885–900. https://doi.org/10.1007/s11625-019-00779-5

Leck H, Conway D, Bradshaw M, Rees J (2015) Tracing the Water – Energy – Food Nexus : Description , Theory and Practice. Geogr Compass 9:445–460

Leipold S, Feindt PH, Winkel G, Keller R (2019) Discourse analysis of environmental policy revisited: traditions, trends, perspectives. J Environ Policy Plan 21:445–463. https://doi.org/10.1080/1523908X.2019.1660462

Lele U, Klousia-Marquis M, Goswami S (2013) Good governance for food, water and energy security. Aquat Procedia 1:44–63. https://doi.org/10.1016/j.aqpro.2013.07.005

Liu J, Hull V, Godfray HCJ, et al (2018) Nexus approaches to global sustainable development. Nat Sustain 1:455–476

Lubchenco J (1998) Entering the century of the environment: A new social contract for science. Science (80-) 279:491–497. https://doi.org/10.1126/science.279.5350.491

Märker C, Venghaus S, Hake JF (2018) Integrated governance for the food–energy–water nexus – The scope of action for institutional change. Renew Sustain Energy Rev 97:290–300. https://doi.org/10.1016/j.rser.2018.08.020

McGrail S, Idil Gaziulusoy A, Twomey P (2015) Framing processes in the envisioning of low-carbon, resilient cities: Results from two visioning exercises. Sustain 7:8649–8683. https://doi.org/10.3390/su7078649

McNie EC (2007) Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. Environ Sci Policy 10:17–38. https://doi.org/10.1016/j.envsci.2006.10.004

Medema W, Adamowski J, Orr C, et al (2017) Building a foundation for knowledge co-creation in collaborative water governance: Dimensions of stakeholder networks facilitated through bridging organizations. Water (Switzerland) 9:. https://doi.org/10.3390/w9010060

Melloni G, Turetta APD, Bonatti M, Sieber S (2020) A stakeholder analysis for a water-energy-food nexus evaluation in an atlantic forest area: Implications for an integrated assessment and a participatory approach. Water (Switzerland) 12:1–15. https://doi.org/10.3390/w12071977

Miller TR, Wiek A, Sarewitz D, et al (2014) The future of sustainability science: A solutions-oriented research agenda. Sustain Sci 9:239–246. https://doi.org/10.1007/s11625-013-0224-6

Mohtar RH, Daher B (2016) Water-Energy-Food Nexus Framework for facilitating multi-stakeholder dialogue. Water Int 41:655–661. https://doi.org/10.1080/02508060.2016.1149759

Mounir A, Mascaro G, White DD (2019) A metropolitan scale analysis of the impacts of future electricity mix alternatives on the water-energy nexus. Appl Energy 256:113870. https://doi.org/10.1016/j.apenergy.2019.113870

Muñoz-Erickson TA (2014) Co-production of knowledge-action systems in urban sustainable governance: The KASA approach. Environ Sci Policy 37:182–191. https://doi.org/10.1016/j.envsci.2013.09.014

Muñoz-Erickson TA, Aguilar-González B, Sisk TD (2007) Linking ecosystem health indicators and collaborative management: A systematic framework to evaluate ecological and social outcomes. Ecol Soc 12:. https://doi.org/10.5751/ES-02092-120206

National Academies of Sciences, Engineering and M (2018) Future Water Priorities for the Nation: Directions for the U.S. Geological Survey Water Mission Area. Washington, DC

Newell JP, Goldstein B, Foster A (2019) A 40-year review of food-energy-water nexus literature and its application to the urban scale. Environ Res Lett 14:. https://doi.org/10.1088/1748-9326/ab0767

Newell JP, Ramaswami A (2020) Urban food-energy-water systems: Past, current, and future research trajectories. Environ Res Lett 15:1–5. https://doi.org/10.1088/1748-9326/ab7419

Newig J, Challies E, Jager NW, et al (2017) The Environmental Performance of Participatory and Collaborative Governance: A Framework of Causal Mechanisms. Policy Stud J 46:269–297. https://doi.org/10.1111/psj.12209

Nilsson M, Eckerberg K (2009) Environmental policy integration in practice: Shaping institutions for learning. Earthscan, London, UK

Olivier DW, Xu Y (2019) Making effective use of groundwater to avoid another water supply crisis in Cape Town, South Africa. Hydrogeol J 27:823–826. https://doi.org/10.1007/s10040-018-1893-0

Ololade OO (2018) Understanding the nexus between energy and water: A basis for human survival in South Africa. Dev South Afr 35:194–209. https://doi.org/10.1080/0376835X.2018.1426445

Opejin AK, Aggarwal RM, White DD, et al (2020) A bibliometric analysis of food-energy-water nexus literature. Sustain 12:1–18. https://doi.org/10.3390/su12031112

Ostrom E (2009) A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science (80-) 104:419–422. https://doi.org/10.1126/science.1172133

Ostrom E (1990) Governing the Commons. Cambridge University Press, Cambridge, UK.

Ostrom E (2005) Understanding Institutional Diversity. Princeton University Press, New Jersey

Overpeck JT, Udall B (2020) Climate change and the aridification of North America. Proc Natl Acad Sci U S A 117:11856–11858. https://doi.org/10.1073/pnas.2006323117

Pahl-Wostl C (2019) Governance of the water-energy-food security nexus: A multi-level coordination challenge. Environ Sci Policy 92:356–367. https://doi.org/10.1016/j.envsci.2017.07.017

Pahl-Wostl C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Glob Environ Chang 19:354–365. https://doi.org/10.1016/j.gloenvcha.2009.06.001

Pahl-Wostl C, Gorris P, Jager N, et al (2020) Scale-related governance challenges in the water–energy–food nexus: toward a diagnostic approach. Sustain Sci. https://doi.org/10.1007/s11625-020-00888-6

Parris TM, Kates RW (2003) Characterizing and measuring sustainable devleopment. Annu Rev Environ Resour 28:559–86. https://doi.org/10.1146/annurev.energy.28.050302.105551

Pascale S, Kapnick SB, Delworth TL, Cooke WF (2020) Increasing risk of another Cape Town " Day Zero " drought in the 21st century. Proc Natl Acad Sci 1–9. https://doi.org/10.1073/pnas.2009144117

Plummer R, Armitage DR, de Loë RC (2013) Adaptive comanagement and its relationship to environmental Governance. Ecol Soc 18:. https://doi.org/10.5751/ES-05383-180121

Plummer R, Crona B, Armitage DR, et al (2012) Adaptive Comanagement: a Systematic Review and Analysis. Ecol Soc 17:290–306. https://doi.org/10.5751/ES-04952-170311

Porter JJ, Birdi K (2018) 22 reasons why collaborations fail: Lessons from water innovation research. Environ Sci Policy 89:100–108. https://doi.org/10.1016/j.envsci.2018.07.004

Potts R, Vella K, Dale A, Sipe N (2016) Evaluating Governance Arrangements and

Decision Making for Natural Resource Management Planning: An Empirical Application of the Governance Systems Analysis Framework. Soc Nat Resour 29:1325–1341. https://doi.org/10.1080/08941920.2016.1185557

Prescott-Allen R (2001) The Wellbeing of Nations: A country-by-country index of quality of life and the environment. Island Press, Washington, DC

Rametsteiner E, Pulzl H, Alkan-Olsson J, Frederiksen P (2011) Sustainability indicator development — Science or political negotiation ? Ecol Indic 11:61–70. https://doi.org/10.1016/j.ecolind.2009.06.009

Rasul G (2016) Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. Environ Dev 18:14–25. https://doi.org/10.1016/j.envdev.2015.12.001

Rasul G, Sharma B (2016) The nexus approach to water–energy–food security: an option for adaptation to climate change. Clim Policy 16:682–702. https://doi.org/10.1080/14693062.2015.1029865

Redman CL (2014) Should sustainability and resilience be combined or remain distinct pursuits? Ecol Soc 19:37–46. https://doi.org/10.5751/ES-06390-190237

Resources AD of W (2020) Fourth Management Plan: Phoenix Active Management Area. Phoenix, AZ

Ringler C, Bhaduri A, Lawford R (2013) The nexus across water, energy, land and food (WELF): Potential for improved resource use efficiency? Curr Opin Environ Sustain 5:617–624. https://doi.org/10.1016/j.cosust.2013.11.002

Rodina L (2019) Water resilience lessons from Cape Town's water crisis. WIREs Water 6:1–7. https://doi.org/10.1002/wat2.1376

Rotenberg R (2010) Assessing Student Learning. In: The Art and Craft of College Teaching, Second. Left Coast Press, Walnut Creek, CA, pp 139–148

Ryan C, Carragee KM, Meinhofer W (2001) Framing, the news media, and collective action. J Broadcast Electron Media 45:175–182. https://doi.org/10.1207/s15506878jobem4501

Saunders B, Sim J, Kingstone T, et al (2018) Saturation in qualitative research: exploring its conceptualization and operationalization. Qual Quant 52:1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Scheufele DA (1999) Framing as a theory of media effects. J Commun 49:103–122. https://doi.org/10.1111/j.1460-2466.1999.tb02784.x

Schoon M, York A, Sullivan A, Baggio J (2017) The emergence of an environmental governance network: the case of the Arizona borderlands. Reg Environ Chang 17:677–689. https://doi.org/10.1007/s10113-016-1060-x

Schreiner B, Baleta H (2015) Broadening the Lens: A Regional Perspective on Water, Food and Energy Integration in SADC. Aquat Procedia 5:90–103. https://doi.org/10.1016/j.aqpro.2015.10.011

Secco L, Da Re R, Pettenella DM, Gatto P (2014) Why and how to measure forest

governance at local level: A set of indicators. For Policy Econ 49:57–71. https://doi.org/10.1016/j.forpol.2013.07.006

Settles T, Lindsay BR (2011) Crime in post-Katrina Houston: The effects of moral panic on emergency planning. Disasters 35:200–219. https://doi.org/10.1111/j.1467-7717.2010.01200.x

Sharma P, Kumar SN (2020) The global governance of water, energy, and food nexus: allocation and access for competing demands. Int Environ Agreements Polit Law Econ 20:377–391. https://doi.org/10.1007/s10784-020-09488-2

Simpson GB, Jewitt GPW, Simpson GB (2019a) The Development of the Water-Energy-Food Nexus as a Framework for Achieving Resource Security : A Review. 7:1–9. https://doi.org/10.3389/fenvs.2019.00008

Simpson NP, Shearing CD, Dupont B (2019b) When Anthropocene shocks contest conventional mentalities: a case study from Cape Town. Clim Dev 12:163–169. https://doi.org/10.1080/17565529.2019.1609402

Singh RK, Murty HR, Gupta SK, Dikshit AK (2009) An overview of sustainability assessment methodologies. 9:189–212. https://doi.org/10.1016/j.ecolind.2008.05.011

Slater MD (2007) Reinforcing spirals: The mutual influence of media selectivity and media effects and their impact on individual behavior and social identity. Commun Theory 17:281–303. https://doi.org/10.1017/CBO9781107415324.004

Smajgl A, Ward J, Pluschke L (2016) The water-food-energy nexus--Realising a new paradigm. J Hydrol 533:533–540. https://doi.org/10.1016/j.jhydrol.2015.12.033

Snow DA, Rochford EB, Worden SK, Benford RD (1986) Frame Alignment Processes , Micromobilization, and Movement Participation. Am Sociol Rev 51:464–481

Sousa P, Blamey R, Reason C, et al (2018) The "Day Zero" Cape Town drought and the poleward migration of moisture corridors. IopscienceIopOrg 1–20. https://doi.org/10.1088/1748-9326/aaebc7

Stake R (2006) Cross-Case Analysis. In: Multiple Case Study Analysis

Sullivan A, White DD, Hanemann M (2019) Designing collaborative governance: Insights from the drought contingency planning process for the lower Colorado River basin. Environ Sci Policy 91:39–49. https://doi.org/10.1016/j.envsci.2018.10.011

Taing L, Chang CC, Pan S, Armitage NP (2019) Towards a water secure future: reflections on Cape Town's Day Zero crisis. Urban Water J 16:530–536. https://doi.org/10.1080/1573062X.2019.1669190

Tanguay GA, Rajaonson J, Lefebvre JF, Lanoie P (2010) Measuring the sustainability of cities: An analysis of the use of local indicators. Ecol Indic 10:407–418. https://doi.org/10.1016/j.ecolind.2009.07.013

Termeer CJAM, Drimie S, Ingram J, et al (2018) A diagnostic framework for food system governance arrangements: The case of South Africa. NJAS - Wageningen J

Life Sci 84:85–93. https://doi.org/10.1016/j.njas.2017.08.001

Thomas CW, Koontz TM (2011) Research designs for evaluating the impact of community-based management on natural resource conservation. J Nat Resour Policy Res 3:97–111. https://doi.org/10.1080/19390459.2011.557877

Trochim WM (1989) Outcome pattern matching and program theory. Eval Progr Plan 12:355–366

Turcu C (2013) Re-thinking sustainability indicators: Local perspectives of urban sustainability. J Environ Plan Manag 56:695–719. https://doi.org/10.1080/09640568.2012.698984

Udall B, Overpeck JT (2017) The twenty-first century Colorado River hot drought and implications for the future Bradley. Water Resour Res 53:2404–2418. https://doi.org/10.1002/2016WR019638

Ulibarri N (2015) Collaboration in federal hydropower licensing: Impacts on process, outputs, and outcomes. Public Perform Manag Rev 38:578–606. https://doi.org/10.1080/15309576.2015.1031004

United Nations (1987) Our common future. Oxford

United Nations (2015) Sustainable Development Goals. https://sdgs.un.org/goals. Accessed 4 Mar 2021

United Nations (2020) Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development

Urbinatti AM, Benites-Lázaro LL, Carvalho CM de, Giatti LL (2020) The conceptual basis of water-energy-food nexus governance: systematic literature review using network and discourse analysis. J Integr Environ Sci 00:1–23. https://doi.org/10.1080/1943815X.2020.1749086

van Gevelt T (2020) The water–energy–food nexus: bridging the science–policy divide. Curr Opin Environ Sci Heal 13:6–10. https://doi.org/10.1016/j.coesh.2019.09.008

Venghaus S, Dieken S (2019) From a few security indices to the FEW Security Index: Consistency in global food, energy and water security assessment. Sustain Prod Consum 20:342–355. https://doi.org/10.1016/j.spc.2019.08.002

Verma P, Raghubanshi AS (2018) Urban sustainability indicators: Challenges and opportunities

Villarroel Walker R, Beck MB, Hall JW, et al (2014) The energy-water-food nexus: Strategic analysis of technologies for transforming the urban metabolism. J Environ Manage 141:104–115. https://doi.org/10.1016/j.jenvman.2014.01.054

Visser WP (2018) A perfect storm: The ramifications of Cape Town's drought crisis. J Transdiscipl Res South Africa 14:1–10. https://doi.org/10.4102/td.v14i1.567

Wackernagel M, Rees WE (1998) Our Ecological Footprint: reducing human impact on the earth. New Society Publishers

Wahl D, Ness B, Wamsler C (2021) Implementing the urban food–water–energy nexus through urban laboratories: a systematic literature review. Sustain Sci.

https://doi.org/10.1007/s11625-020-00893-9

Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, Adaptability and Transformability in Social– ecological Systems. Ecol Soc 9:5

Weitz N, Strambo C, Kemp-benedict E, Nilsson M (2017a) Governance in the water-energy-food nexus: Gaps and future research needs. Stockholm, Sweden

Weitz N, Strambo C, Kemp-benedict E, Nilsson M (2017b) Closing the governance gaps in the water-energy-food nexus: Insights from integrative governance. Glob Environ Chang 45:165–173

Western Cape Government (2017) Socio-Economic Profile: City of Cape Town. Cape Town

White DD, Jones JL, Maciejewski R, et al (2017) Stakeholder analysis for the food-energy-water nexus in Phoenix, Arizona: Implications for nexus governance. Sustain 9:. https://doi.org/10.3390/su9122204

White DD, Wutich AY, Larson KL, Lant T (2015) Water management decision makers' evaluations of uncertainty in a decision support system: the case of WaterSim in the Decision Theater. J Environ Plan Manag 58:616–630. https://doi.org/10.1080/09640568.2013.875892

Wichelns D (2017) The water-energy-food nexus: Is the increasing attention warranted, from either a research or policy perspective? Environ Sci Policy 69:113–123. https://doi.org/10.1016/j.envsci.2016.12.018

Wiek A, Withycombe L, Redman CL (2011) Key competencies in sustainability: A reference framework for academic program development. Sustain Sci 6:203–218. https://doi.org/10.1007/s11625-011-0132-6

Willis HH, Groves DG, Ringel JS, et al (2016) Developing the Pardee RAND Food-Energy-Water Security Index. 60

Wright T, Jacobs HE (2016) Potable water use of residential consumers in the cape town metropolitan area with access to groundwater as a supplementary household water source. Water SA 42:144–151. https://doi.org/10.4314/wsa.v42i1.14

Yeboah-Assiamah E, Muller K, Domfeh KA (2016) Rising to the challenge: A framework for optimising value in collaborative natural resource governance. For Policy Econ 67:20–29. https://doi.org/10.1016/j.forpol.2016.01.008

Yin RK (2018) Case study research and applications: Design and methods. Sage Publications

Yuan MH, Lo SL (2020) Developing indicators for the monitoring of the sustainability of food, energy, and water. Renew Sustain Energy Rev 119:. https://doi.org/10.1016/j.rser.2019.109565

Zhu J, Kang S, Zhao W, et al (2020) A bibliometric analysis of food–energy–water nexus: Progress and prospects. Land 9:1–22. https://doi.org/10.3390/land9120504

Ziervogel G (2019) UNPACKING THE CAPE TOWN DROUGHT:LESSONS LEARNED Report for Cities Support Programme Undertaken by African Centre for Cities