Energy-water nexus in Mexico:

A network-based approach of polycentric governance.

Ricardo Gómez Zamudio

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Abstract

By 2050, sixty percent of human population worldwide is going to live in cities. This will increase natural resource consumption to provide products and services in cities. Additionally, current policy making is done through a silo thinking mindset where unintended consequences can undermine natural resources availability. To overcome this problem, I propose to use the urban nexus approach as a starting point of analysis to increase urban resource efficiency. However, the urban nexus proposal has been directed toward measuring material flows which have not proven to provide enough information for policy and decision-making. Studying social flows, such as governance systems adds an essential social perspective to supplement material flows analysis, as governance sets up the conditions for extraction, consumption and disposal of natural resources. Therefore, I look at urban nexus, especially energy-water nexus, under a polycentric governance lens for providing products and services and enhancing natural resource management in Mexico. Additionally, I supplement urban nexus and polycentric governance frameworks by using the social network analysis to understand stakeholders' relationships between the energy and water sectors in Mexico City. According to my results, Mexico's energy (electricity) governance system is not polycentric, however, the water sector shares some polycentricity governance traits. Due to these central control rules of resources, some barriers appear, such as diminishing local authorities' abilities to implement an energy-water nexus project that drives national authorities to be key stakeholders to manage this kind of project. However, polycentric governance has proven useful to propose recommendations to overcome these barriers through strengthening local authority's capacities. This study contributes by filling the gap between the urban nexus approach and polycentric governance and provides key stakeholders according to current socio-economic settings in Mexico, which can push forward urban nexus initiatives and pave the way to polycentric governance of natural resources.

Keywords: Energy-water nexus, polycentric governance, social network analysis, sustainability science.

Word count (thesis): 13,765

Resumen

Para el año 2050, más de la mitad de la población mundial vivirá en ciudades. Esto aumentará el consumo de recursos naturales para proporcionar productos y servicios a las ciudades. Además, las políticas públicas actuales se realizan en un marco de silos institucionales en donde las consecuencias no previstas pueden socavar la disponibilidad de los recursos naturales. Para superar este problema, propongo utilizar el enfoque de nexo urbano como punto de análisis para aumentar la eficiencia de los recursos urbanos y mejorar el desempeño institucional. Sin embargo, la propuesta de nexo urbano se ha dirigido principalmente hacia el análisis de flujos de materiales los cuales no han demostrado proporcionar información suficiente para la formulación de políticas públicas y toma de decisiones. El estudio de los flujos sociales, como la gobernanza y relaciones entre actores, agrega una perspectiva social esencial para complementar el análisis de los flujos de materiales, ya que estas estructuras sociales establecen las condiciones para la extracción, el consumo y la disposición de los recursos naturales. Por lo tanto, investigaré sobre el nexo urbano, especialmente energía-agua, bajo el marco de gobernanza policéntrica que es útil para proporcionar productos y servicios y mejorar la gestión de los recursos naturales en México. Además, complemento los marcos de nexos urbanos y gobernanza policéntrica utilizando análisis de redes sociales para comprender las relaciones entre los actores del sector energía (electricidad) y agua en la Ciudad de México. De acuerdo con mis resultados, el sistema de gobierno de la energía (electricidad) en México no es policéntrico, sin embargo, el sector del agua comparte algunos rasgos de gobernanza policéntrica. Debido a estas reglas de control central de los recursos, surgen algunas barreras como: la disminución de la capacidad de las autoridades locales para implementar un proyecto de nexo energía y agua, lo cual influye a que autoridades nacionales sean los actores clave para gestionar este tipo de proyectos. Sin embargo, la gobernanza policéntrica ha demostrado ser útil para proponer recomendaciones para superar este tipo de barreras mediante el fortalecimiento de las capacidades de autoridades locales. En conclusión, este estudio contribuye a llenar el vacío entre nexos urbanos y la gobernanza policéntrica y resalta actores clave, de acuerdo con el contexto social actual en México, que pueden impulsar las iniciativas de nexos urbanos y sentar las bases hacia una gobernanza policéntrica de los recursos naturales.

Palabras clave: Nexo energía-agua, gobernanza policéntrica, análisis de redes sociales, ciencias de la sostenibilidad.

Conteo de palabras (thesis): 13,765

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List of Acronyms

ANEAS	National Association of Water and Sanitation Companies of Mexico AC
CCA	Water Advisory Council
CENACE	National Centre for Energy Control
CFE	Federal Commission of Electricity
CRE	Electricity Regulatory Commission
CONAGUA	National Commission of Water
CMM	Mario Molina Centre
GIZ	German Cooperation Agency for Sustainable Development
GWh	Gigawatt-hora
MCMA	Mexico City Metropolitan Area
MFA	Material flow analysis
PNASE	National Program for the Sustainable Use of Energy
PND	National Development Plan
PNH	National Hydric Program
PRONASE	National Program of the Energy Sector
SACMEX	Water System of Mexico City
SENER	Ministry of Energy
SEMARNAT	Ministry of Environment and Natural Resource
SMEs	Small and medium-sized enterprises
UNAM	National Autonomous University of Mexico
WRI	World Resource Institute

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1. Introduction

In a context of environmental degradation, increasing urbanization and population growth, demand for resources is going to increase while their availability will decrease. Therefore, an efficient and integrated management of resources is needed for the survival of current and future generations' (Lehmann, 2018). However, nowadays, the policymaking processes and practices are mostly sector (silo) based, which generates harmful or unintended impacts of one sector over the other, thus undermining resource availability (Lehmann, 2018). To effectively overcome this silo thinking, the implementation of an urban nexus approach for integrating management resources is needed (GIZ & ICLEI, 2014). "Urban nexus" is an integrated resource management and action-oriented framework that looks at nature and social interactions to identify crucial inter-linkages between sectors to achieve efficiencies in water, energy, waste, and food (common focus areas of urban nexus) to ultimately develop projects for their implementation (Dodds et al., 2016). Thus, the urban nexus approach allows the framework to visualize interconnections among different sectors, for instance between energy-water, energy-waste, and water-energy-food, among others.

Current literature on urban nexus approach focuses on material flows which refers to streams of natural resources extracted and moved towards cities to provide the city's good and services (Covarrubias, 2019). Material flows research on extraction, production, consumption and disposal processes by using methodologies such as material flow analysis (MFA) to visualize the physical inputs and outputs of human settlements and their environmental impacts (Covarrubias, 2019). However, material flows analysis has the struggle to provide relevant information for policy and decision making (Binder, 2007). In this regard, social flow is a concept that aims to supplement material flows analysis in urban nexus studies (Covarrubias, 2019). Social flows refer to information, discourses, practices, policies or governance systems shaping resource provisioning systems in cities. Moreover, they also focus on the social organization, actors, networks, and strategies that go along with the material flow of urban nexus (Covarrubias, 2019).

Thus, this research aims to investigate social flows, specifically governance systems of the energy-water nexus in Mexico. In doing so, I use a polycentric governance approach and social network analysis to answer the following questions:

> *Research question 1:* Are the current energy (electricity) and water governance systems in Mexico polycentric?

Research question 2: What are the barriers to implement an energy-water nexus project in Mexico City Metropolitan Area (MCMA)?

Research question 3: Who are the key stakeholders for pushing forward and implementing energy-water nexus projects in Mexico City?

Thus, the first question aims to study the governance status of energy and water governance in Mexico to understand where Mexico is regarding polycentric governance. The second question seeks to understand what the barriers are related to the energy-water nexus project and how it can be solved through polycentric governance approach. Once we know where we are and what problems we must face, the third question seeks to uncover relevant stakeholders that can push forward an energy-water nexus project and thus paving the way to polycentric governance systems.

1.1 Sustainability science

The urban nexus approach assumes that there is an interaction between natural and social systems embedded in sustainable urban resources management (Covarrubias, 2019). On the other hand, polycentric governance is founded in the arguments that for better provision of public good and services, there is a need for knowledge co-production by including local stakeholders such as local government and citizens. Thus, the problem, approach, and questions use and ask above, strongly correlates to the sustainability science field. According to Clark and Dickson (2003):

> *"Sustainability science focuses on the dynamic interactions between nature and society. It is problem-driven, and its goal is creating and applying co-produced knowledge in support of decision making."*

Additionally, Kates (2011) sustainability science's definition supplements the link between my thesis topic and sustainability science:

> *"an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems."*

Based on this, this master thesis contributes to filling the knowledge gap between the urban nexus approach and polycentric governance, aiming to foster sustainable urban resource management strategies and policies.

2. Background.

Nowadays, the policymaking process and practices are mostly silo-based which generates harmful or unintended impacts of one sector on the other, and thus undermines resource availability (Lehmann, 2018).

Before getting into more detail, first, I would like to answer the question; what does silo-based policy and practices mean? There are three different types of silo: political, mental and institutional (Meuleman & Niestroy, 2016). Political silo refers to politicians focusing on their field and defending it as they want to win majorities, mental silos is when people think their approach is the best and only way forward (Meuleman & Niestroy, 2016). Meanwhile, institutional silo refers to the division of complex problems into partial problems conducted by separate sectoral or bureaucratic departments or ministries, that most of the times do not interact with other stakeholders. The latter one is the most common silo type referred to when people talk about "breaking down the silos" which call for policy coherence and policy integration by merging ministries (Meuleman & Niestroy, 2016). However, instead of breaking them down, some authors argue that we should "teach them how to dance" by improving horizontal coordination, institutional flexibility, cross-sectoral interaction and transparent processes (Meuleman & Niestroy, 2016) to foster cooperation, competition and conflict resolution mechanisms that could help to solve sustainability challenges.

An approach to reduce silo-thinking while optimizing institutional performance between sectors is the urban nexus approach (McGrane et al., 2018). This approach guides stakeholders to find possible synergies between industries, jurisdictions and technical dimensions to improve resource management and increase institutional performance. Additionally, its primary objective is to optimize resource management and to counteract silo thinking and trade-offs (GIZ & ICLEI, 2014). For better implementation of the urban nexus approach, the literature says (Blumstein, n.d; Swallow, Johnson, Meinzen-Dick, & Knox, 2006) that new institutions such as inter-ministerial organisms might be required to align different sectors. However, if a decision needs to be taken, it is essential to strengthening existing institutions so they can better coordinate and cooperate among sectors and deal with uncertainty and complexity (Hoff, 2011). Another window of opportunity for urban nexus improvement is through fostering policy coherence and policy integration. Their primary objective is the integration of environmental, social and economic dimensions of sustainable development in policy making. Finally, governance is another strategy to improve urban sector security (e.g., water, energy, food, waste, and transport) through a nexus

approach. Thus, governance includes all processes of decision-making; for instance, if decisions are implemented or not, if they are made by different actors such as the government, market, non-governmental organizations or networks over a population through laws, norms, power or language (Sheng, n.d). Therefore, in this thesis, I will use polycentric governance as a framework to improve implementation of the urban nexus approach in the context of solar-energy based electricity used for water management[1] activities. The theoretical justification of polycentric governance will be introduced in section 3.1 along with its interplay with the urban nexus approach.

Meanwhile, to bring this urban nexus approach from a theoretical to a practical realm, I will present an overview of an energy-water nexus problem in Mexico City. The problem is related to climate change contribution through intensive use of fossil-fuel based electricity for water management activities and how it can be addressed through the implementation of solar energy electricity systems.

2.1 Energy and water nexus in Mexico: solar energy for water management activities in Mexico City Metropolitan Area?

In 2017, around 81% of Mexico's electricity generation mainly came from power plants that burn fossil fuels such as coal, natural gas, and petroleum. Meanwhile, the rest is covered by clean energies[2] with hydropower technology being the most widely used which account for 12%, followed by nuclear power plants (4%), geothermal (2%), wind energy (.8%) and photovoltaic technology (.004%) (SIE, 2019). Mexico City as part of one of the most significant metropolitan areas in the world consumes an enormous quantity of resources such as electricity, materials, water, and food.

An excellent and clear example of Mexico City's high resource consumption and its links with urban nexus approach is given through estimations of how much electricity Mexico City consumes for pumping, distributing, purifying and treating water. Average calculations of electricity consumption used for pumping, purification processes and water distribution of 715, 141.8 million liters of the total 953, 522 million liters account for 570.98 million kWh (Delgado, 2015). This amount of energy

[1] Water management activities understood as pumping, purification, water distribution and water distribution.

[2] Clean Energies: Those energy sources and processes of electricity generation whose emission and waste, when they have, do not overcome the thresholds established in the regulations (Law of the Electric Industry of 2014).

for water management is equivalent to an annual total amount of about 284, 000 to 332,000 tonnes of CO2e. Additionally, in the State of Mexico, this estimation is between 710,000 to 830,000 tonnes of CO2e, both contributing to climate change (Delgado, 2015) As State of Mexico's users are about 60% of the total users of MCMA (Delgado, 2015), inter-state coordination and cooperation has to be present (Fig. 1).

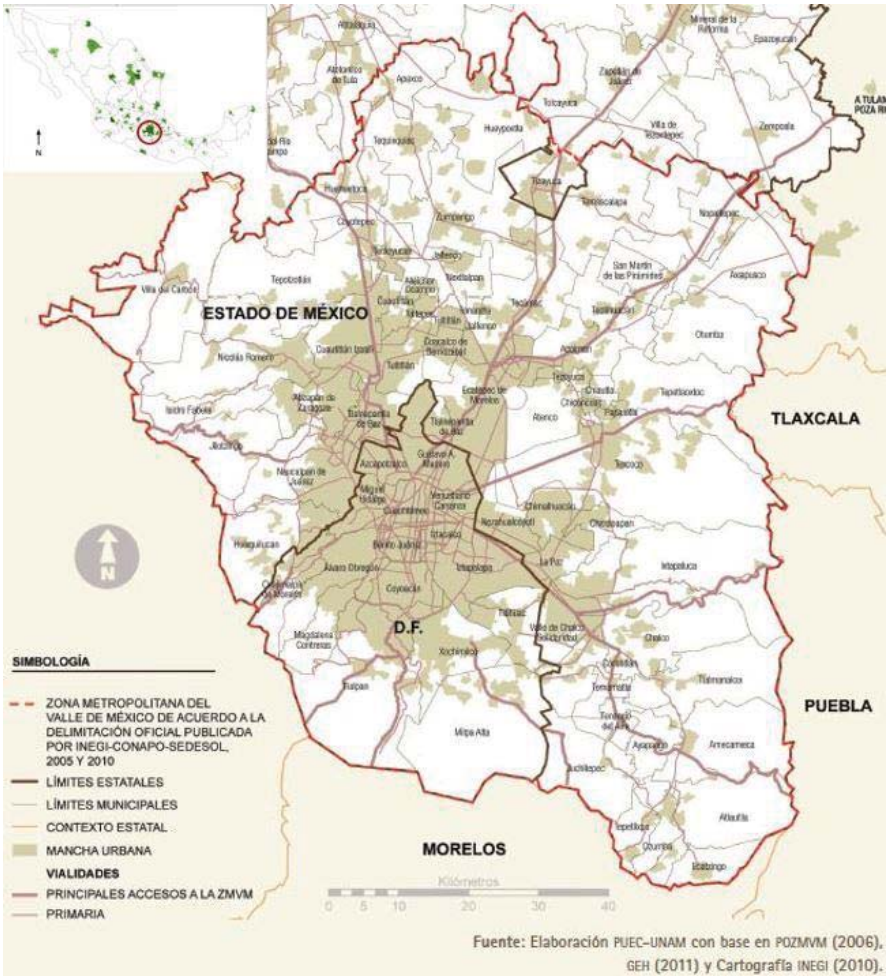

Figure 1. Mexico City Metropolitan Area composed by 16 municipalities from Mexico City, 59 municipalities from the State of Mexico and one municipality from the state of Hidalgo. Symbology translation: Discontinuous red line: delimitation of MCMA, brown line: State limits, green line: municipality limits, yellow line: Other states limits, brown box: urban sprawl Source: PUEC-UNAM based on POZMVM (2006), GEH (2011) and Cartography (2010).

Thus, to address the problem of contribution to climate change, clean energies can be implemented to reduce the use of fossil-fuel generated electricity for water management activities. The state of

Mexico accounts for an annual medium photovoltaic energy potential of 4008[3] GWh/year to 1179[4] GWh/year. Meanwhile, Mexico City's areas for photovoltaic potential is 41GWh/a (SENER, 2019). However, this solution faces social rather than technological barriers such as silo-thinking within energy and water sectors, and lack of metropolitan and cross-sectoral cooperation which could undermine efforts to implement projects between industries and different stakeholders conjointly. Therefore, I propose using a polycentricity lens to improve urban nexus approach supplemented by polycentric governance and social network analysis as a strategy to transform institutional silo-thinking to more flexible, transparent and dynamic thinking where cross-sectoral and metropolitan cooperation can be fostered to implement these types of projects. To facilitate communication throughout this research, when talking about the energy-water project, I will be referring to solar energy for water management activities in Mexico City, until I state the contrary. Moreover, when I refer to the energy sector, I will refer specifically to the electricity sector.

3. Theoretical framework: A network-based approach for the polycentric governance framework.

3.1 Polycentric governance theory.

Polycentric governance refers to multiple, independent, and nested decision-making centres, with cooperative and competitive relationship capable of resolving conflicts (Ostrom, 2010) that could provide public good and services. These decision-making centres are considered multiple because they come from a combination of different organizations from the public, private, community-based organizations and civil society (Carlisle & Gruby, 2017) which have the advantage of using local knowledge and learning (Ostrom, 2010). Moreover, "independent" refers to the capacity of the decision-making centres to establish rules and norms, while, "nested" refers to decision centres overlapping across different levels and political jurisdiction (Carlisle & Gruby, 2017). Also, cooperative, competitive and conflict resolution mechanisms must be in place for well-established decision-making centres.

[3] High potential areas or zones for clean energy generation project development, located at an average distance (20km) from the Transmission Network (SENER, 2019).
[4] High potential areas or zones for clean energy generation project development, located at 2km from the Transmission Network (SENER, 2019).

I am focusing on polycentric governance because it is suitable for improving water-energy nexus due to two reasons: 1) there is evidence that multiple public and private agencies can be involved in the provision of diverse public good and services (Ostrom, 2010) and 2) Polycentricity fits better for managing natural resources than other modes of governance (Carlisle & Gruby, 2017). This latter claim of polycentric governance is based on the concept of "near decomposability" which refers to systems composed of multiple levels of subsystems that are functionally independent but also, they are functionally linked with higher and lower-level subsystems. This trait will allow polycentric governance systems cross-level interactions that may be producing institutions at levels appropriate to the ecological scale of the specific problem (Carlisle & Gruby, 2017).

Additionally, in a context of natural resource management Marshall (2009) highlights theoretical advantages such as better access to traditional or scientific knowledge, closer matching of policy to socioeconomic settings, enhanced policy experimentation, improved information transmission due to overlap and fostered capacity for adaptive management. Meanwhile, empirical studies suggest that polycentricity might be better than monocentric or centralized governance as it increases resilience and adaptive capacity against shocks and disturbances. Coordination, a key trait in polycentric governance, supports experimentation and learning which improves performance in dealing with challenges such as climate change (Pahl-Wostl & Knieper, 2014). Therefore, due to these reasons and advantages of polycentricity, polycentric governance systems fit better for managing natural resources. These arguments of polycentricity are highly related and applicable to energy-water nexus. Thus, it raises the questions of how polycentric governance can be useful for energy-water nexus.

3.2 Social network theory and conceptualization.

Finally, to complement polycentric governance framework, I introduce a network-based approach through social network theory and its three theoretical assumptions which are: 1) relations are essential for understanding observed behaviour, 2) social network affect perception, beliefs, and actions through a variety of structural mechanisms and 3) structural relationships should be viewed as dynamic processes (Yang, Keller, & Zheng, 2017). Therefore, social network theory highlights the importance of connections among actors and how they are going to influence actions and behaviour, for example, how stakeholders will manage electricity and water resources.

On the one hand, social network theory is based on understanding network structures as an entity such as the market is for economists or the state and its institutions are for political scientists. In this first level of research, the network structures are the result of the combined action of its nodes which form ties between them. The social network performance will depend on this combined action that foster collaboration and complement each other's expertise within the network rather than just being reduced to individual characteristics of the system (Yang et al., 2017).

On the other hand, the additional level of research is an individual level where social networks are represented as nodes and their ties between each other. These nodes usually represent actors, groups, teams, organizations, political parties or even nation states (McGloin & Kirk, 2010). Networks that embody nodes of one level of aggregation are called one-mode network — however, there are bipartite networks which represents nodes on different levels of aggregation (Newman, 2010). For instance, a one-mode network is looking at ties between political parties while a bipartite network is looking at relations between politic parties (one aggregation level) and sustainable policies (another aggregation level). Thus, social networks are a representation of relations between social beings. Therefore, these ties influence the type of network that is going to be analysed. For instance, research on friendship ties will generate a different network from enmity ties (Yang et al., 2017). Therefore, it is vital to determine ties relations beforehand.

Additionally, different types of networks depend on the directions of those relations towards the nodes. For example, if the directions of the connection are irrelevant, the network is undirected. However, if these relations between actors is one way but not necessarily mutual it is called "directed." Meanwhile, if these relations are reciprocal, the network is called "reciprocated" (Newman, 2010). Finally, different units of analysis focus on several actors to research on. Therefore, in the lowest level is the individual actors where you look at individual human being, organization or community and its relations. Later, social network relations can be analysed between two actors (dyadic pairs) or three social actors (triadic structures).

Moreover, cliques are substructures densely connected to others. Lastly, the full or complete network is the most macro-level unit of analysis which focus on interactions among a variety of actors (Yang et al., 2017). Density and centralization can be researched by looking at the full or complete network level of analysis. Moreover, the reasons why these social networks are in place or the impact of these social networks will have on a system can be studied (Yang et al., 2017).

As Yang et al. (2017) said “In the world of social networks, actors never act in isolation. Instead, they influence and are influenced by others” (p. 5). Therefore, social network adds valuable theoretical insights and methodological tools to my research to improve the urban nexus approach through polycentric governance. Thus, the primary purpose of using social network analysis (SNA) is to identify key actors to implement electricity-water nexus in Mexico City and to pave the way for polycentric governance systems for resource management.

Up until now, I have introduced the concept of the urban nexus approach to overcome the problem of silo-thinking in resource management in a specific case of the energy-water nexus project in Mexico City. However, implementing the urban nexus approach has its challenges, and the way this thesis wants to contribute to solving them is through polycentric governance based on a network-based approach. Therefore, the following sections are going to address the research approach and methodology used in this thesis to operationalize the polycentric governance framework and social network analysis. On the research approach, I will describe the research design used in this thesis. Meanwhile, in the methodology section, I will explain the specific framework, social network particularities and the data collection process used in this thesis.

4. Research approach

Sustainability science as an interdisciplinary and holistic research area can be enriched and get a better comprehension of the phenomena by selecting a variety of methodologies, allowing to use mixed methods research (Molina-Azorín & Font, 2015; Scudder et al., 2017). Mixed methods research is a methodology of research which refers to an integration of quantitative and qualitative methods within a single analysis (Molina-Azorín & Font, 2015). There are 3 types of mixed methods designs which are: 1) exploratory designs which begins with a qualitative data collection and then an analysis phase, which builds to the quantitative phase, 2) explanatory design which starts with a quantitative data collection and analysis phase to inform the upcoming qualitative phase and 3) convergent design which involves quantitative and qualitative data collection and analysis at similar times, followed by an integrated study (Guetterman, Fetters, & Creswell, 2015).

For the first part of my thesis, I use qualitative methodology through semi-structured interviews based on a polycentric governance framework to measure the degree of polycentricity governance in the water and energy sector in Mexico. For the next question about stakeholders’ relationship I

use the mixed method design called “exploratory design” where I collect qualitative data through interviews, document analysis and archival data inventories that I use for a quantitative analysis through social network analysis. I will use this mixed-approach to supplement findings from two methodologies and look for integration of results at the interpretation level through a side-by-side comparison of the results (AHRQ, 2013). Advantages of this approach are that it could reduce quantitative and qualitative weaknesses by complementing each other, have a broader understanding of the problem by using a variety of tools, and it reduces personal biases (AHRQ, 2013). However, their limitations must be highlighted such as requiring more resources, need multidisciplinary expertise and increase the complexity of the evaluation (AHRQ, 2013).

4.1 Methodology

In this thesis, I use a mixed method approach to collect data and be able to answer the research questions. To answer the first and second research question; 1) “Are the current energy (electricity) and water governance systems in Mexico polycentric?” and 2) What are the barriers to implement an energy-water nexus project in Mexico City Metropolitan Area (MCMA)? I use semi-structured interviews and document analysis.

Among polycentric governance literature (Andersson & Ostrom, 2008; McGinnis & Ostrom, 2012; Oakerson & Parks, 2011; Ostrom, 2010), there are a variety of polycentric definitions related to the degree of independence of actors, diverse types of organizations or scales (Schröder, 2018). Therefore, I first identify my specific problem and set up boundaries and level of scale to narrow down my research as Schröder (2018) proposed to reduce fuzziness in using the policentricity lens.

Later, I perform semi-structured interviews with different stakeholders related to the energy (electricity) and water sector from the government, academia, civil society and businesses via phone call or Skype. I select stakeholders following a network-based strategy called nominalist strategy which consists of choosing actors under a conceptual framework that delineates the boundary of the network (Yang et al., 2017). Thus, I selected actors under the theoretical framework of their relations to electricity or water sectors in Mexico City and according to their expertise in governance, water, electricity, and sustainable urban development topics.

I use the ten polycentric indicators proposed by Aligica and Tarko, 2012 framework (Fig. 2) to form my questions for the semi-structured interview and I supplement them with two critical aspects of

polycentric systems; co-production and local self-governance capacity (Villamayor-Tomas, 2018). This framework is an effort to transform a conceptual level of polycentric governance to a more concrete level of analysis by considering polycentricity attributes to determine indicators. In doing so, Aligica and Tarko, 2012 analyze cases of polycentricity and summarize polycentricity features and indicators. Villamayor-Tomas (2018) operationalized Aligica and Tarko's framework to research on the level and type of polycentricity between the electricity and water sector in an irrigation project in the region of Aragon, Spain. As guidance to formulate my questions for my semi-structured interview, I use guiding questions found at Villamayor-Tomas (2018).

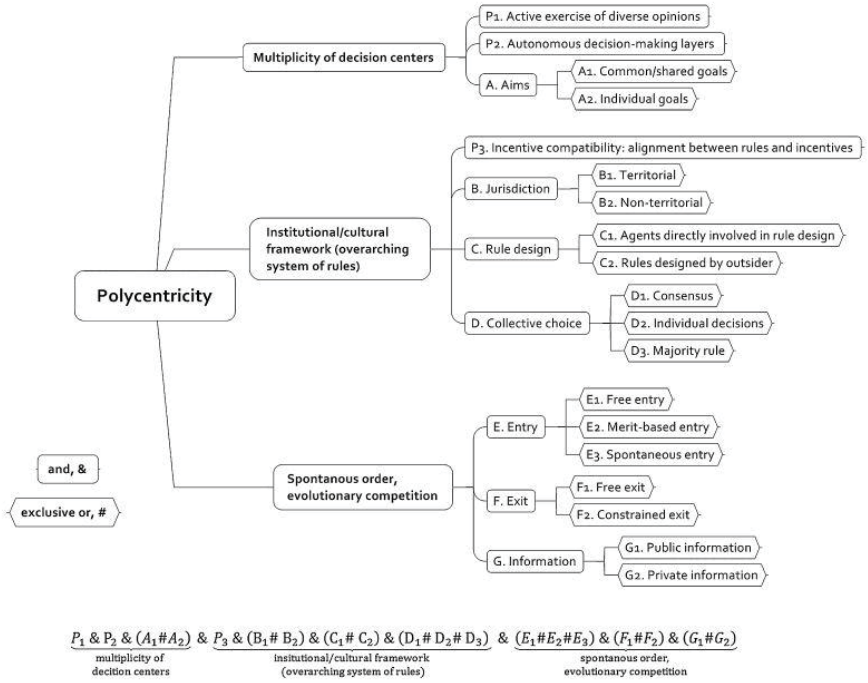

Figure 2. Ten polycentricity indicators derived from three essential features of a polycentric governance system: a) a multiplicity of decision centers, b) institutional and cultural framework (overarching system of rules that coordinates interaction among authorities, and c) spontaneous order by evolutionary competition (Aligica & Tarko, 2012).

The interviews were conducted in Spanish and lasted between 1 and 2 hours. Twelve questions were asked; however, if interviewers had little time only key questions were asked (see appendix 1). Those fundamental questions are based on what Aligica and Tarko consider as three essential conditions that a polycentric system must have; active exercise of diverse opinions (P1), autonomous decision-making layers (P2) and alignment between rules and incentives (P3). The

relevant questions were complemented with questions I consider essential to be answered for my research such as relations between water and electricity stakeholders in Mexico City, and barriers for implementing solar energy for water management activities (electricity-water nexus project). The primary objective of this methodology is to analyze if current electricity and water governance systems are polycentric as well as to visualize barriers to develop an energy-water nexus project.

Moreover, I use document analysis to supplement data gathered from the semi-structured interview and to provide background and context for my research. Document analysis refers to a process that systematically analyses and evaluates print and electronic documents which involves skimming, reading and interpreting texts through content analysis (Bowen, 2009). According to Silverman (2015) content analysis is based on an examination of the data set, grouped by using a code system. Meanwhile, the other form of content analysis that Bowen (2009) recommend is doing a first-pass document review to identify relevant passages of the text or another kind of data. Therefore, I decided to use Bowen's content analysis as I could specifically focus on passages of text that are related to the ten polycentric indicators cited by Aligica and Tarko. Finally, for this thesis, I analysed documents such as water, electricity, urban development, and data transparency laws, institutional reports, non-governmental organization assessment reports, government water and energy programs, and policy documents.

To answer the third research question; "Who are the key stakeholders for pushing forward and implementing electricity(energy)-water nexus projects in Mexico City?" I use social network analysis to analyse and determine the relationship between stakeholders and then to visualize who would be a key actor to foster and implement a project of this kind. In doing so, I use a one-mode network[5] to visualize and statistically analyse the interplay between different actors from the government, business, academia, and non-governmental organizations in a context of electricity generated from solar energy for water management activities in Mexico City. I use an undirected network[6] to study actors' relations based on their connections between the energy and water sector in Mexico City. Finally, my unit of analysis is a full level as I am interested in looking at the reasons and consequences of the resulting network in the management of electricity and water.

[5] One-mode network: Networks that embody nodes of one level of aggregation are called one-mode network *(For more information, see theoretical section).*

[6] Undirected network: Networks where the directions of those relations towards the nodes are irrelevant *(For more information, see theoretical section).*

Therefore, for social network analysis, I use the free online software "Gephi" to map out stakeholders' relations and be able to visualize their interconnections in a graph. For stakeholder selection, I follow the network-based approach called nominalist strategy mentioned before, and I add stakeholders based on interviews and document analysis. Moreover, to explain the network I use "density" measure which looks at how connected the nodes are with each other, and I use "centrality" which measures the importance of an actor in a network. There are two types of centrality measurements which I consider important for my research; 1) "betweenness centrality" which measure the number of times an actor lies on the shortest path between pairs of actors in a network, and 2) "closeness centrality" which measures how fast a specific node can reach other nodes (Yang et al., 2017). Betweenness centrality can be measured by counting the number of times a node (organization) lies on the shortest path between pairs of nodes, and it is an essential statistic as you can identify actors that can be influential regardless if they have a lot of connections or not. Moreover, for stakeholders' relational data collection, I conduct semi-structured interviews, and I use indirect methods for inferring ties through archival data inventories and social events in which actors participate (Yang et al., 2017). This form of archival data inventory, consists of analysing patterns of co-authorship in one or more publications (Yang et al., 2017). Therefore, I look at different organizational and governmental reports and assessments related to water and electricity (energy) topics to look at their co-authorships in order to reveal their relations between different actors.

5. Results

5.1 Is the governance system of the water and energy sectors in Mexico polycentric?

According to Aligica and Tarko, 2012 the ten policentricity indicators are grouped within three basic polycentricity features which are; 1) The multiplicity of decision centres which refers to the ability of decision centres to apply their methods into practice, 2) the overarching system of rules which relates to stakeholders interaction regarding rules design, decision making, and jurisdiction, and 3) the spontaneous social order which refers to the social order result of competition between different ideas, perspectives and methods (see Fig. 2; Aligica & Tarko, 2012). To breakdown my results in more detail, in the following section I present my results according to each of the three basic polycentricity governance features mentioned above.

5.1.1 The multiplicity of decision centres

According to the polycentricity framework, this first essential feature corresponds to three indicators which are: P1. Active exercise of diverse opinions, P2. Autonomous decision-making layers and A. Aims (table 1).

Table 1. Guiding questions to assess the polycentricity essential feature; a multiplicity of decision centres in water and energy sectors in Mexico.

Multiplicity of decision centres	
P1. Active exercise of diverse opinions	Does your organisation have the legal, economic or institutional capacity to cooperate and coordinate with other institutions in a project like
P2. Autonomous decision-making layers	**a)** Can your department make autonomous decision regarding this type of project? **b)** Is the decision-making capacity of local authorities complemented (and not undermined) by higher level authorities?
A. Goals	Do water and energy (electricity) sectors have common/individual goals?

Interviewees expressed to have human and finance capacity to cooperate in and coordinate energy-water nexus initiatives. However, they are not legally capable of managing cooperation and coordination arrangements.

Nevertheless, they can express recommendations to authorities. For instance, non-governmental organizations can voice their opinions and give their suggestions of what a public or private organization should do, however, it is not binding which means that the public or private entity could decide not to follow the recommended path. In this case, expressing their recommendations (methods about how to conduct something) relates to the P1 indicator “active exercise of opinions”. However, this does not completely fulfil this indicator as the recommendation could not be implemented, which P1 indicator definition establish to do so.

Interviewees from academia, a solar energy company, and non-governmental organization reported to have operational, and opinion autonomy as their organizations are duly constituted. However, they cannot decide on this type of projects as the decision-making mainly rests with federal water and energy authorities such as the National Commission of Water (CONAGUA) or Electricity Regulatory Commission (CRE). Decision-making regarding the water sector can also rest on local

authorities such as Water System of Mexico City (SACMEX), however, due to some institutional, economic and cooperation barriers (explain in section 5.2) the energy-water nexus project should be in charge at a federal level. Another interviewee from the Institute of Legal Research at National Autonomous University of Mexico (UNAM), stated that this decision-making process goes along with the concept of governability which is top-down decision-making processes that foster social participation mechanisms. Nevertheless, without any capacity for people to influence governmental action, as people's participation is allowed in later stages of the development of the action. Thus, there is a centralized energy sector where its control rules are mainly federal, while, the water sector is also federal but less centralized. The reason the water sector is less centralized is that water is subject to the principle of concurrency according to Article 73, Section XXIX. G of the Mexican Constitution (Constitución Política de los Estados Unidos Mexicanos, 2016, Art. 73), the water sector is a subject of the principle of concurrency which refers to a nested and multilevel characteristic of control rules for water management between the three levels of government (federal, state and municipal).

Results presented above are related to the indicator P2 "autonomous decision-making layers" which refers to the ability of decision centres to make independent and nested operational decisions. On the one hand, even though organizations have autonomy in their opinions there is no decision-making autonomy from different decision centres, instead this is focused mainly on federal authorities. On the other hand, regarding the nested characteristics of this indicator (P2), even though the Mexican Constitution states that decision making should be supplemented for a higher level of authority, an interviewee said that in practice cooperation and coordination relations between different levels of government is difficult which could constraints autonomous operational decisions to happen, regarding energy-water nexus projects. Therefore, in this case of energy-water nexus projects, P2 indicator is also not entirely fulfilled.

Finally, document analysis of the National Development Plan (PND), National Hydric Program (PNH), National Program for the Sustainable Use of Energy (PNASE) and the National Program of the Energy Sector (PRONASE) from 2014-2018, showed that water and energy objectives are partially separated. For example, in the PND, PNASE, and PROSENER documents, energy's objectives focus on electricity access, decrease electricity costs or improve the energy efficiency of transmission and distribution electricity networks. On the other hand, the water sector states clear individual objectives such as supplying quality water for human consumption or increasing water-related

services. Meanwhile, words such as “multisectoral,” “intersectoral” and “interinstitutional” are very poorly represented in the documents, while there is a particular emphasis on international cooperation for both sectors and private industry cooperation for the energy sector. However, some objectives and strategies link the water and energy sector. These are related to hydroelectric power, increasing energy efficiency in the agriculture and livestock industry and strengthening solar heating system programs. Finally, local water authorities such as the Water System of Mexico City recognize the importance of this nexus between energy and water, as they asked Mario Molina Centre for an economic analysis regarding electricity consumption in water management activities in Mexico City. These results are complemented with interview results that water and energy sectors have mainly but not exclusively, separated goals in practice.

5.1.2 The overarching system of rules

According to the polycentricity framework, the second essential feature corresponds to four indicators which are: P3. Incentive compatibility: alignment between regulations and incentives, B. Jurisdiction, C. Rule design and D. Collective Choice (table 2).

Table 2. Guiding questions to assess the polycentricity essential feature; an overarching system of rules in water and energy sectors in Mexico.

Overarching system of rules	
P3. Incentive compatibility; alignment between rules and incentives & Rule design	Are there rules and incentives to start a project like this?
B. Jurisdiccion	Is your jurisdiction territorial or non-territorial (overlapping)?
C. Rule design	Does your organisation participate on rule design or its design is made by external actors?
D. Collective action	Do you think that decisions between multiple actors are taken by consensus, individual or majority rule in this type of project?

According to interviewees, there are no rules for coordination nor cooperation between the water and energy sectors. Moreover, there is no regulation for ensuring the return of investment, no regulations for the cancelation of commercial agreements and no regulations for hiring long-term infrastructure from water or energy national authorities that apply to energy-water nexus projects.

Nevertheless, an interviewee explained that in the renewable energy area there are incentives not necessarily linked to the water management sector but for implementing solar panels for electricity generation such as the Clean Energy Certification. According to the interviewee, in the Mexican Electric National Market, there are two products to sell: electric energy and electric power which refers to how much energy a power plant could supply if the National Centre for Energy Control (CENACE) ask for it. This certification is a way to compensate renewable energies for their lack of electric power. Thus, this certification can be sold in the Electric National Market and in that way recover their investments.

Additionally, clean energies have the advantage of electricity generation over non-clean energy technologies. Despite the existence of these incentives for renewable energies implementation (including hydroelectric power), there are no rules nor incentives that foster and strengthen energy-water nexus for urban resource management in Mexico. Therefore, the indicator P3 of "alignment between rules and incentives" which refers to the importance of rules for all the agents and establish the consequences of the laws is not fulfilled.

Regarding the indicator of "C. rule design," an interviewee states that academia could participate in policy formulation if the authority asked for it. Additionally, an interviewee from the private sector said that private companies could not design them as they are developers and not regulators. Finally, most interviewees (4 out of 6) agree that the rule design process entirely depends on the federal water and energy authorities.

Meanwhile "D. collective choice" which refers to how decision-making is being done either; collectively, individually or for the majority. Interview results show that it depends on water and energy government authorities. On the one hand, an interviewee said that the energy authorities at a national level such as the Electricity Federal Commission permit a power plant project of less than 0.5M in energy capacity. Meanwhile, if it is more than 0.5M in energy capacity the Electricity Regulatory Commission (CRE) permit or not depending on whether a plant with those characteristics is needed in that place or not. On the other hand, the water sector decision making mainly rest on federal but also local authorities, for instance, the National Water Commission (CONAGUA) or SACMEX, respectively. Finally, all interviewees agreed that the water and energy sectors' jurisdiction are both territorial.

5.1.3 Spontaneous social order

According to the polycentricity framework, the last basic feature corresponds to three indicators which are: E. Entry, F. Exit, and G. Information (table 3).

Table 3. Guiding questions to assess the polycentricity essential feature; spontaneous social order in water and energy sectors in Mexico*.*

Spontaneous social order	
E. Entry	Organisations/departments can freely, spontaneously or merit-based enter the development of this type project?
F. Exit	Could a department/organisation freely exit from the project or is it constrained?
G. Information	Is water/energy (electricity) information publicly available or private ?

According to the Mexican Constitution, Article 134:

> *"Any acquisitions, leases, and disposals of all type of goods, provision of services or contracts for public infrastructure will be done through public tenders to ensure the State the best price, quality, financing, opportunity and other relevant circumstances (Constitución Política de los Estados Unidos Mexicanos, 2016, Art. 134)."*

Moreover, the Law of Public Infrastructure and Services postulates that administrative units of the Presidency of the Republic, the National Ministries, the Attorney General's Office of the Republic and decentralized organs are subject to doing public tenders for public infrastructure contracts. As CRE, CONAGUA or any government are subjects to these laws; if they want to carry out public infrastructure from an energy-water perspective, they must do it through a public tender. Due to the nature of this tender processes, the polycentric indicator "E. Entry" is merit-based. On the other hand, how decision centers exit will be constraint and subject to penalties postulated in the tender.

Finally, the last polycentricity indicator "G. Information" refers to whether information for decision making is public or private (Aligica & Tarko, 2012). According to the Environmental Democracy Index, which is an assessment based on national-level laws, regulations and practices are composed of three pillars; transparency, participation, and justice. Mexico accounts for a grade of 2.43 on a 3-grade scale in the transparency pillar which refers to whether the collection of environmental information is cited by law, access to environmental information on request, and the proactive

disclosure of information to the public (WRI, 2015). This index highlights transparency for information for environmental decision-making focusing on water quality information but not for the energy sector. Despite this, the index gives a general understanding of the status of access to information in Mexico for environmental decision making which is directly linked to energy and water sectors.

The Federal Law for Transparency and Access to Public Information states that obligated individuals[7] in the energy sector need to keep updated information regarding chemicals used on water and water volumes used in the petroleum-related industry. Obligated individuals in the Federal Executive Power are obligated to published information about electricity transported and distributed in the National Transmission Network, goals for clean electricity generation, the levels of electric power generation. The productive enterprises of the State such as Commission National of Electricity must publicize information about the bases, rules, income, costs, cost limits, considerations, contributions and payments made, contracts, assignments, permits, alliances, partnerships and other acts in matter of the planning and control activities of the national electricity system; of the public service of transmission and distribution of electric power.

Regarding the water sector, obligated individuals in the Federal Executive Power must publish information about surface and underground water availability by hydrological region. Meanwhile, on the local level for instance in Mexico City, there must be a list of concessionaire companies responsible for managing water, information on Mexico's City water quality, monitoring mechanisms and reports of the performance of the concessionaire companies ("Ley de Transparencia, Acceso a la Informacion Publica y Rendicion de Cuentas de la Ciudad de Mexico," 2016).

On the other hand, there is no statements talking about publicize electricity information locally, which it might be related to how this sector is managed (federal level rather than locally). An interviewee stated that general energy information is published online by authorities, but a degree of expertise is needed to understand it, which in my opinion questions people's accessibility to information. Moreover, interviewees mentioned that despite general information is available on

[7] Obligated individuals: are any authority, entity, organ and body of the Legislative, Executive and Judicial powers, autonomous organisms, political parties, trusteeship and public funds, as well as of any individual, moral or trade union that receives and exercises federal public resources or acts of authority ("Ley Federal de Transparencia y Acceso a la Informacion Publica ", 2017)

a national scale, if local information wants to be consulted it needs to be requested to authorities which could be more challenging to get it due to administrative barriers such as data not being digitally available. Additionally, another interviewee mentioned that if authorities considered information sensitive, it is not published, even though the data does not gather the characteristics to do so according to the Federal Law of Transparency and Access to Public Information. Finally, interviewees mentioned mechanisms to request information to any governmental organ through the Information Requests System of Mexico City. Therefore, considering environmental democracy index, law, information request mechanisms and interviewees statements, this polycentricity indicator of "information" is fulfilled for both sectors.

5.1.4 Supplementary critical aspects of polycentricity; Local self-governance and co-production

In addition to the ten polycentricity traits by Aligica and Tarko, 2012 I supplement them with two critical elements of polycentricity taken from Villamayor-Tomas (2018); local self-governance and co-production (Table 4).

Table 4. Guiding questions to assess supplement critical aspects of polycentricity; local self-governance and co-production in water and energy sectors in Mexico.

Supplement critical aspects of polycentricity	
Local self-governance	Are there cooperative organizations, indigeneous communities or local governments related to water and energy (electricity) sectors?
Coproduction	Is there a possibility to include citizens into this kind of project?

Local self-governance refers to indigenous communities, cooperative organizations or local governments that can pave the way for co-production (Villamayor-Tomas, 2018). Regarding this, one interviewee stated that there are no citizen organizations that linked both water and energy themes. However, as there are places in Mexico City with no access to water, there are citizens organizations that press the government for water accessibility. On the energy sector, two interviewees stated that there are no energy cooperatives in Mexico City because of a lack of regulation. However, two interviewees mentioned that because of amendments to the Law of the Public Service of Electric Energy in 1992 and 2012, there is regulation for decentralization of the sector through independent producers and self-supply processes that could lead to energy

cooperatives. However, three interviewees mentioned that energy cooperatives do not exist in practice, and one of them highlighted that energy cooperatives are not prohibited, but a certain amount of money, electricity law understanding, and contacts in the Electricity Regulatory Commission is needed, which complicates the process of creating an energy cooperative.

Regarding the second aspect of polycentricity; co-production refers to the idea that citizens are a crucial part of the process of providing public goods (Villamayor-Tomas, 2018). According to the Ley de Aguas Nacionales (2016, Art. 14 BIS) [General Water Law Article 14 BIS], the National Commission of Water jointly with subnational governments, basin organizations, basin councils and the Water Advisory Council, will foster and facilitate the participation of society in the planning, decision making, execution, evaluation and monitoring of the national water policy. Interviewee confirmed this information. However, according to three interviewees there are two aspects to take into account regarding this mechanism; 1) societies' recommendations within, for instance, Water Advisory Council are not binding which means that government organizations have to hear them but they are not necessarily going to apply them and 2) power relations within the participant organizations in the Water Advisory Council or the Basin Councils need to be considered, as the decision-making process could lean towards one specific action due to political or economic reasons. On the other hand, from an interviewee's perspective, including a citizen or small and medium-sized enterprises (SMEs) into energy-water nexus projects at city level scale is difficult, as they do not have the human, technologic and economic capacities to conduct such a project. However, another way to include citizens and SMEs could be through government calls and responsible household water management or through implementing rainwater harvesting systems. In this way, intensive electricity use for pumping water could be reduced and thus its contribution to climate change. Meanwhile, in the energy sector, there are no citizen participation mechanisms associated with its more centralized governance. While there are laws for electricity self-supplies, there are no incentives for energy cooperatives as mentioned before.

The above goes along with what the Environmental Democracy Index says about its participation pillar which for the case of Mexico accounts for 0.78 on a 3-grade scale. This "participation pillar," states that the public has limited capabilities to participate as most laws do not require government department to incorporate citizens comment in environmental decisions (WRI, 2015). Therefore, these two critical aspects of polycentricity are not fulfilled in the energy sector; meanwhile in the water sector partially which make it more polycentric.

According to these results, the energy sector is mainly centralized; meanwhile, the water sector has some degree of polycentricity (Table 5). This centralized governance might enhance some barriers for energy-water nexus projects because of their characteristics of less flexibility, silo-thinking, and top-down approaches. Therefore, in the following section, I present my results about barriers for implementing solar panels for water managing activities in Mexico City which is an example of an energy-water nexus project.

Table 5 Summary of results applying the polycentricity framework from Aligica and Tarko (2012) *Energy and water sectors merge objectives regarding hydroelectric power, energy efficiency in agriculture and livestock industry, and strengthen solar heating system programs.

Sector	----------	Water	Energy
Multiplicity of decision centres	*P1. Active exercise of diverse opinions*	Not completely fulfil	
	P2. Autonomous decision-making layers	Not completely fulfil	
	A. Goals	Individual*	Individual
Overarching system of rules	*P3. Incentive compatibility; alignment between rules and incentives & Rule design*	Not fulfill	
	B. Jurisdiction	Terrirotial (from national to local)	Terrirotial (national)
	C. Rule design	Water authority (CONAGUA)	Electricity authority (CRE)
	D. Collective action	Individually by water authority (CONAGUA)	Individually by energy authority (CFE or CRE)
Spontaneous social order	*E. Entry*	Merit-based	
	F. Exit	Constrained	
	G. Information	Fulfil	
Supplement critical aspects of polycentricity	Local self-governance	Partially	No
	Coproduction	Partially	No

5.2 Barriers for implementation of energy-water nexus projects in Mexico City Metropolitan Area.

5.2.1 Metropolitan coordination

As stated in section 2.1, Mexico City needs collaboration from the State of Mexico for implementing solar energy for water management activities as the State of Mexico has potential areas for solar power which Mexico City does not have. Knowing the barriers of metropolitan coordination is

essential as it is the setting that could allow the conditions to implement an electricity-water project on a metropolitan level successfully.

Unfortunately, as interviewees mentioned, metropolitan coordination in Mexico City and its metropolitan area is poor because of legal, institutional, economic and accountability, and political barriers. The first barrier is legal. An interviewee mentioned that there had been progress on metropolitan cooperation through the General Law of Urban Settlements, Territorial Ordering and Urban Development which has a chapter for metropolitan coordination and jurisdiction, urban metropolitan programs and planning systems, and social participation mechanisms for metropolitan planning such as Metropolitan Commissions (LGAHOTM). However, an interviewee mentioned that there are legal barriers, according to the Mexican Constitution, Article 115:

> *"Each Municipality will be governed by a City Council of direct popular election, composed of a Municipal President and the number of aldermen and trustees that the law determines. The competition that This Constitution grants the municipal government will be exercised by the City Council exclusively and there will be no intermediate authority between it and the State Government (Constitución Política de los Estados Unidos Mexicanos, 2016, Art. 115)."*

Therefore, the interviewee emphasised that this article explicitly prohibited a middle-level government between the national and local governmental level, and he mentioned:

> *"When any of the municipalities that compose the Mexico City Metropolitan Area (MCMA) would disagree before the Supreme Court of Justice, all metropolitan effort would tumble."*

Therefore, not allowing an intermediate authority such as a metropolitan government level to operate a jointly electricity-water nexus project between Mexico City and the State of Mexico.

The second barrier is institutional. An interviewee shared that three sub-federal governments compose Mexico City Metropolitan Area; Mexico City, State of Mexico and the State of Hidalgo which adds complexity to coordination and cooperation mechanisms within the metropolitan area as states and municipalities do not count with enough human capabilities nor the vision to work in a metropolitan way.

The third barrier is economical because of monetary reduction of public funds and public budgetary responsibility problems. There is a policy instrument, called Ramo 23 "Salary and economic provisions," that grant resources from the Ministry of Finance and Public Credit to local authorities (states or municipalities) through specific funds such as the Metropolitan Fund (Gobierno Facil,

2019). Monetary reduction for metropolitan coordination is reflected through a reduction of this Metropolitan Fund 2012-2017 in the Ramo 23 (Fig. 3; Secretaría de Hacienda y Credito Publico, 2019) and endorsed by an interviewee from International Foundation for the Development of Reliable Governments; *"The metropolitan funds decreased significantly, because, in the Ramo 23 that is where they are located, it was reduced. What does that mean? It means that the federal government is not giving an economical place on the agenda to cooperation spaces between states and municipalities"*.

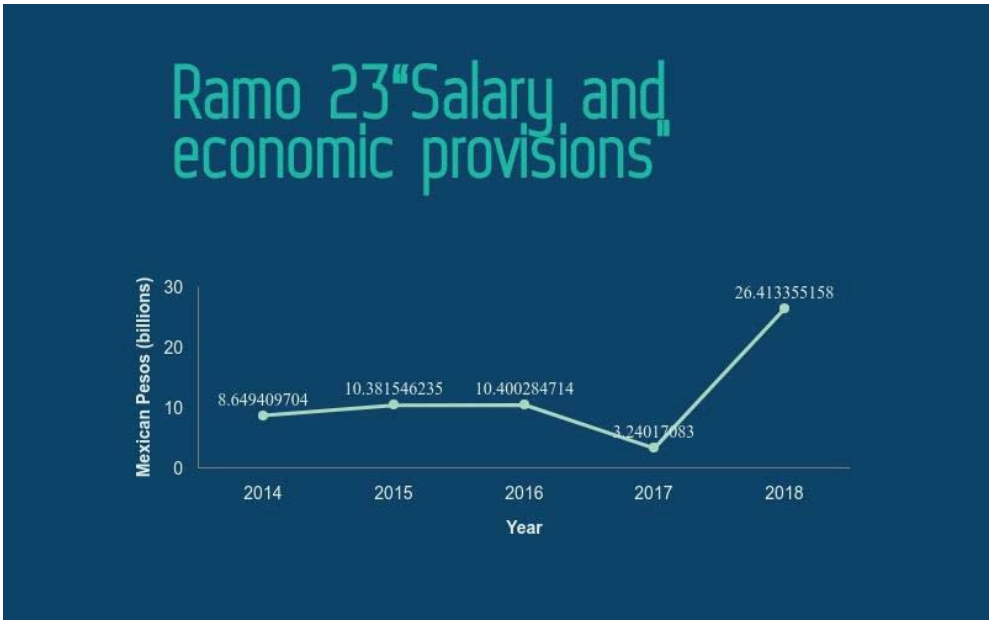

Figure 3. Decrease of the budget for the metropolitan fund at a federal level from 2014 to 2017. Although, in 2018 the fund has a considerable increased Source: *(Secretaría de Hacienda y Credito Publico, 2019)*.

Also, there is a public budgetary responsibility problem as each state within the MCMA; Mexico City, State of Mexico and Hidalgo's municipality receive a yearly budget that needs to be justified. Therefore, if there is a jointly energy-water nexus project among MCMA's states, there is the problem of how much money each state must contribute with. Finally, one interviewee mentioned that the fourth barrier is political, as there is a lack of political will and there are different political interests that can counteract metropolitan efforts.

5.2.2 Cross-sectoral coordination

On the other hand, cross-sectoral coordination refers to coordinated processes for planning, implementing and monitoring across different public sector ministries and agencies involved in the subject (Benson, 2011), for instance, between water and energy sectors.

According to Mexican Constitution, Article 116 refers to how National and State level can merge functions, the execution and operation of constructions, and the provision of public services (Constitución Política de los Estados Unidos Mexicanos, 2016, Art. 116). Additionally, Article 122 sets up the basis for establishing administrative coordination mechanisms related to development planning and execution of regional actions for the provision of public services which could involve cross-sectoral cooperation if needed (Constitución Política de los Estados Unidos Mexicanos, 2016, Art. 122). Finally, according to Ley Orgánica de la Administración PúblicaFederal (2019, Art. 21) [the Organic Law of the Federal Public Administration Article 21], the president of the Republic can create inter-secretarial commissions to solve matters that need the intervention of different ministries or administrative departments.

Thus, there is a legal basis for cross-sectoral coordination and cooperation, and even there are already inter-secretarial and inter-institutional coordination mechanisms for climate change (Inter-secretarial Commission for Climate Change) or drought and floods management (Inter-Secretariat Commission for the Management of Droughts and Floods) in place. However, and interviewee mentioned that in practice there is no synergy between ministries as they work in a silo-thinking way, proposing each ministry their own goals and actions. Moreover, as each ministry receives a budget to be spent and justified, the problem of public budgetary responsibilities rises again which refers to how much money each ministry must contribute to solving the problem. Finally, an interviewee mentioned that there is a barrier of leadership referring to ministries wanting the credit of the project and if it is not granted, they do not participate in the development of it.

5.2.3 Local authority capacity.

Interview results show that for implementing an energy-water nexus, there is an institutional weakness due to the lack of regulations at a local level. Additionally, there is no technical, human and economic capacity from local authorities nor the vision to work jointly to develop a project of this kind. As an interviewee from a solar energy company mentioned:

"There are practically no renewable energy and water projects because of different regulatory scopes the water and energy sector have. The water sector is within a regulatory scope at the local level; there are specific regulations for the states and even more specific for municipalities. Unlike the electric energy which has central control for the whole country, so, you must deal with an entity that is CFE (national level). We do not know any private water project that has been possible to develop at the local level because the city or municipality authorities do not have the conditions of banking, financing or regulatory framework that allows local entities to finance and trigger projects of this nature.

Moreover, political cycles that last three years do not provide a condition of certainty for investors to fund a long-term project for 20 or 25 years. Therefore, at a local level (city or municipal level) there are no financing conditions for this type of project to be developed because there is uncertainty from the private sector that there would not be a return of their investment. Therefore, the project must be done with limited public resources."

5.2.4 Economic and technological barriers

Additionally, an interviewee from Mario Molina Centre mentioned that subsidies are a significant barrier, regarding a project of electricity-water nexus for water pumping through solar energy in the agricultural and residential sector. These subsidies make both water and electricity costs cheaper which do not create enough incentive conditions for individuals to change their outdated water pumping technologies to more efficient ones. Moreover, these subsidies undermine that distributed solar generation systems in the domestic sector are implemented on a bigger scale as it does not provide an economic incentive for installing solar panels in households.

Finally, another barrier highlighted by an interviewee, is related to technological advances, due to the nature of intermittency of the solar electricity energy which does not allow the demand of electricity to be controlled, rising problems when higher demand of electricity is needed. Therefore, there is the need for electricity storage sources such as batteries which can increase costs of the projects making it economically unfeasible.

5.3 Key actors for the implementation of energy-water initiatives in Mexico City.

After looking at the different barriers and governance mode in water and energy sectors for energy-water nexus initiative, the third aim of my master thesis is to identify stakeholders for water and electricity nexus and to visualize the relationships among actors in Mexico City. The importance of

this third inquiry is to determine which stakeholders can push forward water-electricity nexus initiatives for better urban resource management that will pave the way to polycentric governance systems. In the following section, I present my social network analysis results where stakeholders were chosen based on a nominalist sampling strategy mentioned earlier (methodology section, see appendix 2 and 3 for node and edges data). Thus, I first show the interview's result where I asked interviewed stakeholders (n=6) to identify organizations who would be appropriate for an electricity-water nexus project in Mexico City. Next step was using that interview data, official governmental and organizational documents and events to gather additional information about stakeholder's ties to visualize it in a graph.

5.3.1 Stakeholder's ties between water and energy sector based on interviews

Interviewees identify different private, non-governmental organizations, and public organization at the federal and local level, however, they highlighted some organizations as the most appropriate ones for implementing an electricity-water nexus project due to current juridical and socioeconomic settings. These stakeholders are the National Commission of Water (CONAGUA) and the Federal Commission of Electricity (CFE):

An expert on metropolitan coordination from the International Foundation for the Development of Reliable Governments mentioned that:

> *"According to article 115, it is forbidden to have an order level between national and state level. Therefore, this means that metropolitan cooperation is legally weak, thus leading to federal level managed cooperation efforts. The federal government is the one who can really operate a project of this nature. Because the federal government does have a way to work through CONAGUA on water and CFE on energy. This level is the one that would really have better possibilities of realization, not excluding that some progress could be made in metropolitan area issues, from the states, and the municipalities. However, in practice, they (lower levels of government) do not have enough skills, vision nor the institutional structures that allow these issues to be ensured."*

A representative of a solar energy company in Mexico reinforces the above mentioned:

> *"Due to institutional, economic and legal barriers (discussed in barriers section), the interviewee says: "I would recommend working with CONAGUA, either in a project of desalination, not here in Mexico City, there are no conditions but in a pumping project."*

Moreover, other organizations such as UNAM and the Water Systems of Mexico City (SACMEX) are mentioned by two interviewees as necessary for this type of project. The first interviewee is a representative from the Institute of Legal Research at UNAM which said:

> *"Well in the case of Mexico City, the Water System of Mexico City that is SACMEX, as it is empowered to carry out the management and administration of water in the city. Interviewer: In this case, UNAM could be invited to participate in this project? Interviewee: Obviously, if you are looking at it from the polycentric governance, it could be a relevant actor that will help in the construction of management of the information and the management of the implementation of the project.*

Mario Molina Centre has worked already in an electricity-water nexus project to analyse electricity cost for the water sector in Mexico City. An interviewee from this centre mentioned the importance of SACMEX and UNAM for this energy-water project:

> *And we also work for this study with the UNAM, I believe that in that sense the academy is an essential element to consider, particular the Engineering Institute UNAM. Moreover, a lot of the information we asked directly to SACMEX and also to the Lerma Cutzamala system.*

5.3.2 Stakeholder's social network analysis between the water and energy sector.

After gathering and analysing interviews, document, and events relational data, the final completed sample includes ties among 31 stakeholders (see appendix 4). Stakeholders were divided into three categories to understand better their composition. Thus, first, they were classified according to their "organization type" (see appendix 4a) from government (58%), international organization (16%), non-governmental organization (13%), company (10%) and academia (3%). Second, they were divided by "scale" (see appendix 4b) referring if they work at an international (29%), national (52%), national/local (3%) and local (16%) level, and finally, stakeholders were divided according to their sectors (see appendix 4c) such as electricity/water (32%), electricity (23%), water (16%), metropolitan coordination (10%), science, technology and innovation (3%) and others (16%).

To analyse the stakeholder network, I use three different statistical analysis, first, “Degree” metrics which refers to the number of connections a node has. According to social network analysis results, the organizations (nodes) that has more connections are the non-governmental organizations called Mario Molina Centre (CMM) and the World Resource Institute (WRI), the Ministry of Energy (SENER), and the National Commission of Water (CONAGUA). Moreover, organizations such as German Cooperation Agency for Sustainable Development (GIZ), National Association of Water and Sanitation Companies of Mexico AC (ANEAS) and Water Advisory Council (CCA) could have an important role in an electricity-water nexus project (Fig. 4).

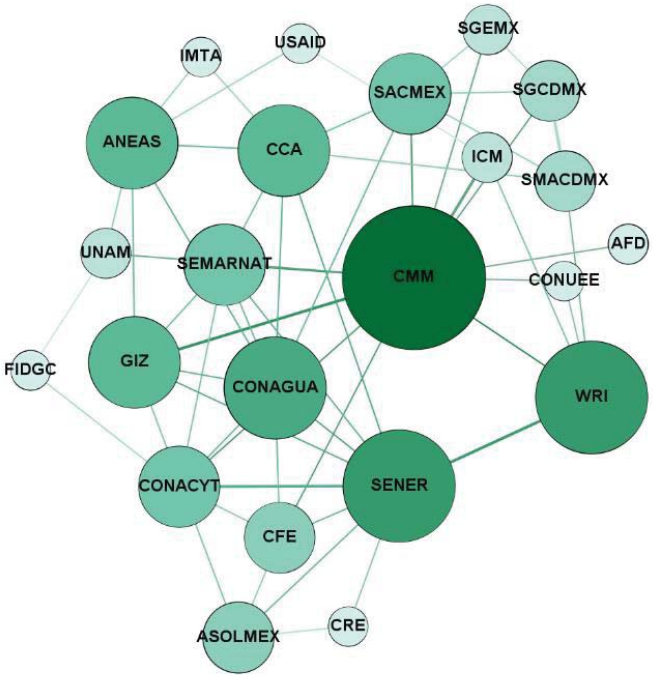

Figure 4. Social network representing “degree” metric which refers to the number of connections each node has. Size and colour scheme of the node represents how many links the node has, the darker and the bigger the node is, the more connections it has.

To complement this analysis, I measure “betweenness centrality” of the network which refers to the importance a node has in connecting or disconnecting other nodes in the network. In practical terms, it means that an organisation “X” connects two set of actors by the relations that organisation “X” has between them. If that organisation “X” is rule out, then those two set of actors would not be connected. As a result of this metric, I found that there are five stakeholders within my network

which have the highest betweenness centrality measurement which are ANEAS, GIZ, SENER, WRI and CMM (Fig. 5).

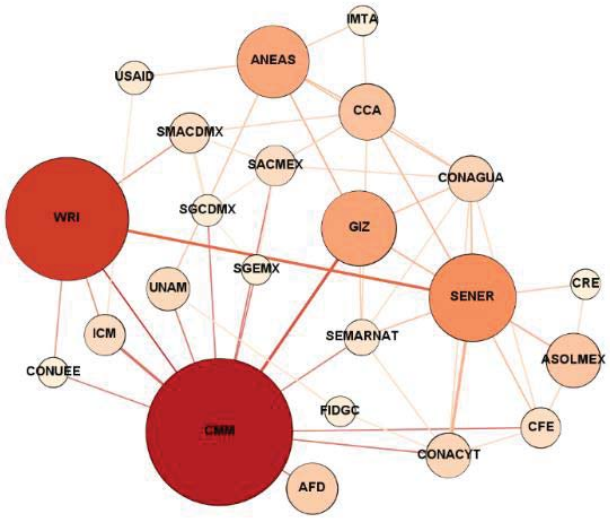

Figure 5. Social network representing "betweenness centrality" metric. Size and colour scheme of the node represents how important a node is, by bridging other nodes. So, the darker and bigger node is, the more important the node is.

Finally, the last metric I use for analysing this network was closeness centrality which measures how close a node is from all the others. So, a node with the highest values (1) refers to be the closest one to all other nodes. Hence, according to this metric Centre Mario Molina (CMM) is the organization with the highest closeness centrality value (Fig. 6). However, it is interesting to see that there are many other organizations with similar closeness centrality values between each other such as the Ministry of Environment and Natural Resource (SEMARNAT), CONAGUA, National Council for Science and Technology (CONACYT) and GIZ which could represent how these stakeholders are closely related to each other.

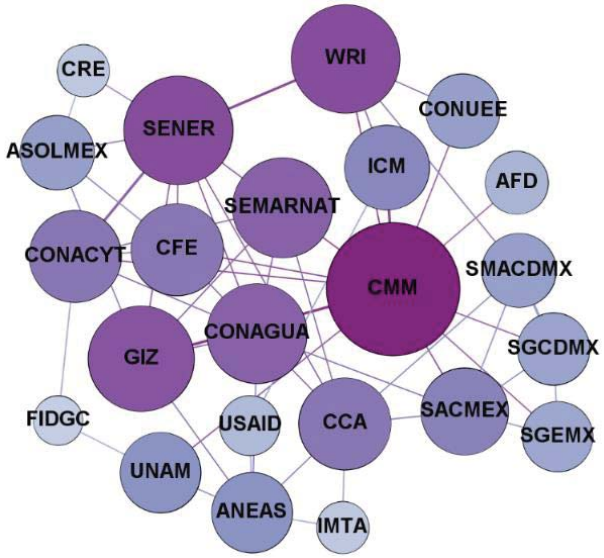

Figure 6. Social network graph representing "closeness centrality" metric. Size and colour scheme of the node represents how close a node is to all the other nodes. So, the darker and bigger node is, the closest the node is.

Additionally, some stakeholders have already explicitly worked with energy-water nexus projects related to hydroelectric power and energetic use of thermal and residual water such as SENER-CONAGUA, SEMARNAT-SENER-GIZ, and SACMEX-CMM. Thus, taking into consideration stakeholders' experience on energy-water nexus projects, interviews, and social networks results, key stakeholders in Mexico City are: Mario Molina Centre (CMM), the World Resource Institute (WRI), the Ministry of Energy (SENER), the National Commission of Water (CONAGUA), National Association of Water and Sanitation Companies of Mexico AC (ANEAS) and the German Cooperation Agency for Sustainable Development (GIZ), National Autonomous University of Mexico (UNAM).

These social network analysis results pave the way for pushing forward an energy-water nexus project by identifying multiple critical stakeholders from business, non-governmental, international and governmental organization working at a national and international level, thus, paving the way for a polycentric governance system in the water and energy sectors. However, as mentioned in the first part of my results, energy and water sector in Mexico are mainly centralized governance systems where decisions are being taken by a federal governmental organization such as SENER or CONAGUA, undermining the participation of lower governmental authorities.

6. Discussion

There are three primary purposes for this section. Firstly, it seeks to highlight the main findings of my research from the polycentric governance assessment and the social network analysis, looking to synthesize the understanding of water and energy governance from this two different but supplementary perspectives (integration of knowledge). Secondly, it seeks to explain how polycentric governance could solve some social barriers when implementing an energy-water nexus approach. Thirdly and lastly, it aims to highlight power relations in polycentric governance systems which was introduced by interviewees in relation with citizen participation mechanisms.

6.1 Integration of knowledge; polycentric governance and social network analysis results.

My overall results from the polycentric governance assessment, conclude that both sectors are monocentric governance systems as the government is the centre of political power and authority (Termeer, Dewulf, & van Lieshout, 2010). However, water sector has some polycentric governance traits which make it less monocentric than the energy sector. These results are backed up through semi-structure interviewed and document analysis that uncovers the existence of multiple stakeholders with human, economic and institutional capacities able to cooperate and coordinate with other institutions an energy-water nexus project. However, even though there are multiple stakeholders engaged in water and energy governance, it does not fulfil polycentric governance definition of multiple, independent, and nested decision-making centres with cooperative and competitive relationship capable of resolving conflicts. First, because even though stakeholders have operational and opinion autonomy, they are not decision-making centres as they give recommendations to public or private entities while the decision-making is done by federal governmental authorities. Second, “nested” which refers to decision centres overlapping across different levels and political jurisdiction, it is not achieved in the energy sector due to the control rules taken at the federal level. Even though water sector’s overlapping is fostered due to the concurrency principle, further research needs to be done to visualize if it is happening in practice, as an interviewee mentioned that cooperation and coordination relations between different levels of government sometimes is difficult. Thirdly and lastly, there is a need to strengthen cooperative and competitive mechanisms between different levels and among a variety of stakeholders to be capable of resolving conflicts.

Regarding social network analysis, my results show that national organizations are taking important roles for managing energy and water resources in Mexico City such as CONAGUA, SENER, CMM, WRI indicated by degree metric. Regarding betweenness centrality measure, stakeholders that have an essential role of bridging nodes in the network are ANEAS, GIZ, SENER, WRI, and CMM. While looking at closeness centrality measure, the organization with the highest value is CMM, although, other stakeholders are closely related to each other, as seen in the closeness centrality graph.

It is interesting to see how results from polycentric governance assessment match with social network results by supporting that national authorities such as CONAGUA, SENER, CMM, WRI are the ones with more ties, and therefore the key stakeholders to implement an energy-water nexus project. Besides CMM and WRI are shown as the ones with the highest values in the three metrics, they do not have the legal capacity to manage an energy-water project as those responsibilities lie in national authorities. Although, CMM and WRI do not have the legal ability to implement the project, according to their betweenness centrality value (Fig. 5) they are an essential bridge between other nodes in the network, as they have collaborated with private and public stakeholders. The reason behind why CMM and WRI have more connections could be due to the significant availability of CMM's and WRI's archival data and will of CMM's project managers to be interviewed. Notice that WRI's project managers were not asked to be interviewed as they are an outcome of archival data analysis for stakeholder's relationships. On the other hand, there were some difficulties to contact governmental stakeholders; therefore, to strengthen this analysis, in-depth semi-structured interviews to government stakeholders needs to be done. However, archival, legislative, political and regulatory data give a vital input to uncover relations between international, national and local stakeholders in the energy and water sector.

Other organizations to highlight are: 1) CCA which has essential ties, and it is closely related to other nodes in the network. This stakeholder is crucial as it is a mechanism for citizen participation, although power asymmetries need to be considered (discussed in section 6.3), 2) ANEAS, which is an organization that represent water companies, is also highlighted as a bridge in the network and it was mentioned by interviewees as a participant of CCA's meetings where power relations came into consideration again. Finally, 3) GIZ is identified by the three metrics which highlights the participation of international organizations in energy and water projects in Mexico — correlating with polycentric governance assessment section 5.1.1 "A. Goals," related to how energy and water sectors strengthen international cooperation.

Finally, it is important to bear in mind that social connections and networks influence stakeholder's behaviour. In the literature there are three possible mechanisms to explain this: 1) By "social pressure" which refers to how the behaviour of a stakeholder A influences the behaviour or attitude of other stakeholders connected to it. 2) By "homophily" which refers to how stakeholders with the same status (being in the energy sector or being in the water sector) come to form social relations with each other and 3) By "environmental cofounding" where environmental factors play a role in determining how networks are formed (Yang et al., 2017). Regarding, polycentric energy-water governance research, this could be used to explain and understand silo-thinking in water and energy nexus through a "homophily" analysis. Or by knowing how "social pressure" works in an energy-water network, it could help to identify stakeholders that have the most influence over other stakeholders, persuading them to implement and support an energy-water nexus project.

6.2 How can polycentric governance help to overcome the institutional barrier in Mexico City Metropolitan Area?

The most highlighted social barrier among metropolitan coordination, cross-sectoral and local authority capacity is institutional which covers a variety of problems: lack of vision and capacities at a federal and most noticeable at a local level, silo-thinking mindset, complexity to coordinate and collaborate between states of MCMA and accountability problems.

6.2.1 Overcoming barriers of local authorities' capacities

According to polycentric governance, public and private stakeholders (including local authorities such as city and municipalities) can provide public goods and services (Ostrom, 2010), for instance, a project to implement solar energy for water management activities. Within the institutional barriers, interviewees stressed that local authorities do not have the capacities to develop this kind of project, and therefore to successfully implement it, the project needs to be managed at a federal level.

Lately, municipalities are increasingly viewed as innovator, laboratories and groundswell actors of environmental sustainability (Homsy & Warner, 2015) that better understand local needs to provide local public goods than higher governmental authorities (Homsy & Warner, 2015). According to polycentric theory, local capacity is needed to enable independent municipal action on sustainability (Homsy & Warner, 2015). Thus, for local authorities to meet people's expectations of solving environmental issues, local authorities need to bring the right resources such as funding and

technical skills (Thompson, 1965). These resources as established by Gargan's typology can break down into three subsets which are: managerial capacity, fiscal capacity, and civic capacity. "Managerial capacity" is defined as local government having the human resource to undertake new policy as well as having the technical capacity to create local policies based on information from advisors and experts in a central government (Gargan, 1981). "Fiscal capacity" is the ability of local authorities to have the financial resources to enact policies, while "civic capacity" is a way that local governments can supplement their ability to implement policy based on citizen expertise (Gargan, 1981). Enabling citizen engagement in problem-solving scenarios will create policy innovation (Homsy & Warner, 2015) that will enhance political legitimacy and lead to local action (Kronsell, 2013), thus increasing sustainability policy adoption (Portney, 2013). It is important to bear in mind that in a polycentric system, these components of capacity are crucial to motivating and enabling action (Homsy & Warner, 2015).

Additionally, as shown in the social network analysis results, local actors are interlinked with state and national levels, revealing that municipalities are not isolated actors, but it is a dynamic network of interactions. Thus, further research needs to be done to strengthen overlapping collaboration (essential in polycentric governance systems) where state and federal government use incentives and regulations to establish broad goals and provide the capacities discussed above. It would be interesting to visualize which incentives, regulation and mechanisms can enable this to happen.

Thus, according to polycentric governance theory and interview results implementation of energy-water project can be done locally by strengthening local government capacities through the following recommendations. First, I recommend increasing energy-water regulations at a federal level (CONAGUA or SENER) that create, support and strengthen the local energy-water regulatory framework. Second, I suggest increasing information flows and enhance collaboration and cooperation mechanisms between national and local government's practitioners to fortify municipalities' human resources for them to be able to implement sustainability policies. Third, increase local authorities' financial capacities that allow them to have banking conditions to finance, trigger and implement innovative sustainable policies and energy-water nexus projects. Lastly fourth, I recommend engaging citizen participation and create trustworthy citizen participation mechanisms through citizen engagement campaigns and creation of local councils where citizens and local authorities work together to identify a problem, develop an innovative strategy, execute and monitor it.

6.2.2 Overcoming silo-thinking, lack of coordination between states of MCMA, and accountability problems.

Complementary to strengthening local capacities, polycentric governance can help to overcome silo-thinking, complexity coordination problems between states or accountability problems by enhancing Aligica and Tarko (2012) polycentric indicators. For instance, having a multiplicity of actors actively exercising and implementing the recommendation (P1) for metropolitan coordination and rule design (C) could overcome institutional barriers of metropolitan coordination between states. This diversity of ideas and opinions could overcome silo-thinking and develop coordination and cooperation mechanisms that could ease collaboration between the three different governments from the Mexico City Metropolitan Area.

Finally, accountability problem highlighted by an interviewee: *"A lot of citizen participation but at the end, someone has to be responsible. If it is everyone's accountability, it is none"* referring to who is responsible for the action, if there are many decision-making centres engaged. This problem can be addressed by relating to polycentric characteristics. Even though there are authors (Blomquist & Schlager, 2005; Lieberman, 2011) saying that citizens found it difficult to blame who is responsible for an action when conjointly projects are implemented. Sovacool (2011) suggests that polycentric governance systems may enhance accountability because it might be more difficult for powerful actors to put forward their interest in multiple levels of governance than to dominate and influence a single level. Similarly, E. Ostrom (2000) observes that polycentric governance systems, with their multiple centres of power at different levels, provide more opportunity for citizens and officials to correct power asymmetries. Although strategies to delegate responsibilities need to be further research.

6.3 Power relations in a polycentric governance system.

An essential trait of polycentric governance systems is co-production which is understood as the idea that citizens are a crucial part of the process of providing public goods (Villamayor-Tomas, 2018). Interview results regarding polycentricity governance assessment of the water and energy sector in Mexico, conclude that citizen participation is not enhanced in the energy sector due to its centralized federal governance. Even though the water sector's decisions are also made at a national

level; the water sector is subject to the concurrency principle stated by Mexican law which fosters its management at different scales. Thus, promoting citizen participation at different levels through participatory social mechanisms such as the Basin Councils or the Water Advisory Council where power asymmetries can be studied. An interviewee from a non-governmental organization highlighted these power relations within the Basin Council:

> *"…I think they (Basin Councils) are important, I think a lot of actors are uncovered although they are not all the actors and sometimes the political weight or the interests, let's say, make decision making between different alternatives for solving the problem, a little easier to be more attached to a specific diagnosis or a cost-benefit analysis"*

Meanwhile, another interviewee from academia highlighted power relations in participatory social mechanisms such as the Water Advisory Council:

> *"Well, the Water Advisory Council. I am a little distrustful when one begins to see who support certain actors. At this moment the Water Advisory Council is sponsoring a project called "Social Pact for Water "which is a project financed by the World Bank… Then, we must thoroughly understand who is behind the Water Advisory Council, what are its objectives.*
>
> *Moreover, there is another organization called "Water for All," this organization has been working for a new National Water Law which has not passed due to very high interest around this resource. The Water Advisory Council under the framework of "Social Pact for Water" has arranged many meetings, but you realize how the process is very directed and elitist because you do not see the actors who really suffer from water-related problems. You do not see the actors who really need a guide to solve these problems, and you do not even see people from "Water for All." One can notice that they are selecting certain actors to meet, and I think it is a kind of strategy, even using universities and certain actors to legitimize processes; "here is the list, they signed this, and everybody agrees for the Social Pact for Water." But in there, it doesn't say what those actors say or arguments saying why "Water for all" and water users do not participate? There are just some sectors participating, and that is what I think is very skewed."*

Looking back at polycentric governance definition, Ostrom (2010) highlights the importance of multiple, nested and independent decision-making centres for natural resource management for providing public goods. Moreover, Aligica and Tarko (2012) through its concept of co-production, add another essential decision centre which is citizens. However, when looking at a variety of multiple polycentric governance definitions (Schröder, 2018), power relations are often dismissed or barely mentioned.

Power relations in multi-stakeholder forums or networks can be vulnerable, and when these governance systems are captured by powerful actors, it can be dominated by hegemony ideas and interests that influence the dialogue and creative problem solving (Adger, Brown K., & Tompkins E. L., 2005). Moreover, the presence of power asymmetries in cross-scale linkages can drive to powerful actors to further their interests and dominate the system in a way that there are skews of knowledge and information in their favour. A problem illustrated with Water Advisory Council's project of "Social pact for Water" in Mexico City mentioned above by the interviewee from academia. Thus, more empirical research is needed to have the benefits of cross-scale linkages while undermining power asymmetries. For instance, researchers are identifying strategies for preventing or mitigating power asymmetries on cross-scale ties such as ensuring that actors have resources to enable their participation (Adger et al., 2005). Additionally, according to Carlisle and Gruby (2017), the research on power relations in polycentric governance systems goes in the direction of how coordination mechanisms may be reproduced and amplify power asymmetries and how this can be managed.

Differences in power and values among stakeholders sharing a resource can develop conflict. However, as long as, the dispute does not escalate where the governance system does not function properly, it can bring learning and exchange of interests, ideas, and perspectives that can contribute to developing deliberation processes and conflict resolution mechanisms (Dietz, Ostrom, & Stern, 2003). Therefore, cooperation, competitive and conflict resolution mechanisms are essential in polycentric governance system for the proper functionality of the system, which could diminish power asymmetries while undermining possibilities for conflicts to intensify.

7. Future research

Because of the study design and scope of this research, it was not possible to go further into other aspects of polycentricity governance systems in Mexico's water and energy sector. Since the polycentric governance framework and social network methodology used in this thesis, look at different degrees of policentricity and relational ties between energy and water sector, respectively. Therefore, they do not have the scope to uncover power relations among stakeholders or visualize which cooperation, competitive and conflict resolution mechanisms are in place.

Based on interviewees' statements regarding power relation (see section 6.3), it would be interesting to use social network analysis to map out more deeply, not only energy and water linkages between stakeholders but also map out who has interests in and power over and influence on the energy and water systems. In this regard, it would be interesting to compare between states of Mexico City Metropolitan Area which local stakeholders are the most influential in proposing an energy-water nexus project that could influence CONAGUA or SENER not only to support this project but to push forward regulation reforms, so energy and water sector could be better integrated in practice. As interviewees stated: *"decisions are made on higher government levels. However, local authorities have the capacity to propose an energy-water project."*

To finish, according to my research there are collaboration and coordination difficulties between different government levels (see section 5.1.1) that drives ministries to propose their own goals and actions even though they are part of cross-sectoral organs (see section 5.2.2). Additionally, there is a need to strengthen overlapping collaboration between state and municipal level (see section 6.2.1) and there is the need to overcome power asymmetries in citizen participatory mechanisms. Thus, further research efforts need to address which cooperative, competitive and conflict resolution mechanisms are in place and how they can be improved. In this regard, it would be interesting to see how polycentric governance literature can support the development of better mechanisms for sector integration, local participation, conflict resolution mechanisms and homogeneous distribution of power.

8. Conclusion

The urban nexus approach focuses on material flows; however, they have an issue of providing relevant information for policy and decision making. Therefore, social flows are needed to supplement that analysis. A type of social flow is governance systems which it is stated in urban nexus literature as being a window of opportunity for better implementation of urban nexus framework.

In conclusion, energy (electricity) and water sectors in Mexico are centralized governance systems where control rules lie mainly with national authorities. However, the water sector as being subject to the concurrency principle, its control rules goes down to lower levels of government such as state and municipality level. Thus, the water sector has some polycentric traits, not necessarily linked with the energy sectors, such as local-self-governance mechanisms (citizen organisations for demanding solution for water-related issues) and co-production (CCA, at a national level) which makes it more polycentric than the energy sector.

Regarding the second part of my research, different barriers for implementing an energy-water nexus project in MCMA were identified such as economic, political, institutional and legal barriers that can be addressed by key stakeholders identified by social network analysis. These barriers play a role in how energy and water resources are managed in MCMA by setting adverse conditions for local authorities to manage this kind of problem and favouriting national authorities to take the lead.

In conclusion, the polycentric governance framework has demonstrated to be useful to propose relevant actions that can counteract these barriers, especially the ones related to institutional barriers. Thus, energy-water nexus projects can be implemented at a local level by strengthening local government capacities (managerial, fiscal and civic capacity). In doing so, the following recommendations are: First, I recommend to increasing energy-water regulations at a federal level (CONAGUA or SENER) that create, support and strengthen local energy-water regulatory framework. Second, I suggest increasing information flows, and enhanced collaboration and cooperation mechanisms between national and local government's practitioners to fortify municipalities' human resources for them to be able to implement sustainability policies. Third, I suggest to increase local authorities' financial capacities that allowed them to have banking conditions to finance, trigger and implement innovative sustainable policies and energy-water nexus

projects, and fourth recommend engaging citizen participation and creating trustworthy citizen participation mechanisms through citizen engagement campaigns and creation of local councils where citizens and local authorities work together to identify a problem, develop an innovative strategy to solve it, execute and monitor it.

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10. Appendices

Appendix 1. Questioner for the semi-structured interview, blue questions are key questions.

Opening questions

1. What is your name and role in the organisation?
   ¿Cuál es su nombre?

2. In which sector of society do you think you form part of, for instance, civil society, government, business or academia?
   ¿En qué sector de la sociedad considera forma parte de, por ejemplo, de la sociedad civil, gubernamental, empresarial o de la academia?

3. Are there examples of this kind of projects in Mexico City or surroundings?
   ¿Existen ejemplos para este tipo de proyectos en la Ciudad de México o alrededores?

Questions related to polycentric governance

Multiplicity of decision centres

4. *Active exercise of diverse opinions:* a) Does your organization have legal, financial and institutional capacity to cooperate and coordinate a project of this type with other institutions? b) what would be those organizations with which you could cooperate and coordinate?
   Ejercicio activo de diversas opiniones: a) ¿Su departamento/organización/secretaria tiene la capacidad legal, financiera e institucional, para cooperar y coordinar con otras instituciones un proyecto de este tipo? b) ¿Cuáles serían esos departamentos, organizaciones o secretarias con las que podría cooperar y coordinarse?

5. *Autonomous decision-making layers:* a) Would your organization have the autonomy (independence) to be able to make decisions in this type of project? b) is decision-making by local authorities complemented (and not diminished) by authorities at higher levels?
   Toma de decisión autónoma: a) ¿Su departamento/organización/secretaria tendría la autonomía (independencia) para poder tomar decisiones en este tipo de proyecto? b) ¿La toma de decisiones de autoridades locales es complementada (y no disminuida) por autoridades de niveles más altos?
6. *Goals and objectives:* ¿a) Do the water and energy (electricity) sectors have common or individual objectives?
   Metas y objetivos: a) ¿Los sectores agua y energía(electricidad) tienen objetivos comunes o individuales?

Institutional and cultural framework (overarching set of rules that coordinates interactions between the authorities)

7. *Alignment between rules and incentives (design of rules):* Are there rules (coordination, cooperation, competition and conflict resolution) and incentives to start a project like this?

If yes: a) Can your institution participate in the formulation of the rules or the formulation of these rules are made by external actors? ¿b) Are they useful and the consequences of the rules transparent?
Alineamiento entre reglas e incentivos (Diseño de reglas): ¿Existen reglas (coordinación, cooperación, competencia y resolución de conflictos) e incentivos para poder iniciar un proyecto como este? En caso afirmativo: a) ¿Su institución puede participar en la formulación de las reglas o la formulación de dichas reglas es hecha por actores externos? b) ¿Son útiles y las consecuencias de las reglas son transparentes?

8. *Jurisdiction (territorial and non-territorial):* Is your jurisdiction territorial or non-territorial (overlapping)?
   Jurisdicción (territorial y no territorial): ¿Su jurisdicción es territorial o no territorial (superponen)[8]?

9. *Collective choice:* Do you think that collective choice can be made by consensus, individual decisions or majority rule?
   Elección colectiva: ¿Usted piensa que las decisiones hechas entre múltiples actores son tomadas por consenso, individuales o por mayoría en este tipo de proyecto?

10. What are the barriers and opportunities for cross-sectoral cooperation and coordination and with other academic, governmental, civil society or business stakeholders in this kind of project?
    ¿Cuáles son las barreras y oportunidades para la cooperación y coordinación intersectorial y con otras organizaciones del campo académico, gubernamental, sociedad civil o empresarial en este tipo de proyecto?

Spontaneous order generated by evolutionary competition

11. *Entry:* Organisations can freely entry to the development of the project or would it be spontaneous or merit-based?
    Entrada: ¿Nuevos centros de decisión podrían decidir ingresar libremente (otros centros de decisiones no pueden intervenir), espontáneamente (no hay decisión) o es seleccionado de acuerdo con sus méritos)?

12. *Exist:* Can a department/organisation can freely exit from the project or is constrained?
    Salida: ¿Puede un centro de decisión salir libremente del proyecto o está restringido?
13. *Information:* Is the information important for decision-making public (for all decision-making centers) or is it private?
    Información: ¿La información importante para toma de decisiones es pública (para todos los centros de decisión) o es privada?

Local self-governance

[8] Jurisdicción que puede ser ejercida simultáneamente por otras instituciones sobre el mismo tema y dentro del mismo territorio [Jurisdiction that can be exercised simultaneously by other institutions on the same subject and within the same territory] .

14. Are there cooperative organizations or local governments related with water and energy (electricity) sectors?
    ¿Existen cooperativas, comunidades indígenas o gobiernos locales relacionados con los sectores de agua y energía (electricidad)?

Coproduction

15. Is there a possibility of including citizens in this Project? For example, in the water sector is the Water Advisory Board where you can go to propose projects, for the case of the electricity sector can this be done? For example, energy cooperative that can invest or be suppliers of photovoltaic systems.
    ¿Existe la posibilidad de incluir a la ciudadanía en este proyecto? Por ejemplo, ¿en el sector agua está el Consejo Consultivo del Agua en donde se pueden ir a proponer proyectos, para el caso del sector eléctrico esto se puede hacer? Por ejemplo, cooperativas energéticas que puedan invertir o ser proveedores de sistemas fotovoltaicos.

Closing questions

16. Is there something I have forgotten to ask, or do you think I would need to understand?
    ¿Hay algo que haya olvidado preguntar o piensa que yo necesitaría entender?
17. Do you have any questions?
    ¿Tiene usted alguna pregunta?

Appendix 2. Node table used in social network analysis

Id	Label	Stakeholder	Stakeholders (English)	Organization type	Scale	Sector
1	GIZ	Cooperación Alemana al Desarrollo Sostenible	German Cooperation for Sustainable Development	International Organization	International	Water and Electricity
2	AFD	Agencia Francesa de Desarrollo	French Development Agency	International Organization	International	Water and Electricity
3	WRI	Instituto Global de Recursos	World Resource Institute	International Organization	International	Electricity
4	FIDGC	Fundación Internacional para el Desarrollo de Gobiernos Confiables	International Foundation for the Development of Reliable Governments	NGO	International	Metropolitan coordination
5	SACMEX	Sistemas de Aguas de la Ciudad de México	Water Systems of the City of Mexico	Government	Local	Water
6	SMACDMX	Secretaria de Medio Ambiente de la Ciudad de México	Ministry of Environment of the City of Mexico	Government	Local	Water and Electricity
7	SGCDMX	Secretaria de Gobierno de la Ciudad de México	Ministry of Government of the City of Mexico	Government	Local	Metropolitan coordination
8	SGEMX	Secretaria de Gobierno del Estado de México	Ministry of Government of the State of Mexico	Government	Local	Metropolitan coordination
9	CONAGUA	Comisión Nacional del Agua	National Water Commission	Government	National	Water
10	SEMARNAT	Secretaria de Medio Ambiente y Recursos Naturales	Ministry of the Environment and Natural Resources	Government	National	Water and Electricity
11	SENER	Secretaria de Energía	Ministry of Energy	Government	National	Electricity
12	ASOLMEX	Asociación Mexicana de Energía Solar	Mexican Association of Solar Energy	Company	National	Electricity
13	ANEAS	Asociación Nacional de Empresas de Agua y Saneamiento de México AC	National Association of Water and Sanitation Companies of Mexico AC	Company	National	Water
14	ICM	Iniciativa Climática de México	Climate Initiative of Mexico	NGO	National	Electricity
15	CMM	Centro Mario Molina	Mario Molina Center	NGO	National	Water and Electricity
16	CCA	Consejo Consultivo del Agua	Water Advisory Council	NGO	National	Water
17	CONACYT	Consejo Nacional de Ciencia y Tecnología	National Council for Science and Technology	Government	National	Science, technology and innovation
18	SEDATU	Secretaria de Desarrollo Agrario, Territorial y Urbano	Ministry of Agrarian, Territorial and Urban Development	Government	National	Water and Electricity
19	UNAM	Universidad Nacional Autónoma de México	National Autonomous University of Mexico	Academia	National/Local	Water and Electricity
20	INECC	Instituto Nacional de Ecología y Cambio Climático	National Institute of Ecology and Climate Change	Government	National	Water and Electricity
21	SEDUVI	Secretaria de Desarrollo Urbano y Vivienda de la CDMX	Ministry of Urban Development and Housing of Mexico City	Government	Local	Others
22	SRED	Secretaria de Relaciones Exteriores de Dinamarca	Ministry of Foreign Affairs of Denmark	Government	International	Others
23	SREPB	Secretaria de Relaciones Exteriores de Países Bajos	Ministry of Foreign Affairs of Netherlands	Government	International	Others
24	SE	Secretaria de Economía	Ministry of Economy	Government	National	Others
25	USAID	Agencia Internacional de Desarrollo de EUA	United States Agency for International Development	International Organization	International	Water and Electricity
26	WATERGYMX	Watergy Mexico	Watergy Mexico	Company	International	Water and Electricity
27	SIDA	Agencia Internacional de Cooperación y Desarrollo Sueca	Swedish International Development Cooperation Agency	International Organization	International	Others
28	CFE	Comisión Federal de Electricidad	Federal Electricity Commission	Government	National	Electricity
29	CONUEE	Comisión Nacional para el Uso Eficiente de la Energía	National Commission for the efficient use of energy	Government	National	Electricity
30	IMTA	Instituto Mexicano de Tecnología del Agua	Mexican Institute of Water Technology	Government	National	Water
31	CRE	Comisión Reguladora de Energía	Energy Regulatory Commission	Government	National	Electricity

Appendix 3. Edges table used on social network analysis.

Source	Target	Type
2	20	Undirected
15	10	Undirected
15	1	Undirected
15	2	Undirected
15	5	Undirected
15	29	Undirected
15	7	Undirected
15	8	Undirected
15	14	Undirected
15	3	Undirected
15	28	Undirected
15	19	Undirected
15	17	Undirected
17	11	Undirected
17	10	Undirected
4	19	Undirected
4	17	Undirected
1	11	Undirected
1	10	Undirected
1	18	Undirected
1	9	Undirected
5	9	Undirected
5	8	Undirected
10	9	Undirected
11	31	Undirected
11	10	Undirected
11	28	Undirected
11	9	Undirected
17	28	Undirected
17	9	Undirected
9	28	Undirected
12	24	Undirected
12	28	Undirected
12	31	Undirected
12	1	Undirected
12	11	Undirected
13	25	Undirected
13	9	Undirected
13	26	Undirected
13	1	Undirected
13	19	Undirected
13	30	Undirected

Source	Target	Type
16	13	Undirected
16	9	Undirected
16	10	Undirected
16	11	Undirected
16	6	Undirected
16	5	Undirected
16	30	Undirected
7	8	Undirected
7	6	Undirected
7	5	Undirected
6	5	Undirected
3	11	Undirected
3	29	Undirected
3	6	Undirected
3	14	Undirected
3	27	Undirected
3	22	Undirected
3	23	Undirected
3	21	Undirected
14	25	Undirected

Appendix 4 a) Stakeholders divided by organization type **b)** Stakeholders divided by scale **c)** Stakeholders divided by sector.