Mapping the Innovation Ecosystems for the Deployment of Small Modular Reactors in Canada and Mexico: An Innovation Policy Approach Through Strategic Niche Management and Social Network Analysis.

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Disclaimer Statement

Abstract

Small Modular Reactors (SMRs) have received considerable attention as their specific designs reduce implementation times and costs, allowing modularity to increase the installed capacity for energy generation. Although SMRs represent a reliable, affordable, and sustainable alternative to meet our growing energy demands, this technology faces deployment obstacles that may require outside interventions to speed up their adoption so that people can enjoy their societal, environmental and economic benefits. Just as a country´s best energy mix approach varies by resource availability and institutional capabilities, the actors promoting SMR adoption constitute an innovation ecosystem uniquely responsive to country-specific characteristics. This thesis uses a Strategic Niche Management (SNM) framework that proposes interventions in protected spaces to determine the optimal conditions for successful deployment and appropriate policy while consolidating a community of early adopters.

Through Social Network Analysis (SNA), this thesis compares how these SMR innovation ecosystems are formed in Canada and Mexico, highlighting structural differences between developed and developing countries. This primary framework and research method are then complemented with the Helix Model IV for a comprehensive review of the governance of SMR innovation ecosystems. Policy and network structures are assumed to have a feedback loop effect on each other and SMR deployment potential. Secondary data were collected from publicly available information and processed under the software Gephi 9.5.

Contrary to most research, which focuses solely on centralized actors in a network, this thesis explores the contributions of both centralized and peripheral actors to the network, so policymakers can discern where to efficiently allocate resources depending on their intervention objectives and their main focus. Results indicate that the Mexican SMR ecosystem, with its visually different network structure in all the snapshots, is more vulnerable than the Canadian ecosystem. This difference is especially apparent in the scene where five of the most centralized actors are removed from the two SMR ecosystems.

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More than an academic achievement, the time in this program has been one of immense personal growth that would not have been possible without each of the circumstances that brought me to write these thanks today. I write this flooded with gratitude and wholeheartedness, seeing that, looking back, every obstacle has contributed to being who I am and has been worth everything. Although I have an army of people who have supported and accompanied me in this process, the first recognition is to myself for all the internal and uncomfortable work of returning to myself, reorganizing priorities, and learning and unlearning in equal opportunities measure. Thank you for regaining balance and allowing us to redirect ourselves towards a healthy and harmonious life. Infinite thanks to my psychoanalyst Raúl Gallardo for accompanying me with patience, empathy and compassion in each of the stages of this adventure and for listening to me with the same song over and over again until it dismantled into bearable pieces. Thank you for helping me see things differently and arrive at life-changing conclusions on my own and for my well-being.

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Dedication

For you, grandpa Lupe; Your love remains.

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List of Abbreviations

A6N	Aecon Six Nations
AB	Government of Alberta
ACE	Atlantica Centre for Energy
ACEA	Atlantic Clean Energy Alliance
ACNO	Allied Canada Nuclear Operations
ACOA	Atlantic Canada Opportunities Agency
AECL	Atomic Energy of Canada Limited
AECOM	AECOM
AECON	AECON
AEIF	Asociación Estudiantil de Ingeniería Física
AIM	Academia de Ingeniería de Mexico
AJENM	Asociación de Jóvenes por la Energía Nuclear en México
ARCAL	Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean
BAU	Business-As-Usual Baseline
BDC	Business Development Bank of Canada
BNFL	British Nuclear Fuels Limited
BP	Bruce Power
BWR	Boiling Water Reactor
BWXT	BWXT Canada Ltd
B2B	Business to Business
B2C	Business to Costumer
B2G	Business to Government
B2G2C	Business to Government to Costumer
C3E	Clean Energy, Education and Empowerment Initiative (C3E)
CALIAN	CALIAN

CAMECO	CAMECO
CANHC	Canadian Association of Nuclear Host Communities
CBTU	Canada´s Building Trades Union
CC	Compute Canada Government Agency
CCAB	Canadian Council for Aboriginal Business
CCC	Canadian Commercial Corporation
CCHEN	Comisión Chilena de Energía Nuclear
CCNS	Centre for Canadian Nuclear Sustainability
CCRE	Council for Clean & Reliable Energy
CEA	Canadian Electricity Association
CECA	Canadian Electrical Contractors Association
CEM	Clean Energy Ministerial
CF	Creative Fire Agency
CFE	Comisión Federal de Electricidad
CFI	Canada Foundation for Innovation
CHFCA	Canadian Hydrogen and Fuel Cell Association
CIB	Canadian Infrastructure Bank
CIRNAC	Crown-Indigenous Relations and Northern Affairs Canada
CJM	Ciencia Juvenil Mexicana
CME	Canadian Manufacturers & Exporters
CNA	Canadian Nuclear Association
CNEA	Canadian National Energy Alliance
CNEN	Comissao Nacional de Energia Nuclear
CNER	Centre for Nuclear Energy Research
CNIC	Canadian Nuclear Isotope Council
CNL	Canadian Nuclear Laboratories

CNLV	Central Nucleoeléctrica Laguna Verde
CNRI	Canadian Nuclear Research Initiative
CNS	Canadian Nuclear Society
CNSC	Canadian Nuclear Safety Commission
CNSNS	Comisión Nacional de Seguridad Nuclear y Salvaguardias
CNWC	Canadian Nuclear Workers Council
CO2	Carbon Dioxide
COG	CANDU Owners Group
CONACYT	Consejo Nacional de Ciencia y Tecnología
COSIA	Canada's Oil Sands Innovation Alliance
CPAJV	Chipewyan Prairie-Aecon Joint Venture
CPUS	Canadian Power Utility Services Ltd
CRDA	Canada's Regional Development Agencies
CRISAMEX	Control de Radiaciones e Ingenieria
CSA	Canadian Standards Association Group
CSA	Canadian Space Agency
CSIP	Centre for the Study of Science and Innovation Policy
CSO	Civil Society Organization
CSMR	Centre for Small Modular Reactors/ Energy Systems and Nuclear Science Research Centre
DND	Department of National Defence
DNRED	Department of Natural Resources and Energy Development
DOE	US DOE Laboratories
DR	Durham Region
EAJV	Enoch-Aecon Joint Venture
ECC	Energy Council of Canada
ECCC	Environment and Climate Change Canada

EDC	Export Development Canada
EDGSJ	Economic Development Greater Saint John
EFRN	English River First Nation
EHRC	Electricity Human Resources Canada
EM	Energy minute Education Foundation
ENEA	National Agency for New Technologies, Energy and Sustainable Economic Development
ENSA	Equipos Nucleares ENSA
EPRI	Electric Power Research Institute
EPSCA	Electrical Power System Construction Association
ES Fox	Fox Construction Nuclear Services
Euratom	European Atomic Energy Community
FNPA	First Nations Power Authority
FRACL	Federación de Radio protección de América Latina y el Caribe
GAC	Global Affairs Canada
GAC	Golder Associates Ltd.
GC	Government of Canada
GHG	Greenhouse Emmissions
GIF	Generation IV International Forum
Georgia Tech	Georgia Institute of Technology
GNF	Global Nuclear Fuel
G2C	Government to Costumer
HC	Health Canada
HEI	Higher Education Institution
HSM	Historic Saugeen Métis
IAEA	International Atomic Energy Agency
IBEW	International Brotherhood of Electrical Workers FIOE

IBEW Canada	International Brotherhood of Electrical Workers
ICA	Ingenieros Civiles Asociados
IDOM	IDOM Consulting, Engineering, Architecture SAU
IE	Innovation Ecosystem
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFNEC	International Framework for Nuclear Energy Cooperation
IGGE	Institute of Global Energy Education
IIE	Instituto de Investigaciones Eléctricas
INEEL	Instituto Nacional de Electricidad y Energías Limpias
ININ	Instituto Nacional de Investigaciones Nucleares
INIS	International Nuclear Information System
IPM	Integrated Project Management Inc
IRG	Innovative Research Group
IRPA	International Radiation Protection Association
ISED	Innovation, Science and Economic Development Canada
ISO	International Organization for Standardization
ITER	International Thermonuclear Experimental Reactor
ITESM	Instituto Tecnológico de Estudios Superiores de Monterrey
ITT	Instituto Técnico de Toluca
IUOE	International Union of Operating Engineers
JELF	John R. Evans Leaders Fund
JSGS	Jhonson Shoyama School of Public Policy
LEI	Lithuanian Energy Institute
LINX	Laboratorio de Instrumentación Espacial
LIUNA	Labourers' International Union of North America

LLRWMO	Low-Level Radioactive Waste Management Office
LTN	Let´s Talk Nuclear
MAC	McMaster University
MA Canada	The Mining Association of Canada
MCAC	Mechanical Contractors Association of Canada
MELCO	Mitsubishi Electric Co.
MIRARCO	Mining Innovation Rehabilitation and Applied Research Corporation
MIP	McMaster Innovation Park
MMRI	McMaster Manufacturing Research Institute
MS	Mad Science
MSE	Computational Materials Engineering Laboratory
MTLLP	McCarthy Tétrault LLP
MVP	Minimum Viable Product
MWe	Megawatt Electrical
MZC	MZ Consulting Inc
NAABA	Northeastern Alberta Aboriginal Business Association
NAH	North American Helium
NAOC	NATO Association of Canada
NAYGN	North American Young Generation in Nuclear
NB	Government of New Brunswick
NBP	Énergie NB Power
NEAC	Nuclear Energy Advisory Council
NETCO	National Electrical Trade Council
NewDip	New Diplomacy of Natural Resources
NIAC	Nuclear Insurance Association of Canada
NII	Nuclear Innovation Institute

NRC	Natural Resources Canada
NRCC	National Research Council Canada
NSERC	Natural Sciences and Engineering Research Council of Canada
NSMDC	North Shore Micmac Distric Council
NWMO	Nuclear Waste Management Organization
OCE	OCE
OCNI	Organization of Canadian Nuclear Industries
OECD NEA	OECD Nuclear Energy Agency
OIEA	Organismo Internacional de Energía Atómica (IAEA)
OIT	Ontario Institute of Technology
OMA	Ontario Mining Association
ON	Government of Ontario
ONB	Opportunities New Brunswick
OPG	Ontario Power Generation
OPS	Organización Panamericana de la Salud
ORF	Ontario Research Fund
ORLN	Oak Ridge National Laboratory
OSPE	Ontario Society of Professional Engineers
OSU	Ohio State University
PDAC	Prospectors & Developers Association of Canada
PDAC	Prospectors' and Developers' Association of Canada
PE	Government of Prince Edward Island
PHAI	The Port Hope Area Initiative
PHWR	Pressuriez Heavy Water Reactor
PMI	Project Management Institute
POLITO	Polytechnic University of Turin

PPP	Public Private Partnerships
PWR	Pressurized Water Reactor
PWU	Power Worker´s Union
QEC	Qulliq Energy Corporation
QP	Querencia Partners
QU	Queen´s University
R&D	Research and Development
RCIS	Rander Canadian Innovative Solutions Inc
RMTL	Reactor Materials Testing Laboratory
RUHF	Royal University Hospital Foundation
Sask TED	Sask. Trade and Export Development
SCA	Saskatchewan Cancer Agency
SCCS	Saskatchewan Centre for Cyclotron Sciences
SENER	Secretaría de Energía
SFCCNI	Sylvia Fedoruk Canadian Center for Nuclear Innovation
SHR	Saskatoon Health Region
SIECA	Saskatchewan Industrial Energy Consumer Association
SIMSA	Saskatchewan Industrial Manufacturing Suppliers Association
SJCCCA	Saint John Citizens Coalition for Clear Air
SK	Government of Saskatchewan
SMA	Saskatchewan Mining Association
SMR	Small Modular Reactor
SMSR	Sociedad Mexicana de Seguridad Radiológica A.C.
SNA	Social Network Analysis
SNM	Strategic Niche Management
SNM AC	Sociedad Nuclear Mexicana AC

SNC-LAVALIN	SNC-LAVALIN
SNO	Sudbury Neutrino Observatory
SON	Saugeen Ojibway Nation
SP	SaskPower
SRC	Saskatchewan Research Council
SUNCOR	SUNCOR Energy
TBRHRI	Thunder Bay Regional Research Institute
TCA	Toronto Construction Association
TCS	Trade Commissioner Service
TRL	Technology Readiness Level
TIT	Tokyo Institute of Technology
TJ	Terajoules
TTO	Technology Transition Office
TWh	Terawatt per hour
UAEM	Universidad Autónoma del Estado de México
UAMIZT	Universidad Autónoma Metropolitana de Iztapalapa
UANL	Universidad Autónoma de Nuevo León
UC Berkeley	University of California Berkeley
U of T	University of Toronto
UAMPS	Utah Associated Municipal Power Systems
UM	University of Manitoba
UNAC	United Nations Association in Canada
UNAM	Universidad Nacional Autónoma de México
UNB	University of New Brunswick
UNENE	University Network of Excellence in Nuclear Engineering
UNIPI	University of Pisa

UNIZIG	University of Zagreb
UNSM	Universidad Nacional de San Martin
UofG	University of Guelph
UofR	University of Regina
UOIT	Ontario Tech University
URAMEX	Uranio Mexicano
USask	University of Saskatchewan
USNC	USNC Ultra Safe Nuclear
UTIAS	Fusion Materials Laboratory
UTK	University of Tennessee
WANO	World Association of Nuclear Operators
WIN Canada	Women in Nuclear Canada
WIN Mexico	Women in Nuclear Mexico
WNA	World Nuclear Association
YGN	UK Young Generation Networks
YT	Government of Yukon

Chapter 1. Problem Statement

1.1 Introduction

Small Modular Reactors (SMRs) have received considerable attention, as their specific designs reduce implementation times and costs while allowing modularity to increase the installed capacity for energy generation. Although SMRs represent a reliable, affordable, and sustainable alternative to meet our growing energy demands, this technology faces deployment obstacles that may require outside interventions to speed up their adoption. These obstacles range from nuclear regulation to barriers to entry in a market dominated by more polluting energy generation sources that answer to an economic rationale instead of sustainability and energy efficiency criteria.

Despite these deployment problems, little research has investigated their cause. Policy analysis has prioritized safety, regulation, and public perception of SMRs, but a market failure approach has remained on the margins. We still lack a comprehensive understanding of what supporting policies might be required to leverage SMR deployment. Although resources have been invested in designing viable small reactors, deployment scenarios remain pessimistic as occasional piloting is far more often the current approach towards nuclear technology rather than strategic deployment on a wider scale. Policymakers have failed to address the entire innovation cycle for nuclear energy technology from a policy delivery perspective. Focusing on policy delivery could ensure support, funding, and progress monitoring at all stages of the innovation process, from idea to decommissioning the reactors from the market at the end of its life cycle. It is essential to mention that a technology´s delay or decay due to unsuccessful commercialization in this stage of the innovation process is lamentable, as all kinds of efforts were invested in the research and development (R&D) stages, which one could assume was the hard part. Moreover, one of the main challenges of this specific technology is how the industry is a complex system in which a series of heterogeneous institutions are responsible for deciding the energy generation sources and not individuals with their decision-making. SMR deployment then challenges the current innovation theories and their sole applications to simpler business models or more straightforward industries.

In addition, the institutions promoting SMR technologies face a global phenomenon known as the valley of death, referring to the high failure rate of new technology prior to commercialization when facing entrenched incumbents. Even more prone to failure are the industry institutions that require a larger investment and carry great risk and uncertainty, which is the case of nuclear technologies such as SMRs. This valley of death phenomenon suggests that those who survived it are not representative of the entirety of research and development investments. Many promising technologies did not make it and have vanished along with their respective investment in all kinds of resources.

Although limited, what we have learned from the existence of technologies that have survived the valley of death, is the need for supportive institutions behind them that have learned the best practices for survival. These institutions are considered actors who exchange knowledge and value through formal or informal collaborations that underpin an innovation ecosystem (IE) [1] for SMR deployment. These actors also prepare the ground for agenda-setting and expansion from a managerial perspective and in return, this managerial approach would involve understanding the institution's challenges and providing tailored policies accordingly.

Although from a public policy perspective, innovation ecosystems are often analyzed through social network analysis [2]–[4], little effort has been devoted to understanding the deployment of Small Modular Reactors, highlighting a lack of understanding of the actors in a complex systemic dynamic such as the energy sector. The challenges of promoting a technology without fully understanding what is preventing its deployment arise when limited information is available to policymakers, who rely on comparative policy to leverage or block a specific technology. Therefore, mapping industry and institutional actors and their collaboration structures will deepen understanding and identify strategic market niches where SMRs can be incubated.

Innovation ecosystems vary significantly from one country to another, where past policy and cultural dynamics also influence the SMR ecosystem and limit their replicability from developed to developing countries. Thus, this research identifies the actors driving SMR adoption or deployment through a comparative analysis of the SMR ecosystem in a developed country, Canada, and a developing country, Mexico. Comparing two SMR ecosystems will show that policies must be tailored to a country's needs and institutional capacities and that these policies influence governance, as in agenda-setting or resource allocation. Likewise, the contrast between developed and developing countries identifies additional systemic challenges developing countries face in deploying SMR technologies. This research describes some of the main challenges for SMR deployment from an innovation policy perspective and provides a baseline for non-experts interested in understanding the obstacles facing SMRs.

1.2 Problem Definition

Governing a technology transition represents a challenge, especially in complex systems such as the energy sector, where numerous actors are involved, their interactions are complex, and the transition needs to be approached from a systemic perspective. Rather than being driven by environmental priorities, energy transitions have historically responded to economic rationale, and they require adaptive policies to ensure effective deployment [5], [6]. Also, approaches are different for each technology, buyer-seller relationship, the actors' governance, and country-specific drivers and blockers. In this complex environment, policy makers lack of understanding of specific technologies' innovation processes limits the impact that policy might have on leveraging SMR deployment.

In addition, energy transitions are slow. The historical shifts from carbon to petroleum to natural gas have each taken more than 50 years to reach between 10-20% of the market share, and renewables have not even reached such a pace yet [6]We do not have 50 years as the world is about to start suffering the irreversible consequences of inaction on the climate crisis despite constant warnings from the scientific community [7], [8] and the existence of exponentially cleaner technologies such as SMRs.

Furthermore, current world events, such as the Russian invasion of Ukraine, have focused on the importance of energy security, achieved if a given country can generate the electricity it consumes from a diverse energy mix that aligns with its capabilities and energy consumption needs. When a country heavily depends on energy from foreign sources, it is vulnerable to supply blockages due to war, trade bans, an adverse climate, or a lack of political will. For instance, Mexico’s vulnerability and codependence were exposed in the “Big Freeze”[9] in Houston in early 2021, when Mexico suffered severe blackouts in all its states, and most economic activities were paralyzed when their supplier could not provide natural gas. These blackouts show that energy is essential and crucial for economic development.

1.3 Conceptual Model

The premise with which my research starts recognizes uncertainty and ignorance on how innovation ecosystems are consolidated and the policy implications of their structural formation for the deployment of small modular reactors in Canada and Mexico. Historical policy and contextual scenarios have contributed to shaping the networks driving the deployment of SMR technologies, influencing the countries’ institutional capabilities to deploy SMRs. This relation is illustrated in Figure 1.1 It is assumed that:

A) The network structure of the SMR innovation ecosystems influences the capabilities for deploying SMRs.

B) Existing policy has influenced the way networks are currently constructed.

C) The current network structure is a snapshot of how the policy has shaped the actors while determining the readiness to deploy sustainable technologies like SMRs.

The analysis for this research describes an ongoing process that is susceptible to changes in the policy or in the innovation ecosystem itself.

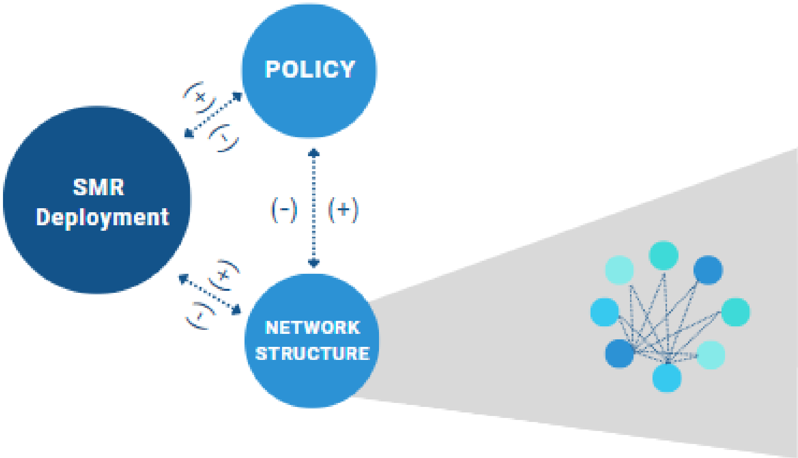

Figure 1.1 Relational Diagram

The literature review highlighted above led to research on the following question:

What is the current structure of the SMR innovation ecosystem in Canada and Mexico for deploying small modular reactors?

The following specific questions were also asked:

1) What is the helix of the actors dominating each SMR innovation ecosystem?

2) Who are the central actors connecting the innovation ecosystem?

Chapter 2. Literature Review

2.1 Introduction

Humankind has historically resorted to models and theories to explain the reality of our complex world. Researchers and policy analysts have conducted empirical studies of innovation systems to describe and understand their structure, dynamics, and performance and to create a policy that supports their deployment and replicates their success. This broad work on technologies from all sectors reflects the need for innovations to find their way into the competitive global markets and the varying formulae for success in different technologies.

This is not the first time the need to adopt policies on a specific energy source has been demonstrated, especially when the energy source is not dominant and an energy transition is intended [10]. Although approaches are diverse (from economic, political, managerial or behavioural studies), these are often not applied in the energy sector, even less in the specific context of SMRs. This situation highlights our ignorance of the challenges blocking SMRs' successful deployment and the opportunity to explore this complex sector.

Although dozens of frameworks are available, Strategic Niche Management (SNM) stands out because it applies to broader systemic sectors such as the energy sector and has been previously applied to nuclear technologies. This framework allows for consolidating community networks that serve as the early adopters of the technology from a bottom-to-top policy approach, which applies to developed and developing countries. At the same time, it considers both country-specific and broader characteristics for site selection. The bibliographic analysis made through connected papers on the Boolean search "Strategic Niche Management" and "Nuclear Technologies" can be found in Appendix 1.

This framework is especially relevant. SMRs have not been deployed in either country, highlighting the need for policies to promote their acquisition, protected spaces to pilot SMRs' introduction to their market, and momentum to prepare a deployment strategy. This momentum enables actors to take advantage of the knowledge that these protected spaces generate. This knowledge is critical if actors are to learn how to tackle better challenges for deployment and benchmark best practices to replicate the successes.

2.2 Strategic Niche Management

The Strategic Niche Management (SNM) framework provides guidelines for action, as it promotes selected geographical spaces to test technology adoption. Often considered to be part of the Multi-Level Perspective ([11], [12]), this framework continues to gain relevance as it emphasize she importance of actors and their interrelations among complex and dynamic networks, such as the ones encountered in nuclear energy. This framework and its experimental protected spaces allow the strategic allocation of resources for SMR deployment while enhancing new market formation, consolidating a community of early adopters, and contributing to deployment by learning how to replicate success.

This framework suggests different schemes or layers that tend to verticality. SNM contemplates niches, regimes, and a general landscape, as illustrated in Figure 2.1. As can be seen, the landscape level includes the regimes and embedded niches and how actors interact at and within each level. Likewise, the regime level has its respective regimes and niches. This framework, therefore, inclines its frame of action towards a collective strategy for procuring the given technology rather than toward stand-alone projects, which is especially relevant for the timely deployment of SMRs.

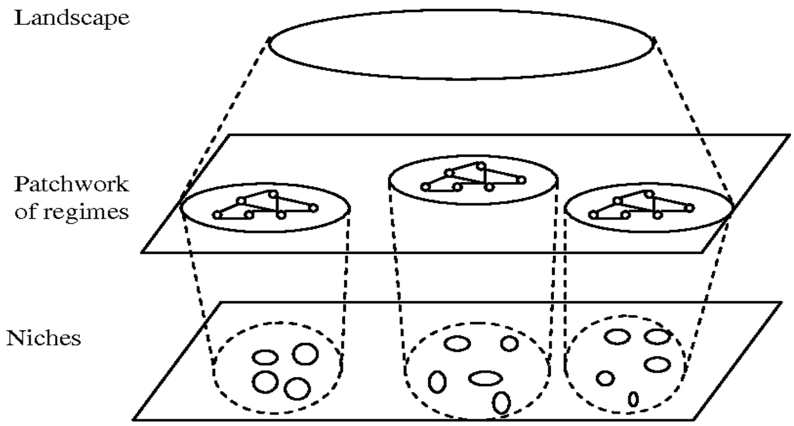

Figure 2.1 SNM Scheme of Analysis
Source: [13]

The layers found in Figure 2.1 also illustrate that SNM goes beyond simply selecting a site for a deployment trial. It proposes a managerial approach in which a strategy is presented with several potential niche sites simultaneously constituting different regimes and the landscape. In this way, this managerial approach recognizes the governance of individual yet diverse niches as part of the collective success of deploying SMRs. For this reason, SNM approaches require adaptable policymaking and a diversity of institutions capable of providing this flexible environment to pivot with the conditions needed for successful deployment. Thus, SNM promotes realistic energy transitions and an innovation procurement strategy through policy instruments such as incentives, tax exemptions, or changes to regulations compatible with successfully deploying SMRs.

From the literature consulted, insightful analyses stand out where the broader Water-Energy-Food (WEF) ecosystems and their complex interrelations improve governance at the regional level [14]. These applications also highlight the framework's potential to analyze complex and interrelated ecosystems. Researchers have previously proposed an SNM approach to meet the needs of low-carbon energy transitions [12]. Scholars have addressed the general electric regimes [15], the general approach to renewables [10], and the specific case of biogas [16], all within the particular context of the Netherlands. Other applications highlight the case of solar panels in the UK [17] or the analysis of the Colombian bio-economy sector [2] in the case of a developing country. In the literature on national comparative studies with SNM, the biogas sector stands out for Denmark and the Netherlands [18], as well as six low-carbon case studies in the Netherlands and the UK [19], [20].

In the specific case of SMRs, two pertinent studies are the works by Iakovleva, Rayner, and Coates in 2021 [21] and Hussain et al. in 2018 [22]. Their papers review SNM for deploying SMRs in Northern Saskatchewan, Canada, from a public policy perspective. In addition, two other pieces of literature apply the niche concept for SMR deployment, although neither of these papers recognizes the SNM framework as part of their work [23], [24]. Another key paper is "Prospects for Nuclear Energy in Canada, USA and Mexico" [25], which, although it does not use SNM as a guiding framework, emphasizes the social, economic and environmental context, as well as the characteristic extra-regional linkages of innovation ecosystems in the nuclear energy sector. As well, the paper "The Entrepreneurial Development of Regions -- Exploring the Socio-Technical Transition of Lusatia from a Multi-Level Perspective" [26] is crucial to overlapping this framework with innovation ecosystems. Their schemes for Strategic Niche Management in innovation ecosystems are presented in Figures 2.2 and 2.3.

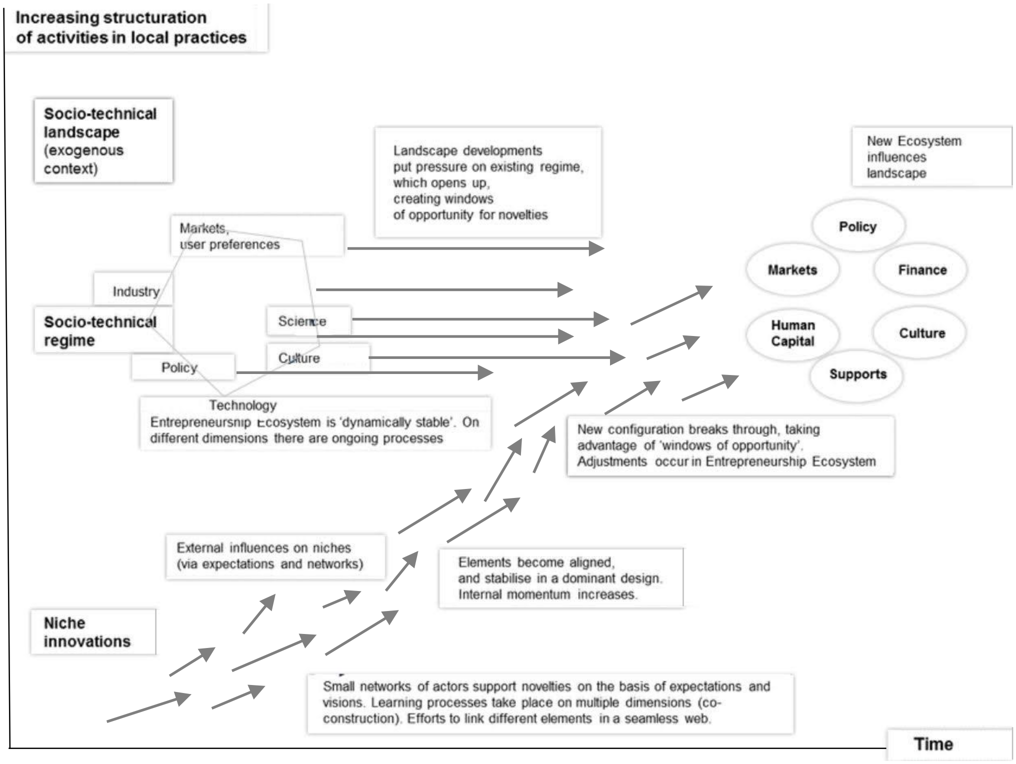

Figure 2.2 SNM and Innovation Ecosystems

Source: [26]

In Figure 2.2, it is possible to observe the non-linear process for niche innovations through time. This framework considers the socio-technical spheres that impact the network consolidation at the niche, regime, or landscape level. This network involves technology and considers the influence of policy, industry, market, science, and even culture intertwined with technology. These influences on the landscape are especially relevant to the country comparison in this research. Although this research's scope allows only an in-depth review of policy and market, the other spheres are touched upon throughout this document.

For Canada and Mexico, the most notorious case of landscape development is the Paris Agreement and each nation's carbon reduction commitments. These obligations create momentum for institutions promoting the deployment of SMRs to find their opportunity window. In an ideal scenario, this landscape development would be followed by responsive policy to promote the changes required to meet these international commitments—not necessarily locking in SMRs as the only technology but as a reasonable and proportional part of the energy mix according to the available data.

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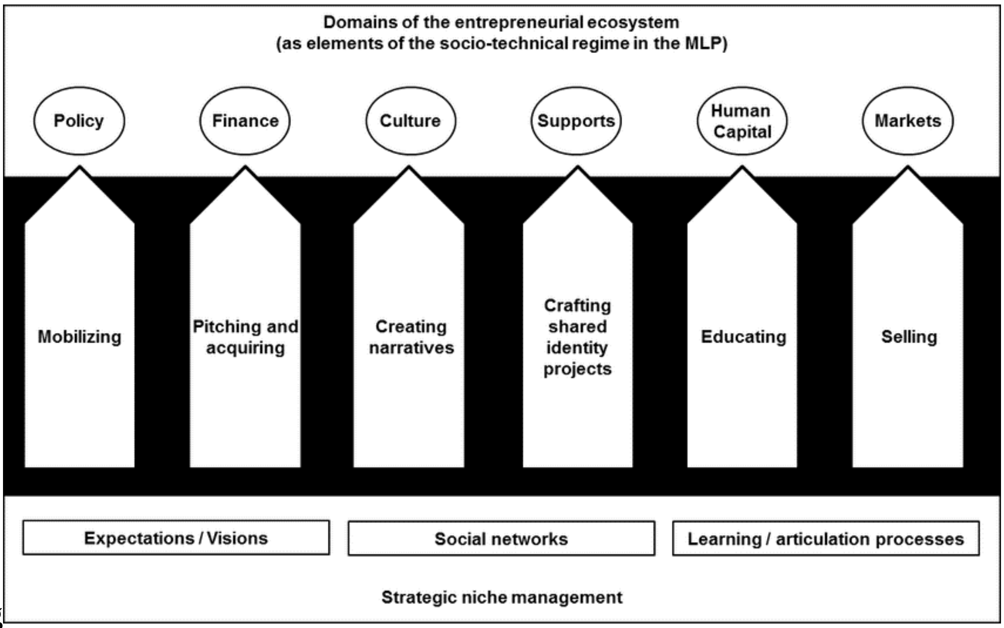

Figure 2.3 SNM and Innovation Ecosystems 2

Source: [26]

Figure 2.3 delves deeper into the three main dimensions of SNM: expectations, social networks, and learning and articulation processes. Again, it is possible to can find the socio-technical influences that affect an innovation ecosystem embedded with the actions required for each one. Importantly, these actions do not represent a mutually exclusive order of events but rather a consolidation of a series of actions that must be made simultaneously and adjusted at each step. For example, policy might be required to promote the acquisition of SMRs at the expense of their polluting peers. This process might involve creating incentives for the actors driving this technology, and further policy might follow on tax incentives and tailored regulatory frameworks that represent the risks these small reactors take on compared with big nuclear projects.

Specifically, each country's expectations and visions toward nuclear technology are highlighted in section 2.5 of this document. The social networks presented in Chapter 4 are the method chosen for this research project, and the articulation processes address the descriptive analysis of the niche markets for both countries, while the education factor is out of the scope of this research. The learning, however, is directed to the knowledge generation and transmission from the niches themselves and the legitimation process of the technology on its way to commercialization.

The experimental component of strategic niche management also requires a series of complementary policies, such as the divestment of polluting energy sources. Here, I briefly highlight those occasions where new technologies are found in a legal framework not created for them and represent the first barrier to market entry. Other examples of how strategic niches and policy intertwine are, for example, the adjustment in purchasing laws so that SMRs and other sustainable technologies can be prioritized in purchases made with public money.

2.2.1 Strategic Niche Management as a Learning Tool Towards Network Development

One of the biggest challenges for public policies is that the people who propose them must respond to a busy, changing, and pressing public agenda. For technologies like SMRs, which have not previously been a priority in the national energy strategy, becoming part of the public agenda is quite challenging. Therefore, the relevant information about these technologies must be available and democratized. However, circulating this information is difficult because the literature on public policies in SMR deployment is limited and inaccessible to non-experts.

Although SNM is an innovation policy, it is also a policy instrument that could involve a series of other instruments and be as straightforward or complex as the resources allow. This modularity and experimental nature of SNM highlights the value generated by the network actors; it also reveals the work involved with monitoring or governing networks to simulate diverse deployment scenarios because "no simple or mechanical substitute yet exists to replace painstaking and careful immersion in the particularities of a real domain" [27] (p.151). Notably, the way institutions interact with each other is far from static. They not only evolve with time; they also respond to both external and internal influences. Developing a network typically leverages creativity to fill existing gaps and needs. This market formation has positive economic consequences since it encourages the creation of more specialized functions and the entering of new actors into the ecosystem to collaborate or encourage market competence, promoting SMR deployment.

When resources are finite, they must be distributed strategically and efficiently in site selection and by the actors carrying out the deployment. These actors often consist of technology-leading institutions and a set of supporting institutions, and these institutions generate knowledge continuously that could serve as input for policymakers and other actors promoting SMR deployment. When SNM is used, network collaborations allow firms to "attain economies of scale and scope in their R&D endeavours" p.10 [28].

Moreover, policymakers should seek network development to aim for network sustainability and resilience—the capabilities of the "network arrangements to resist system shocks and external factors" and "to function in the face of external and internal challenges until a goal is met. [29]. These capabilities are especially important when the political and economic landscape is uncertain, affecting network actors' availability, willingness, or abilities.

2.3 Network Governance

Among all the problems of humanity, governance issues often stand out. Usually, these issues arise not because resources are lacking but because coordination is inadequate or absent. Lauman and Knoke argue that, although the nuclear-electric-environmental public issue attracts some actors mainly interested in other issues, "without the involvement of the regulatory and railway publics, the nuclear group would have a unique constellation of interest" [27] (p.148.) Specifically, inter-institutional network governance includes formal governance structures and processes and "the use of formal and informal institutions to allocate resources and joint coordinate action in a network of organizations" [29] (p.4). In this sense, network governance considers the formality and informality of both "public" and "private" actors and their given governance dynamics.

In their methodological book on Social Network Analysis [30], Knoke and Yang (p.15) argue that there is an emphatic difference between relational forms and content: relational form refers to the "property of relations that exist independently of any specific context." Contents are individuals 'interests, purposes, drives, or motives in an interaction." Thus, inter-institutional networks aim to increase collective capabilities to address common challenges but are often faced with challenges of having different drivers, motivations, and cultures. Moreover, networks have a hybrid nature due to the heterogeneity of their actors and their governance systems. In addition, networks and their governance represent a very peculiar phenomenon, where both influence each other, as Hapucu and Hu [29] argue:

> *On the one hand, properties and relational patterns of networks influence how networks are managed and how power is distributed. (…) On the other hand, network governance will shape network structures and network evolution. (p. 8, Ch 15)*

Another great advantage of network governance is that it legitimizes the selected technology, in this case, SMRs, and the institutions promoting it. This legitimacy creates trust among actors and, directly or indirectly, promotes cross-institutional collaborations that increase the institutional capabilities to deploy SMRs. As well, the fact that "there might not be a formal leader with managerial responsibility, designated power, or a hierarchical relationship with followers" [29] (p.3, Ch5) suggests that we should not study a sole helix but rather understand them all as a whole—as a continuous interaction in the formation of a whole network. In this way, network governance acts as a knowledge generator and manager with a privileged managerial understanding of the actor's behavioural collaboration patterns.

Despite the research that exists on networks [28], [31], [32], there is a need for comparative research on innovation ecosystems and their governance structures and processes that comes from the learning generated by understanding network governance. The necessary research includes identifying actors, understanding ruling mechanisms and collaboration patterns, and deciding where to allocate efforts. The scope of this research only touches on the first process: identifying members as the baseline for future research and subsequent action.

2.4 The Helix Model IV: A Complementary Framework for a Strategic Niche Management Approach

The Helix classification used by [33]–[35] and first proposed by Leydesdorff and Etzkowitz in 1996 is relevant as a complementary framework for this research as each helix embeds a particular governance dynamic with its specific intrinsic drivers. This framework categorizes helices primarily into three: government, industry, and academia, although there is a later-recognized fourth helix [36]: civil society. This fourth helix responds to the need to represent organized citizenship and citizens and their importance in interactions with other helices, especially in a field where anti-nuclear groups have historically had the de facto power to stop nuclear projects entirely.

Beyond classification, this framework provides relevant insight into the mix of governance dynamics within the pool of actors involved in SMR, highlighting each helix's systemic weaknesses and strengths and showing how a diverse network can make up for sole helices' deployment obstacles. Although the helices' characteristics and intrinsic governance properties will be discussed, a visual classification with some examples of which institutions comprise each helix is represented in Figures 2.4 and 2.5. These figures show how the diverse helices form ecosystems at all levels and how different mixes of actors might better serve the niche according to their needs. In this figure, the appearance of international organizations in each helix responds to their distinct role in nuclear projects that might not be required with technology in another field.

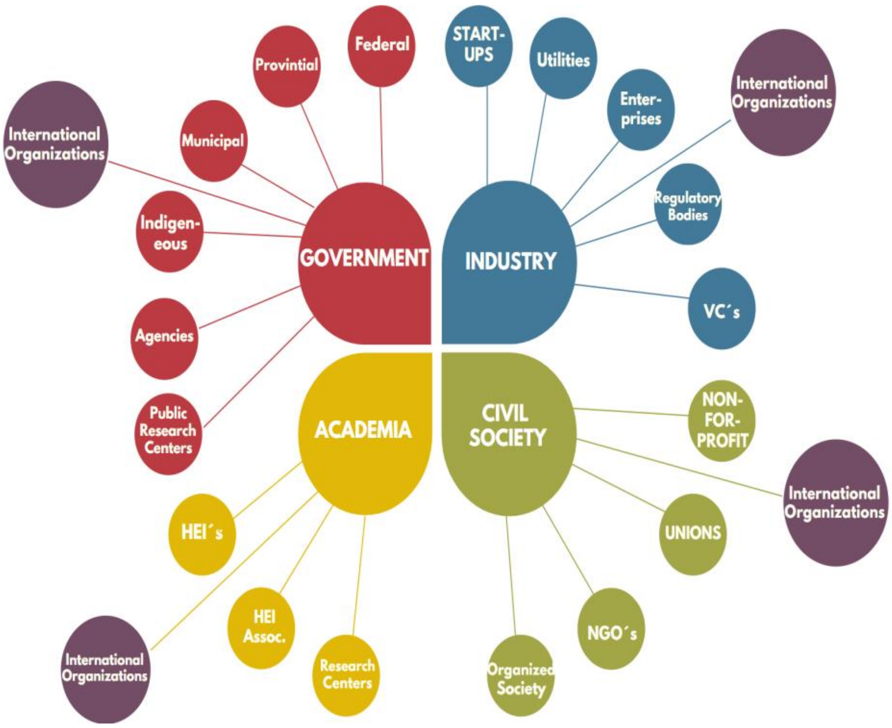

Figure 2.4 Actor´s Classification

Source: Adapted from [33]

Innovation ecosystems comprise heterogeneous actors under different legal forms, which determine most of the various institutions' challenges. However, the current literature promoting or giving recommendations for new nuclear projects has been directed mainly at the government helix [37]–[40], with a few articles either considering shared leadership between the government and industry helices or focusing solely on the transition of human resources from the academy to industry. In this literature review, no articles were found that addressed the ecosystem helices as a whole, and our current understanding and recommendations largely ignore other helices and their interactions.

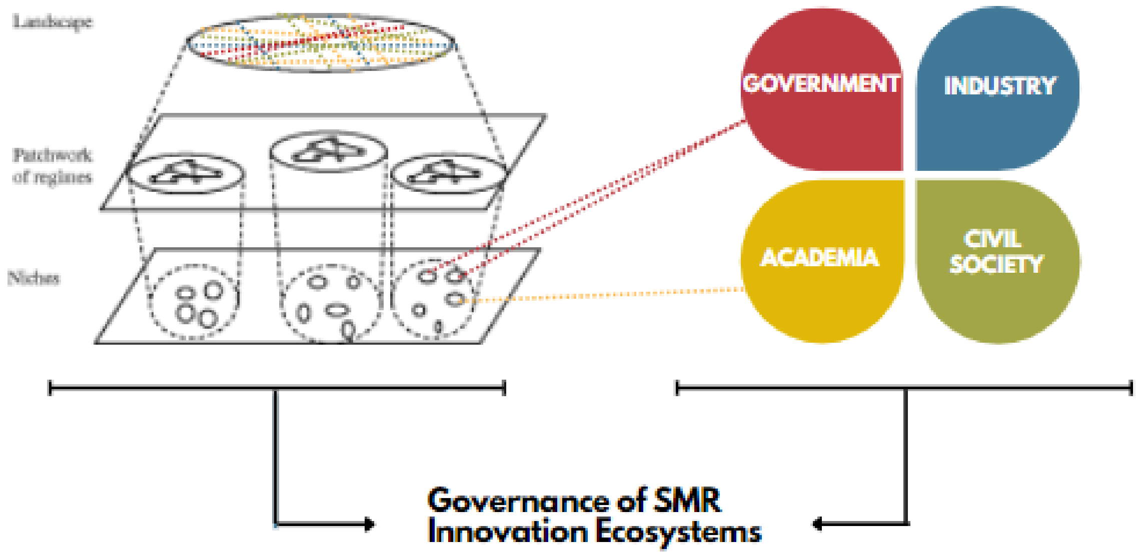

Figure 2.5 Governance of SMR Innovation Ecosystems
Source: Adapted from [26], [33]

Figure 2.5 illustrates the diversity of actors contributing to each or various niches and shows how the institution's mix might vary from one niche's needs to the others' needs. In this way, we can think of the institutions conforming to the SMR innovation ecosystem of each country as a pool of actors to choose from. In an SNM approach, this means taking advantage of each institution's governance strengths and making up for their individual weaknesses and constraints with the diversity of the collaborations.

Notably, although knowing the governance of the innovation ecosystems for SMR deployment is important, SMRs might not need to be governed. Naim and Qian maintain that networks "might not [have] a formal leader with managerial responsibility, designated power, or a hierarchical relationship with followers" [29] (p.3, Ch. 5). Other authors (Jessop, 1998; Kooiman, 2003; Koppenjan and Klijn, 2004; Sørensen and Torfing, 2007 in [41]) caution SMR actors and governments not to take a westernized or colonialist approach by intervening to govern these ecosystems when they may only need to be supported. :

> *The success of governance networks in promoting collaborative innovation depends on the degree to which networks are skillfully meta-governed in the sense of being steered and managed in ways that influence their processes and outcomes without reverting too much to traditional forms of command and control. (p.826)*

The literature also indicates that niches are not created by governments but are "assumed to emerge on their own" [11] (p.538), highlighting the organic and sometimes informal collaborations that have opened to consolidate the institutions of the network and their interaction patterns.

2.4.1 Government

Publicly funded institutions such as governmental agencies are often subject to scrutiny, regulations, and processes because they are held to a high standard of accountability and transparency and are often limited by the institutional rigidity accompanying the public disbursement of money. Governments also face regulations for purchases, finite resources, and additional spending restrictions due to the public nature of their budget, as well as bureaucracies, red tape, path dependency, and the administration changes characteristic of their governance system.

Although historically government has been the prominent financier of innovation in times of war, without an emergency or conflict, this Helix is not known for its efficiency and quick service delivery. As Weintraub argues, the "government's willingness to make long-term commitments are often rare, and often respond only to the urgent momentum of abrupt market changes or national energy security challenges" [42] (p.173) Although this Helix is crucial for the SMR ecosystem, its governance challenges prevent it alone from making SMR deployment happen, highlighting its need to create strategic alliances to overcome these structural weaknesses typical of its public nature.

Importantly, although institutions may be affiliated, they are not necessarily aligned or work in collaboration. The governments of both Canada and Mexico operate in an environment of different political currents distributed at various levels of government and present different governance styles. Sometimes, even a current administration holds opposition parties at the provincial and federal levels. The government levels also represent sub-networks or subsystems that help form the bigger picture, and this verticality is illustrated in Figure 2.6.

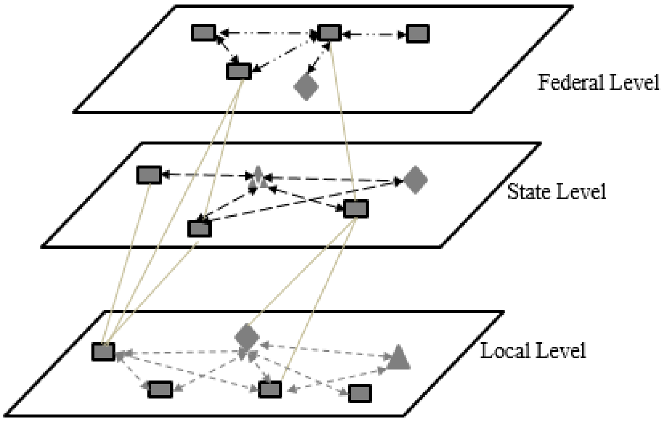

Figure 2.6 Government Level
Source: [29]

Public organizations often make their own decisions. There are opportunity costs and a constant debate on the "right mix" between public and private service delivery. However, according to Besley, one thing is certain: "High-quality public services require high-intensity efforts" [43] (p. 240) regardless of the selected mix of private and public institutions or if public institutions are the ones leading the deployment of SMRs. Although the literature on strategic niche management tells us that "Niches are not inserted by governments, but are assumed to emerge"[11] (p. 538) from a governance perspective, there is plenty of support that can help them thrive while not micromanaging the SMR ecosystem or falling into a colonialist intervention.

This helix's characteristic electoral cycles affect researchers who depend on government aid and entrepreneurs who rely on tax incentives [6]. The allocation of the government budget represents a large part of the financing available for the actors in the ecosystem and for their decision to prefer to take advantage of the windows of opportunity of the Paris Agreement Commitments with sustainable alternatives such as small modular reactors. The presence of these stimuli, fiscal incentives, or investments largely determines the behaviour of the actors that currently make up the SMR ecosystem, but also that this market is attractive to new actors. It could be these other utilities joining the energy transition. For instance, as the National Nuclear Laboratories argue [23] (p.13): "Most of the utilities currently contemplating new nuclear generation are basing their decisions, in part, on the availability of federal government subsidies and/ or other federal incentives."

While most actors take an apparent financing approach in executing projects to deploy SMRs [37], [44], [45], another approach is usually omitted from innovation policies: the creation of strategies that seek and prefer sustainable technologies and innovations within public procurement. It is important not to underestimate the magnitude of public spending since it is estimated that in the European Union alone, "the purchasing power of public buyers accounts for around 14% of their GDP" [46]. While not everything is geared towards sustainable technologies, the simple fact of favouring SMRs in buying opportunities would make a significant difference in reducing carbon emissions. To put it in perspective, let's contrast this 14% of GDP with the two countries' 2019 national spending on research and development (R&D): Canada spent 1.5% of GDP on R&D [37], while Mexico spent 0.5% [47].

The European Commission in [48] (p.1), defines Innovation Procurement as:

> *Any procurement that has one or both of the following aspects:*
> *- buying the process of innovation – research and development services – with (partial) outcomes;*
> *- buying the outcomes of innovation created by others.*
>
> *In the first instance, the public buyer buys the research and development services of products, services or processes which do not exist yet. The public buyer describes its need, prompting businesses and researchers to develop innovative products, services or processes to meet the need. In the second instance, the public buyer, instead of buying off-the-shelf, acts as an early adopter and buys a product, service or process that is new to the market and contains substantially novel characteristics.*
>
> *Such innovation, bringing better performance and added value for various stakeholders, sometimes fits the traditional setting (incremental innovation) but often disorders the old system by creating different actors, flows, and values (disruptive innovation) or even requires a more comprehensive transformation, as it addresses unmet needs and calls for structural or organizational reforms (transformative innovation). This guidance attracts attention to the benefits of various forms of innovation and explains how to approach them in the public procurement process.*

This definition seems especially relevant to this research project since technology is constantly being sought, and actors actively campaign for technological development, consolidation, and even deployment of SMRs. This procurement strategy for innovation also represents an economic strategy for certain countries because the "countries that successfully found carbon-neutral businesses and industries will lead the global economy for decades to come"[6] (p.52). This advantage and desire for power have historically motivated countries and their governments to invest significantly in innovation and technology.

SMRs represent a much smaller financing opportunity than large-scale nuclear projects, and private investors might be increasingly interested in investing in SMRs. However, the contextual conditions of both Canada and Mexico eliminate both governments from a mere price regulation function, giving them the role of financer of these projects. Public financing, specifically for SMRs, not only encourages and legitimizes the relevance of this technology but also validates the energy vision of governments and the actors in the innovation ecosystem, especially SMR vendors who have found a market for their products.

Although government financing is extremely important for SMR vendors, this support does not cover all the economic needs of the institutions leading these efforts. For example, in the SMR Strategic Plan [49], the 2020 financing of the Terrestrial Energy startup (of 20 million Canadian dollars) required the startup to also contribute 91.5 million in R&D (more than four times their granted funding). Another example is the investment of 20 million in ARC Canada, funding that is conditional on the vendor contributing another 30 million. [49]. These examples illustrate the importance of public-private partnerships in deploying expensive and uncertain technology (in comparison with technologies in other sectors, such as software) in the R&D pathway toward commercialization.

Other financing implications for the government helix relate to the cost of inaction. These costs can be seen in the lack of action after natural disasters. For example, Hurricane María set Puerto Rico's electricity grid and other infrastructure back two decades[6]. Puerto Rico's setback reflects an infrastructural challenge for developing countries that accentuates the gaps between developing and developed countries.

2.4.2 Industry

In addition to being a key player in innovation, industry is a job generator and, therefore, a key part of the economy of any country. According to Coase, the role of firms is to absorb "transactional costs" [50]. This role suggests that institutions are limited when it comes to belonging to other helices to execute projects efficiently and promptly. It also suggests the need to outsource activities to meet the market's growing demands. The industry helix encompasses companies of all sizes, startups, public companies, private utilities, regulatory bodies, and individuals or financing groups such as venture capitalists or angel ventures. Some private research centers might also be considered as part of this helix. The institutions in this helix have financial freedom since their budget does not come from public money and is not subject to the level of scrutiny that accompanies public institutions. The governance of industries focuses on creating favourable conditions to execute projects promptly and efficiently.

Importantly, the capital with which companies are started and operated initially comes from the founders' private sources, such as savings, inheritance, or profits from another business, and subsequently from the generation of income through sales. Although industries' operating budgets may vary in their mix of public and private funds depending on their pool of clients, unlike government institutions, companies do not have to dispense public resources once they receive them. However, the execution of industry contracts with the government does assume unique project execution processes.

The case of public companies is interesting because it represents a hybrid governance model between public and private. These are born and consolidated as companies under a governance style until they enter the stock market, changing their character from private to public and subjecting their governance to new regulations. It is worth highlighting the peculiar case of Hydro-Quebec, a public company where the only stakeholder is the Quebec government of this province. It could be hypothesized that, in this way, the Quebec government has found greater freedom to execute this service delivery through a public enterprise rather than under rigorous government governance.

As mentioned, startups or newly created companies are also found in the industry helix. These companies may have special characteristics because they face different and more difficult challenges than their peers that also belong to this helix. For example, economic theory [50]tells us that organizations seek to increase their profits and decrease their expenses and that they are risk averse and aligned with a behavioural theory that presumes bounded rationality in their decision-making. However, startups challenge these assumptions [51] since entrepreneurship essentially takes advantage of the higher risk that comes with risking more and has a high chance of losing more. Moreover, startups often arise as inventors seek commercialization or an R&D project. These inventors have not only invested tremendous effort into developing their ideas or a minimum viable product (MVP), but they are about to be burdened with ten times the current investments per advancing stage [52]. Startups are also where the most promising innovations are often found. They are often financed by big multinationals interested in acquiring their intellectual property, buying or licensing their technologies, or co-creating with them from the research and development stages [53].

2.4.3 Academia

It is important to differentiate first if a higher education institution (HEI) is private or public since this largely determines the challenges and strengths of its governance and the helix in the broader context. Public institutions typically obtain their resources from the federal, provincial/state government or a combination of these, and many receive funding dedicated to R&D. They are also transparent on their use of public resources, and they may be subject to more budgetary restrictions than their private counterparts and sometimes to political pressure in the allocation of budgets. Their research may also be influenced or even directed by the political party in power. Canadian HEIs conduct about 39% of national R&D [54]. In the Mexican context, the *Consejo Nacional de Ciencia y Tecnología (*CONACYT) indicates that the country must invest at least 8% of its GDP in education, of which 1% should be directed to scientific research and technological development of public higher education institutions.

Because HEIs focus on knowledge, this helix forms human capital and incubates ideas [55]. Academia also represents a space of convergence for future professionals and in today's different helices: government, industry, the academy, or civil society. These spaces and teaching or research tasks act as vehicles of knowledge and facilitators of its application in innovations. Academia, in this way, attracts global talent in students, professors, and researchers and provides a career path in the helix itself for current students wanting to pursue a career in academia. Academia also legitimizes research projects and innovations, as it is subject to academic and methodological scrutiny. Key for deployment purposes, the institution's prestige might play a role in this legitimation.

It is not only universities that are grouped in this helix but also polytechnic institutions, post-secondary colleges, and institutes of applied sciences. While universities collaborate with industry as far as possible, these other institutions consider these collaborations a must in their project conception. Many projects themselves respond to an already identified industry need. Another strength of these other institutions is their "efficiency to bring a project to the market by the hand of an industry partner in record time" [53] (p.43), attributable to their decisions not to pursue their property rights and cede them automatically to their peers in the industry. These peers bear the high costs of R&D and those involved with protecting intellectual property. In this way, the polytechnics and institutes of applied sciences provide scientific legitimacy and foster innovation without making a significant investment, taking on potential risks, and decapitalizing their institutions. However, these academic institutions are socially conferred with a lower prestige or legitimacy than their peers and are not usually considered on equal terms in calls or research funds [53].

Institutions in the academia helix often rely on Technology Transfer Offices (TTOs), which are crucial to leap from research and development to commercialization. Providing their institutions with advice and support on deploying their research, TTOs follow their institutions' specific frameworks for intellectual property based on the research needs of their academic and scientific community.

2.4.4 Civil Society

Civil Society Organizations (CSO) often emerge to tackle gaps in governmental policy delivery gaps, as they are associated with a strong “capacity to identify new needs and demands (…), and deliver them using innovative means” [56] (p.viii). These needs and demands might be for charities, non-profits, non-governmental, or voluntary associations. Here I also find unions, professional or industry associations, and simple, organized societies without the formality of an institution. The creation of CSOs is usually measured as the associative density of a country, which may reflect a latent need to satisfy an unmet social need [57].

To compare the associative density of Canada and Mexico with the global density, I will use the United States as a reference, the country with the most institutions per capita, with 670 CSOs per hundred thousand inhabitants [57]. In Canada, for every hundred thousand inhabitants, this density is 460 institutions; in Mexico, it is only 33 [57]. Although associative density could be a sole indicator of market gaps, it is important to also contrast it with the legal barriers to formalizing this kind of institution and the legal autocracies and administrative burden they face upon creation to be able to receive donations. While this helix is very young in the Mexican context, in Canada, it represents an opportunity for further exploration as “civil society has become a legitimate partner with the state and the market in a democratic system of governance" [56] (p.1). Even culturally, this sector conveys that these organizations arise as a response to Canadian organizations that support fundamental causes since it is estimated that more than 50% of Canadians [56] are members of at least one organization. Consolidation and permanence are characteristic of this helix, and the source of funding defines a CSO's institutional governance. The CSO might have a membership base participation, boards, or committees regulating its progress and strategies and limiting or enhancing its impact potential. CSOs are also characterized by having less reliance on a sole funding source compared with other helices. Typically, skilled at sourcing strategies, their leadership attracts an admirable diversity of sources that allows them to reduce their risk, dependency, and vulnerability.

One crucial attribute of CSOs is that they can fundraise directly from individuals, minimizing their reliance on bureaucracies. In fact, CSOs raise 30% more money from individuals than from governments, foundation grants, and corporate donations combined [56]. In an individual-based business model, an individual consumer's interests are more clearly reflected in the institution itself. CSOs are then a way of engaging citizens in public matters; they also provide a counterweight power usually distributed among the elites of each helix [42].

2.5 Expectations for SMR Deployment

2.5.1 Current Status of the Nuclear Ecosystem

As an introduction and diagnostic approach to the current situation, this section will briefly describe the nuclear projects in Canada and Mexico as of June 2022. These projects are presented below under two categories: commercialization focus and research focus.

2.5.1.1 Commercialization Focus

All reactors in Canada are CANDU reactors. In Canada, four nuclear sites are in commercial operation, three in Ontario and one in New Brunswick [58]. In these two provinces, the difference in the governance of the institutions in charge of power generation stands out. New Brunswick's key player is Énergie NB Power, a provincial Crown corporation subject to the government helix governance dynamics. In Ontario, key players are Ontario Power Generation, another provincial Crown corporation, and Bruce Power, a limited partnership and Canada's only private nuclear generator.

In the Mexican case, the only power generation plant for commercialization purposes to date is the Laguna Verde Nuclear Power Plant in the state of Veracruz, which has two light boiling water reactors (BWR-5). This site is owned by the Federal Electricity Commission (CFE), which operates it under a legal form of a productive state company, the exclusive property of the federal government. It has a legal personality as a public company and has its own assets, although the influence of the administration on the energy agenda and how these resources are disbursed in the energy mix is socially recognized. One of the great challenges of the CFE is the need for impeccable efficiency to participate in the wholesale electricity market and a need to considerably increase the level of competition, derived from the window of opportunity that the 2013 Energy Reform allowed, further explained in section 2.5.2.

2.5.1.2 Research Focus

According to the Canadian Nuclear Safety Commission, there are 14 research reactors in Canada. While most reactors are located at universities, including one in the Royal Military College, and other reactors are found in hospitals and other research facilities. Figure 2.7 below illustrates the geographical location of these research facilities, with a much higher density in Ontario and a scattered distribution in the rest of Canada.

Figure 2.7 Research Reactors in Canada
Source: [29]

In the Mexican context, there are four research reactors: one in the National Institute for Nuclear Research (ININ for its acronym in Spanish), the "first organization dedicated to the development of nuclear science and technology for peaceful purposes" [59], and three others in public universities. As shown in Figure 2.8 three of them are geographically concentrated in the country's capital, with the remaining research reactors further north in the Universidad Autónoma de Zacatecas, where the only SMR design found to date was designed as a doctoral dissertation of its nuclear program.

ININ is dependent on the Ministry of Energy and, therefore, belongs to the federal level of government. It has a Triga Mark III nuclear research reactor, which has a pool with a mobile core and uses low-enriched uranium fuel and natural water with low salt and mineral content. Despite being one of the most important institutions for the nuclear field in Mexico, this institution faces capability limitations because, first, it can no longer independently plan its R&D and, second, its license to market radioisotopes or radioactive material was suppressed entirely with the law reform LRA27CMN in 1998 [60].

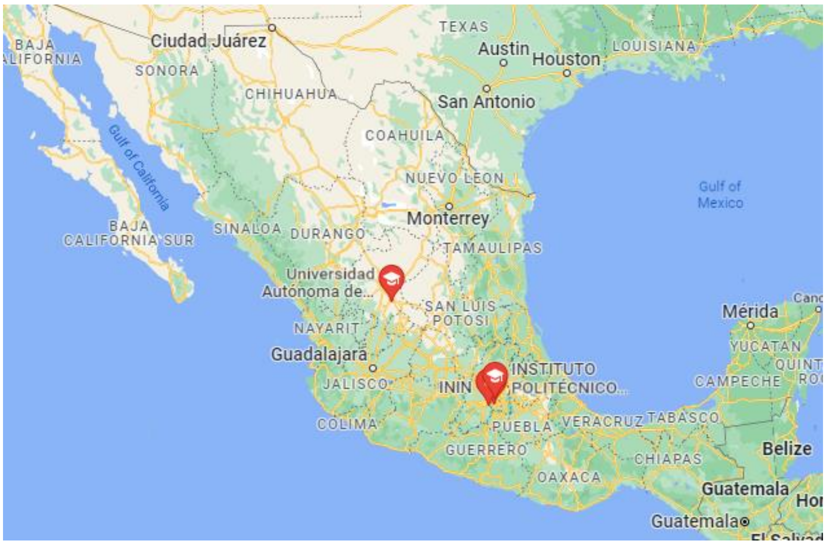

Figure 2.8 Research Reactors in Mexico
Source: [59], [61]

2.5.2 Country-Specific Energy Agendas

This analysis starts from the understanding that both countries already have an energy agenda, in which, first, exploitation capacities for each source of energy generation are evaluated, and second, the generation of sources is based on their availability, cost, and relevance. These factors configure the percentage of participation of each type of energy or a country's energy mix. The geographical location of both countries plays an essential role in the climatological disposition, allowing more constancy in generating energy from solar or wind sources for the Mexican context [62]. These weather conditions differ substantially for both countries, impacting decisions about energy mix. This difference in their mix is especially relevant for Mexico, whose climate is less extreme than Canada's. Mexico has, therefore, a stronger nudge to solar and wind energy.

If the governmental approach favours an economic rationale over an environmental one. An energy agenda can be seen as the first gatekeeper for sustainable technologies like SMRs. A country's energy agenda is influenced by its commitment to attaining energy security in its productive economic activities and reducing emissions in the Paris Agreement. Table 2.1 details the baseline of each country´s motivation in setting its energy agenda.

Table 2.1 Country-Specific Motivations

	Canada	**Mexico**
Governance System	Federal Constitutional Monarchy	Federal Republic
Population (2020)	38.01 million	126.95 million
Energy Production (2020)	21 567.044 TJ	6 291.923 TJ
Energy Production Increase since 1990	+ 86.33%	-23.15%
Electricity Final Consumption (2020)	549.68 TWh	307.48 TWh
Total CO2 Emissions	523.19 Mt of CO2	381 Mt of CO2
Nuclear Energy Generation Share	15%	4.7%
Dominant Energy Generation Source	Hydro (60%)	Oil (45%)
Commercial Nuclear Reactors	21	2
Nuclear Centrals	4	1
Research Nuclear Reactors	14	4
Total of Reactors	25	6
National Determined Contributions (NDCs) to the Paris Agreement	GHG reduction emissions from **30%** below 2005 levels by 2030 and net-zero emissions by 2050.	Mexico is committed to reducing unconditionally 25% of its Greenhouse Gases and Short-Lived Climate Pollutants emissions (below BAU) for 2030. This commitment implies a reduction of **22%** in GHG and a reduction of **51%** in Black Carbon
Updated NDC´s	GHG reduction emissions of **40-45%** (new target) below 2005 levels by 2030 and net-zero emissions by 2050.	Unconditional reduction of 22% GHG and 51% of Black Carbon Emissions as compared to the baseline business-as-usual-scenario Conditional reduction of up to 36% of GHG emissions and 70% of Black Carbon Emissions as compared to the baseline business-as-usual-scenario

Source: [58], [63]–[65]

In addition to energy consumption needs and international commitments to reduce greenhouse gas emissions, the country´s energy mix also responds to the leader's political agenda and vision for the best combination of economic and social development of the country. Although both countries follow a federal system of government, Canada's sovereignty at the provincial level is stronger compared to that of Mexico at the state level, although they are equivalent levels. The greater strength of Canadian provincial governments is especially relevant because they play a key role in proposing, financing, and developing nuclear projects. In contrast, in Mexico, such decisions are centralized. Mexican states only collaborate when a decision has been made at the federal level and the site falls under the states' jurisdiction.

When a new technology is on the horizon for deployment, the certainty that even the inclusion of SMRs in a discourse provides is gained ground towards their adoption. The technology can be legitimized through support in speeches, memorandums of understanding, agreements, contracts or collaborations. There is a notable difference in the public support given to SMRs in Canada and Mexico. Canada has been consistent in its narrative about nuclear energy, making collaborative efforts such as the SMR Roadmap and Action and Strategic Plans involving 119 organizations from all four helices. In contrast, Mexico struggles to maintain a clear priority over sustainable energy sources and therefore lacks an equivalent inter-institutional effort.

Canada´s political federal landscape is mostly pro-nuclear, with both major parties in favour of this technology and even the support of powerful unions to make this energy transition a reality. This stance contrasts with that of most countries, where nuclear energy is still being debated, as it is in Mexico. The Canadian government, led by Prime Minister Justin Trudeau for seven years, is consistent on environmental and climate change policies. Its vision has been transformed into policies that encourage collaborations with the territorial and provincial governments. Canada's SMR Roadmap and Action and Strategic plan provide not only each helix's steps for commercialization but also certainty and accountability for the actors involved, with commitment dates. Collaborative deliverables signal to technology vendors or developers to decide whether or not to keep investing resources in their technology.

In contrast, Mexico, under the leadership of Andrés Manuel López Obrador (AMLO) from the Morena party and for the first time in federal power (2018-2024), has mainly supported oil industries and invested in sectors that other countries are transitioning away from. While the energy secretary, Rocío Nahle, has stated her support for nuclear energy and SMRs, the federal administration shows no evidence of a genuine commitment to nuclear projects. This stands in stark contrast to the previous administration under the leadership of Enrique Peña Nieto from 2013 to 2018. Under this administration, the first energy reform was made after decades of stagnation. This energy reform diversified energy generation sources and focused on sustainability, while removing some of the power centralized in the national government companies that had monopolized the energy sector for decades. This shift enabled third parties to enter the energy market, increasing competition in the industry and making prices more competitive. Under this administration, in 2015, Mexico´s Development Plan outlined commissioning reactors to reduce carbon emissions [66]. These reactors were supposed to start operating in mid-2020. This never happened, nor has there been any official communication about these plans due to political opposition in both parties.

Mexico's AMLO administration has attempted to reverse the progress made with the energy reform, but this attempt was rejected by the Mexican Congress in early 2022 [67]. This rejection represented a historical moment as stopping the counter-reform involved the cooperation of all the other political parties in Congress.

While the broader implications of each country's historical energy agendas are out of this research's scope, they constitute a contextual baseline of a country's readiness to deploy SMRs. We can already observe a notable difference between the two countries and assume that their expectations and visions will impact the procurement and deployment of SMRs.

2.6 Relevant Policy for SMR Deployment

Although there are few policies on SMRs (for Canada only), the reality is that regulation of energy strategies and climate change action directly or indirectly influences the conditions for SMR deployment. Regulations may indicate that there is a significant share of nuclear technologies in the energy mix and the resource allocation needed to implement these technologies. This section describes some of the more relevant policies for SMR deployment.

In Canada, the most relevant and direct policy is, without a doubt, the 2020 Investments in Small Modular Reactor Technology [64]. This resource allocation recognizes the role of SMRs in a sustainable energy mix and indicates the government funding needed to make SMRs a reality. This investment in SMRs is also sustained in prior policies, such as the 2030 GHG reduction commitment, the Net Zero Emissions by 2050 Accountability Act and A Healthy Environment and a Healthy Economy Plan. These plans include Canada's efforts to reduce oil and gas methane emissions by 75% in 2050 and the Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (SOR/ 2018-66) [64]. The continuous introduction of policies supporting cleaner technologies like SMRs and those discouraging polluting technologies incentivizes institutions to innovate, promotes new institutions, and encourages existing businesses to reinvent themselves [29].

In contrast to Canada, Mexico has fewer substantive programs. These comprise the Special Program on Climate Change 2021-2024 and the Transition to Promote Cleaner Technologies and Fuel Use. The current policies stand out to open tender calls for third-party verifiers to control methane emissions from the hydrocarbon sector. The government, therefore, is not the only institution ensuring that businesses comply with the regulations for reducing GHG emissions. It shares this watchdog role with institutions from other helices, demonstrating that the Mexican government needs to address its operational limitations for energy transitions.

Although not as recent, the most relevant policy shaping the SMR Innovation Ecosystem in Mexico is constitutional article 27, which states that ""It also corresponds to the Nation to take advantage of nuclear fuels for power generation and the regulation of its applications for other purposes." [68]. Private individuals and institutions are prohibited from using nuclear fuels by concession, contract, or licensing. But the manufacturing of steam or radioisotopes for the private sector and civil society are considered exceptional cases in accordance with the strategic activities of the nuclear industry for Mexico in article 28 of its constitution. However, these still require the approval of the same few centralized governmental organizations in control of all nuclear activities in the country. Although this policy is not intrinsically harmful to the deployment of SMRs, it does favour actors in the government helix. This may demotivate entrepreneurs from starting companies outside the government, highlighting the governance limitations in this helix. As bureaucracy and red tape limit institutional capabilities, SMR deployment is likely to be slower when constrained to governmental institutions only rather than counting on governance diversity.

However, Canada has no similar limitation. In this ecosystem, the affiliated institutions are found in all the helices and can therefore form alliances regardless of their style of governance, taking advantage of each helix's strengths and adjusting for their limitations. The differences in Canada and Mexico's policy context and environment impact the formation of SMR Innovation Ecosystems. A brief description of each country's regulatory framework is presented in Appendix 2.

2.7 SMR Market Specifics

Although innovation can be studied using a general approach, each industry has peculiarities in its innovation process. These characteristics dictate the dynamics of the Innovation ecosystems, impacting the actors. To navigate these dynamics, a blueprint of the most general approaches to innovation should be used alongside the specific characteristics of the SMR. In other words, actors should take advantage of the advances made in all disciplines and fields to translate and apply that knowledge in deploying SMRs. Another factor to consider when studying energy innovation is that the energy field is unique because the final consumers of the energy all receive the same product, e.g., electricity, no matter how this energy is produced, its cost, efficiency, and sustainability. This specific field characteristic describes a complex business model that is not often considered in innovation frameworks that attempt to explain technology adoption, such as the Chasm [69] or the Traction Gap [70].

These complementary innovation frameworks are described in Appendix 3. Integrated Lifecycle provides a common understanding of the challenges for deployment, the Chasm [69] was designed for a Business to Consumer (B2C) business model and the Traction Gap [70], even more specifically, for a Business to Business (B2B) business model in the software industry with a subscription model. While they serve as a reference, their applications are inherently different from energy technologies such as SMRs that follow a Government to Consumer (G2C), a Business Government to Consumer (B2G2C) or even more complex business model, depending on their institutional governance or the type of economy they are part of.

Moreover, the marginal costs are significantly different from industry to industry, where there is "not much margin to reduce on the energy industry costs" upon deployment [6] (p. 63), as operating costs are always going to be there. This industry characteristic highlights an additional challenge to direct investments in these technologies over others with less risk and uncertainty, even if they do not follow an environmental priority. This challenge aligns with the insight of the venture capitalist Bruce Cleveland [70] (p.47), which emphasizes that entrepreneurs need to fulfill the expectation of both the product or service their niche market is expecting and "be or become" themselves the financial opportunity that investors are interested in.

The regulatory process for the commercialization approval of SMRs and other nuclear technologies is illustrated in Appendix 3: SMR Integrated Lifecycle. This analysis is my own, created from the graph presented by Sulveza [71], with the application of the appropriate regulatory framework [72], [73], as well as the frameworks for Technology Readiness Levels [74], The Chasm [69], and The Traction Gap [70]. In addition, the country flags represent a "you are here" symbology on their position towards deployment. Notably, none of the frameworks illustrated in Appendix 3 comprehensively covers the needs of technology and the support that these may require from start to finish, especially with sustainable innovations.

The appendix overlays the three frameworks for a better perspective, showing a dotted line, generally omitted in most models but correctly pointed out by Sulveza in his presentation on Innovation Management [71]. This line represents the negative profit faced by the institutions developing technology before financially recovering with commercialization. For SMRs, this dotted line should possibly be even more pronounced towards the negative due to the high costs of their development and the significant risk and uncertainty accompanying their investments. This dotted line is particularly relevant as it highlights the vulnerability SMRs face at this stage, where challenges are about to become exponentially different from everything they have experienced to date.

2.8 Our Current Stand Point

SMRs in Canada and Mexico have neither been licensed nor deployed [22]. While few SMR vendors are on the licensing pathway in Canada, the developers in Mexico are still far from a licensing or commercialization path and are still on the research and development pathway. According to the milestones published in the SMR Strategic Action Plan in 2022, the current SMR vendors in Canada have proposed tentative dates for deploying their technologies, as shown in Figure 2.9 below:

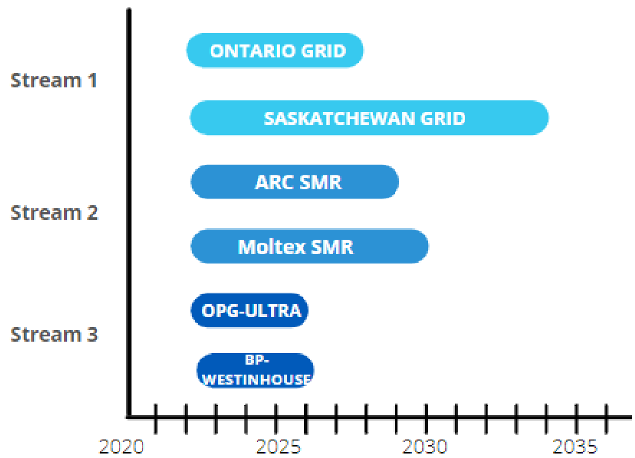

Figure 2.9 SMR Deployment Expectations
Source: [49]

The vendors have formed alliances that strengthen and facilitate their efforts, such as the current nuclear power generators with large-energy companies such as Ontario Power Generation and Bruce Power. Although the SMR Strategic Plan represents a formal commitment, with delivery dates and a certain degree of accountability by the actors, the regulatory process is especially long and unpredictable. Figure 2.10 illustrates the pre-licensing and licensing stages that SMR vendors face in Canada before deployment. Vendors in dark gray represent processes on hold, while the processes of vendors in blue are progressing.

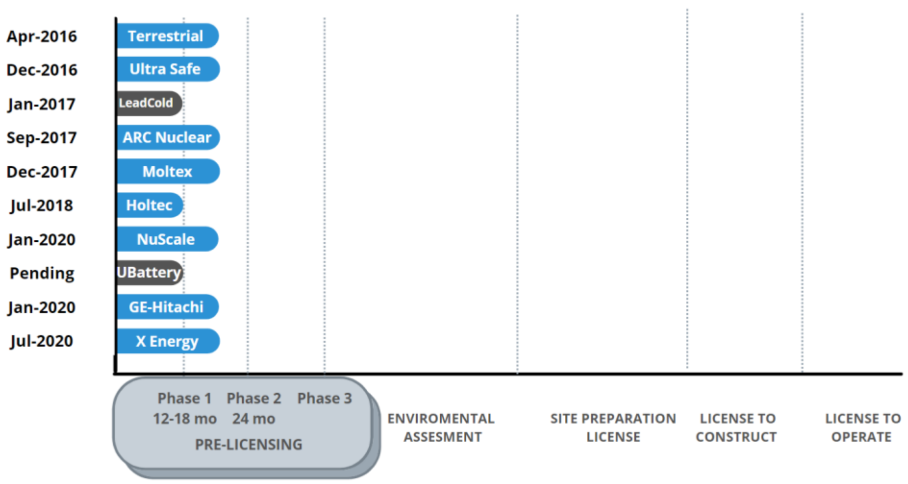

Figure 2.10 Regulatory Process for SMR Vendors
Source: [73]

The Canadian Nuclear Safety Commission [72], [73] (CNSC) provides estimates of time per process. From this estimate, the total time required for regulatory processes is at least ten years. It is also important to contrast these estimations with the real amount of time needed for these processes and the time it takes an SMR vendor to apply for the next phase of the process, in this case, phase 2 of the pre-licensing vendor process. All of this is displayed below in Table 2.2, the SMR Regulatory Timeline:

Table 2.2 SMR Regulatory Timeline

	CNCS Estimate	**Average of Real-Time**	**Average of Months from an Application to the Next One**
Phase 1- Pre Licensing	12-18 Months	30 Months	47 Months
Phase 2- Pre Licensing	24 Months	38 Months	-
Phase 3- Pre Licensing	"multi-year exercise, with a cost commensurate with the scope and depth of review" [75]		
Environmental Assessment	24 Months	-	-
Site Preparation License		-	-
License to Construct	32 Months	-	-
License to Operate	24 Months	-	-
Two-part Public Hearing Process	4 Months	-	-
Commission Decision-Making	90 days	-	-
TOTAL FOR DEPLOYMENT	**129 Months + Phase 3**	**155 Months + Phase 3**	**172 Months + Phase 3**
License to Decommission	24 Months	-	-

Source: [76]

Although supposedly the environmental assessment can be done within 24 months of the site preparation license, the real-time average was calculated from the available information from Arc Nuclear (24), Moltex Energy (42), and SMR LLC (24). As well, the standard of months to transition from phase 1 application to phase 2 was calculated from the available information from Terrestrial Energy (33), Ultra Safe (55), and Arc Nuclear (54). Notably, no vendor has yet completed Phase 2, but the timeline for Terrestrial already exceeds the 24-month timeline with an additional 14 Months (from its review start date to January 2022, which is the latest update on the CNSC website [73]). Other vendors have not reached the 24-month timeline yet. To better understand the characteristic process of SMRs, the relevant approaches have been superimposed for further analysis in Appendix 3.

In Mexico, regulatory institutions approving SMR designs face less pre-licensing work than their Canadian counterparts because early SMR designs do not comply with regulatory processes, the centralized policies discourage procurement of nuclear projects, and the public institutional infrastructure is often rigid and slow to change. For example, in Mexico, private companies are prevented from procuring nuclear technologies without government support [77]. However, SMRs represent a better opportunity for small generators (-500 kW) and clean energy (i.e., renewables or efficient cogeneration) than other nuclear peer technologies, as the regulatory burden is much lower, especially for off-grid solutions. SMRs require only a contract if they are connected to the national grid.

2.9 Potential Niche Markets

A new technology can be introduced from a business approach if a potential market for its consumption has been validated and the pilot in each phase of its innovation process can be adjusted accordingly. The global SMR market is forecast to be worth USD 10.42 billion by 2027, according to a new report by Emergen Research [78], and approximately 65-85GW by 2035 [79]. The latter is illustrated in Figure 2.11: SMR Global Market.

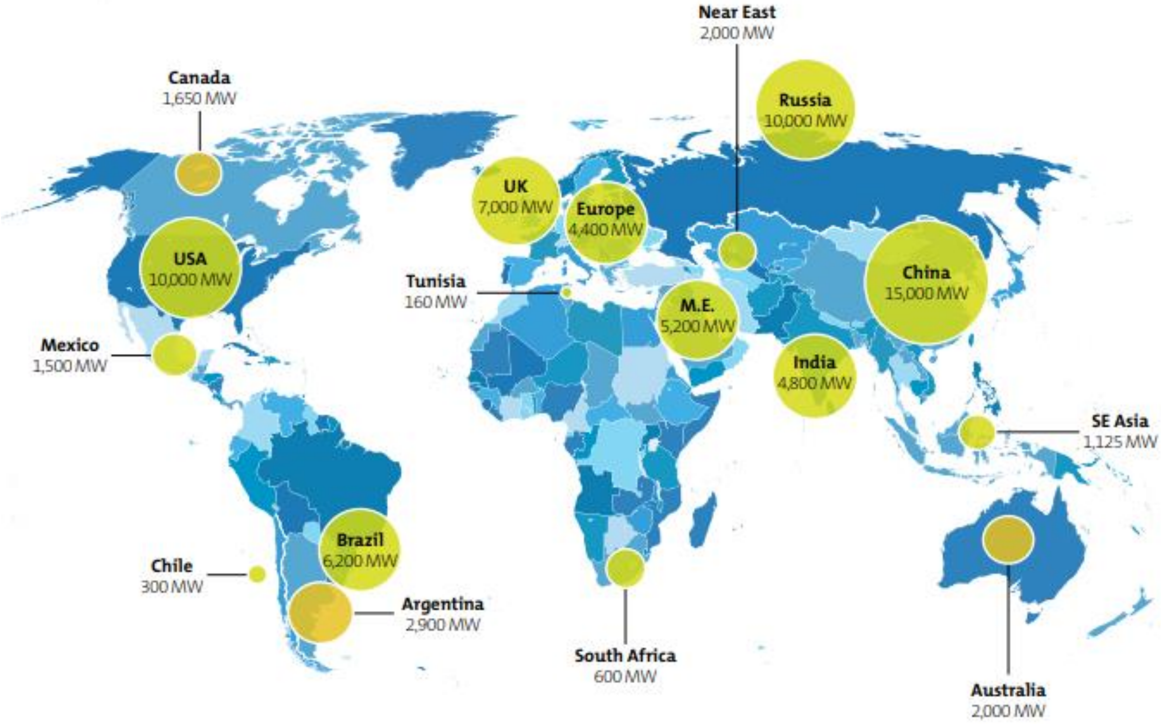

Figure 2.11 SMR Global Market

Source: [79]

Table 2.3 shows forecasts for the installed capacity for both Canada and Mexico.

Table 2.3 2035 SMR Forecast

Country	**Grid Size- Total Installed Grid Electricity Capacity** (MW, IEA projected 2035)	**SMR Installed Capacity** (MW, 2035)	**SMR as % of Grid Size** (2035)
Canada	179, 963	1,650	0.92
Mexico	109, 467	1,500	1.37

Source: [23]

Once a potential market has been validated, each country must know potential niches, given the needs of its jurisdiction. This is especially relevant since the SMRs have several purposes according to their model, and their procurement must match the model and the need to be covered. In addition to determining how to manage these niche needs with the appropriate technology, the contrast between Canada and Mexico allows us to obtain a glimpse of the managerial task required for global deployment, as what could be the biggest niche market for one country might be non-existent for the other. Although SNM approaches are individualized, a global approach must be managed to deploy this technology. This comparison serves as a basis or reference for replicating deployment strategies in other developed and developing countries. Besides markets and niche availability, SNM must consider the geological and hydrological conditions and the minimal distance required from volcanos and seismic zones.

Next, the categories of different market niches will be presented based mainly on the purpose of the different models of this technology, with the addition of a niche for Learning and Development because it is relevant in both countries for the consolidation of capabilities.

2.9.1. Desalination Niche Markets

Currently, there are at least 15 SMR designs targeting desalination. While fresh water is not a significant market in Canada, this niche represents an important opportunity for SMR deployment in Mexico, where 12% of Mexicans lack access to potable water and 97.7% of the water available is seawater [80]. Most SMR literature on deployment in Mexico focuses on desalination [81]–[84]. A 1965 study by Mexico and the United States Government recommended desalinizing water through nuclear reactors. Referring to northwest Mexico and the southwestern United States [85] (p. 12), Espinoza, Cueto and Oliveros argue, “If they had acted proactively back then [in 1965], the water supply problem would have been mitigated and in turn, boosted development in those regions [Mexico northwest and U.S.A southwestern].”

Some freshwater bodies in Mexico have been contaminated with salt water due to a lack of infrastructure or bad practices in water extraction [86]. At least 17 aquifers were detected in 2004 with saline intrusion in Baja California Sur, Baja California Norte, Sonora, Veracruz, and Colima [85], although other studies highlight a much higher number of affected aquifers, as illustrated in Figure 2.12 below.

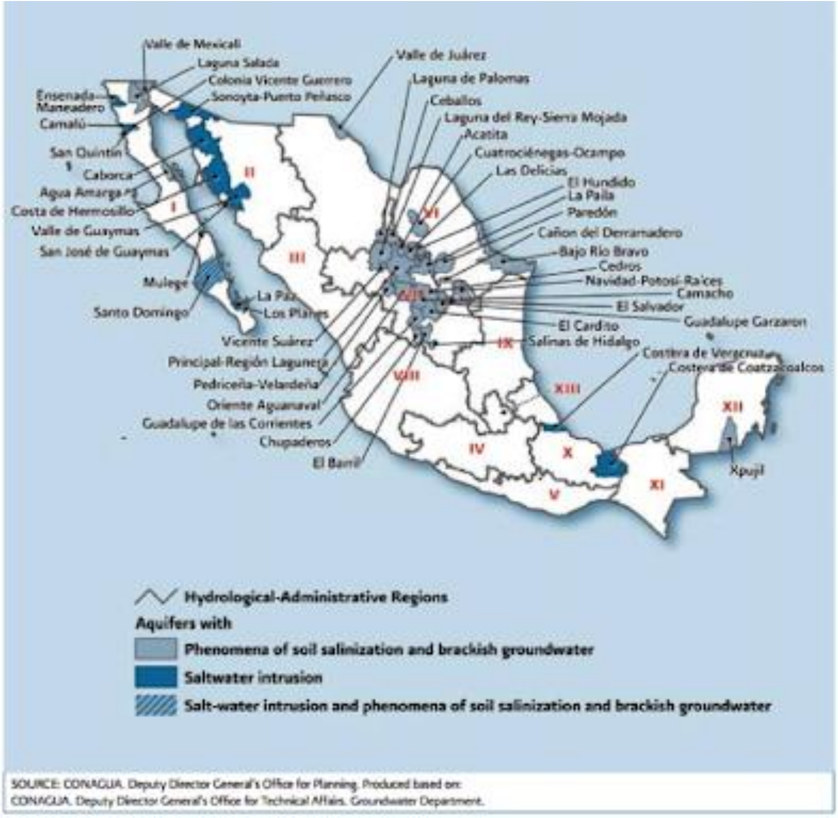

Figure 2.12 Salinization and Salt Water Intrusion in Mexico

Source:[86]

The paucity of studies on water salinization problems can be attributed to the Mexican government's interest in keeping these problems from the public, as salt water is free in Mexico, and the government could lose millions in freshwater contracts. In addition, salinization is a common bad practice in tourist areas, where hotels contaminate water wells with salt water to avoid paying for the water consumed. The current federal austerity policy has also limited the institutional capabilities of government actors, such as the National Water Commission in Mexico, which regulates this natural resource and manages it according to exploration studies of land for which no federal budget has been prepared for ten years.

The most advanced SMR proposal in Mexico is a desalination model with proposed implementation in Isla Coronado Sur, an inhabited island east of the Baja California Sur State on the peninsula, as illustrated in Figure 2.13.

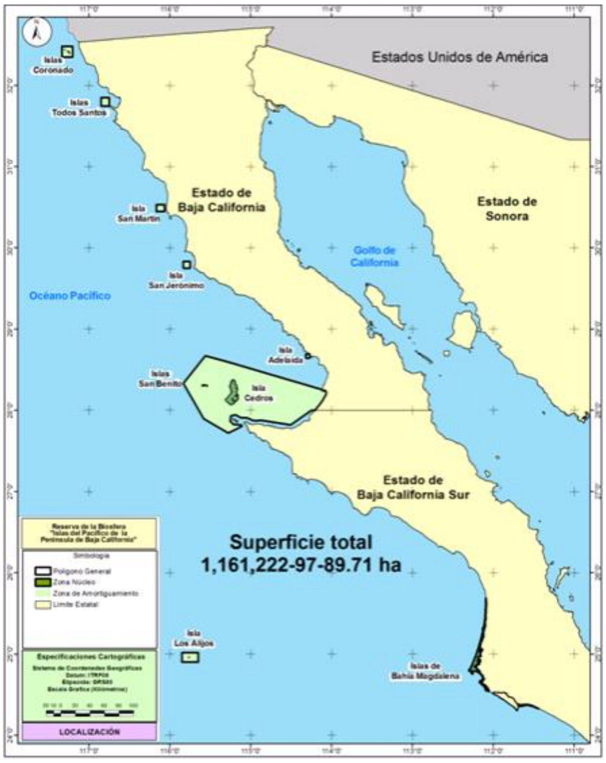

Figure 2.13 Coronado´s Island Location
Source:[87]

2.9.2 Local Electricity Niche Markets

Currently, there are at least 12 SMR designs with local electricity generation as their target application. This is a niche in which both countries have a significant market opportunity, especially since one of the prominent segments in this category is remote and off-grid areas in need of electricity, the majority of which are indigenous communities. This segment is especially relevant because not only is a need validated, but also intervention means fewer barriers to entry by not competing against an existing actor and its percentage of market share in a particular area.

On the one hand, for Canada, the literature identifies communities with at least ten dwellings not currently connected [24], as well as 319 communities without electricity in the Remote Community Database [88], of which 75 are in British Columbia, 45 in Quebec, 38 in Ontario, 37 in the Northwest Territories, 29 in the Newfoundland & Labrador, 25 in Nunavut, and 21 in Yukon. These are illustrated in Figure 2.14 below. Notably, each of these small communities could be the recipient of an SMR whose power is more than enough to guarantee their energy security.

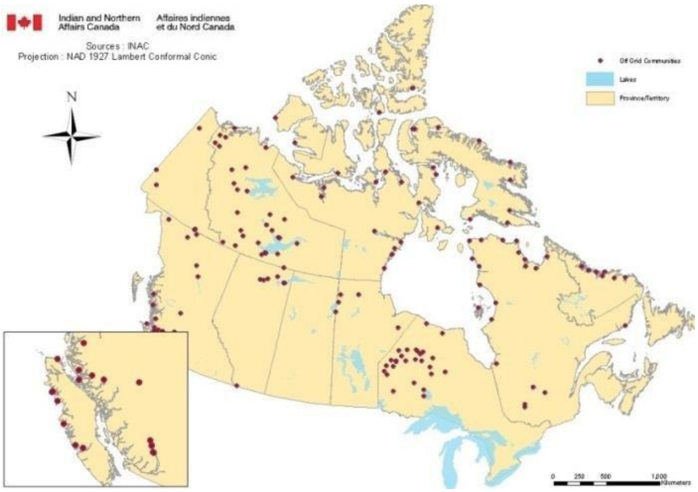

Figure 2.14 Remote Communities in Canada
Source: [89]

The Canadian Nuclear Safety Commission is currently working on a case-to-case modus operandi. These cases would challenge a managerial approach because they require deploying several niches, for example, to 50 remote communities simultaneously rather than in single projects. However, there is little evidence of risk assessment under these conditions or beyond a case-by-case application. This is an important area for further research.

On the other hand, for Mexico, several scholars have identified niche markets that require more electricity than what is currently being generated. The main focus of the literature is Mexico´s peninsula [85], [90] in the states of Baja California and Baja California Sur in the country´s peninsula, as they are not part of the interconnected electrical system that connects the rest of the Mexican territory. In addition, the National Electricity Sector Development Program 2015-2029 proposes an electric interconnection line between Sonora and Baja California [91]. The geographical distribution of the electrical systems is illustrated below in Figure 2.15. Other literature has focused on the northwest region of Mexico [81], [83], [84], as Sonora and other northern states require a higher capacity of what is already being generated.

Figure 2.15 National Electrical Systems

Source: [92]

It is estimated that there are around 7 million Mexicans without electricity in rural areas and at least 3,954 communities without electricity in the entire country, which is more than ten times the number of communities with equivalent circumstances in Canada. These are illustrated in Figure 2.16, where the yellow dots represent 5-50 dwellings without access to electricity, the orange dots 50-100, and the red ones more than 100 dwellings without access to electricity.

Figure 2.16 Localities with Homes without Access to Electricity (2020)

Source: [93]

2.9.3. Co-generation Niches

Cogeneration refers to generating electricity and heat simultaneously from the primary source of energy, and it is especially relevant for energy efficiency as the heat increases from 100% to 200% of the electricity outputs [94]. This characteristic represents a tremendous market opportunity for SMRs, given that they can use these other primary generation sources and complement their modularity to increase the energy generated by these processes. This category has different applications, such as district heats, process heats, steam, offshore oil, and oil sands. There are at least ten SMR designs for district heat, six for process heat, five for steam, two for offshore oil and one for oil sands.

For district heat, 57 energy systems were operating in Canada in 2015, of which 77 have fewer than 20 MWe capacity[24]. In terms of process heat, there are currently 216 cogeneration plants in Canada [24], highlighting their application in universities [94], hospitals, paper and chemical manufacturing industries, as well as in oil refining and gas extraction fields [24].

No equivalent estimation was found for Mexico in the literature; however, the literature indicates that district heating is needed in the states of Mexico City, Monterrey, and Guadalajara while cooling districts are required in northern states [95] due to extreme temperatures becoming more common and the not prepared housing infrastructure. Mexico has a strong potential for cogeneration [81] [84], which is expected to contribute to 3.6% of the installed capacity between 2018 and 2032 [95]. Interestingly, 60% of them come from the iron, steel, chemical, cement, and mining industries [74]. Some industries where cogeneration is underused are hospitals, restaurants, hotels and malls that need heating and cooling and the Mexican sugar industry [85].

In both countries, mining and oil sands can potentially benefit from cogeneration with SMRs. Canada has at least 1,000 operating mines, of which 32 are off-grid [24]. Of these, five are found in Yukon, four in the Northwest Territories, two in Quebec, one in Nunavut, and one in Newfoundland & Labrador. Canada has a total of 267 transnational mining companies [96] and 19 proposed off-grid mines. Off-grids have power requirements under 200 MWe, perfect for SMR capacities, and most of them currently use diesel power [24]. The geographical distribution of mines in Canada is illustrated below in Figure 2.17. In this image, the red dots belong to the top 100 exploration projects, green ones to metal mines, yellow ones to non-metal mines, gray to coal mines, purple to gold and precious metal mines, brown to iron mines, dark green to uranium, and mines as part of the metal mines category, and aqua blue to diamonds mines as part of the non-metal mines. In addition, there are at least another 1,558 operating mines in Mexico, where the United States owns 87% of the concessions generated from 2019-2021. Mexico has 960 approved projects in Cuenca de Burgos, which can be seen in Figure 2.18 in the denser dot population in the center of the country.

Figure 2.17 Mining and Oil Extraction in Canada

Source: [97]

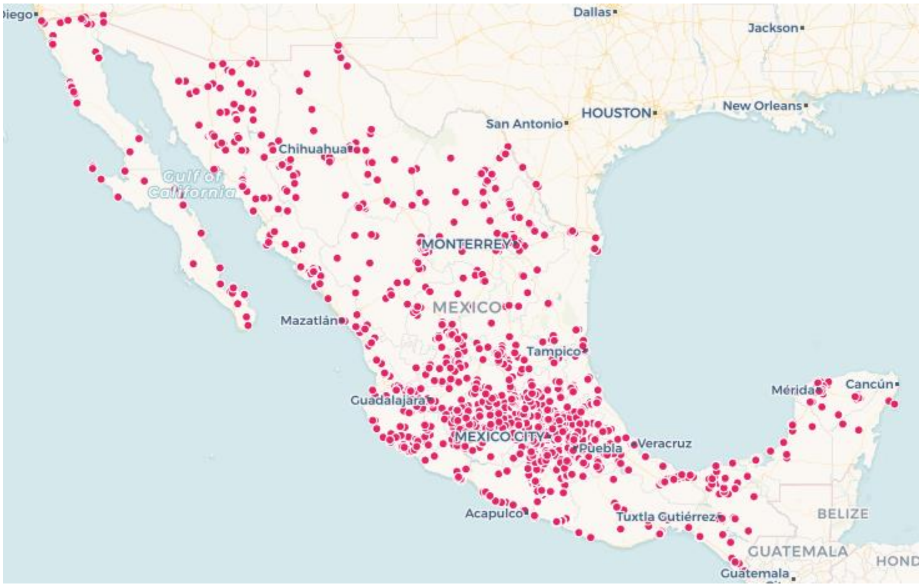

Figure 2.18 Mining and Oil Extraction in Mexico

Source: [98]

Finally, both countries have a niche market for SMRs in offshore oil extraction. In Canada, there are at least seven operating projects and eight approved projects. It is estimated that 21 SMRs of 300 MWe would be required to meet the 2025 demand for surface extraction alone[24]. In addition, in situ extraction has 31 operating projects with 55 other approved ones, which would require 21 SMRs of 300 MWe and upgrading facilities estimated to need 16 to 45 other 300 MWe SMRs [24]. Figure 2.19 illustrates Canada's offshore oil extraction projects.

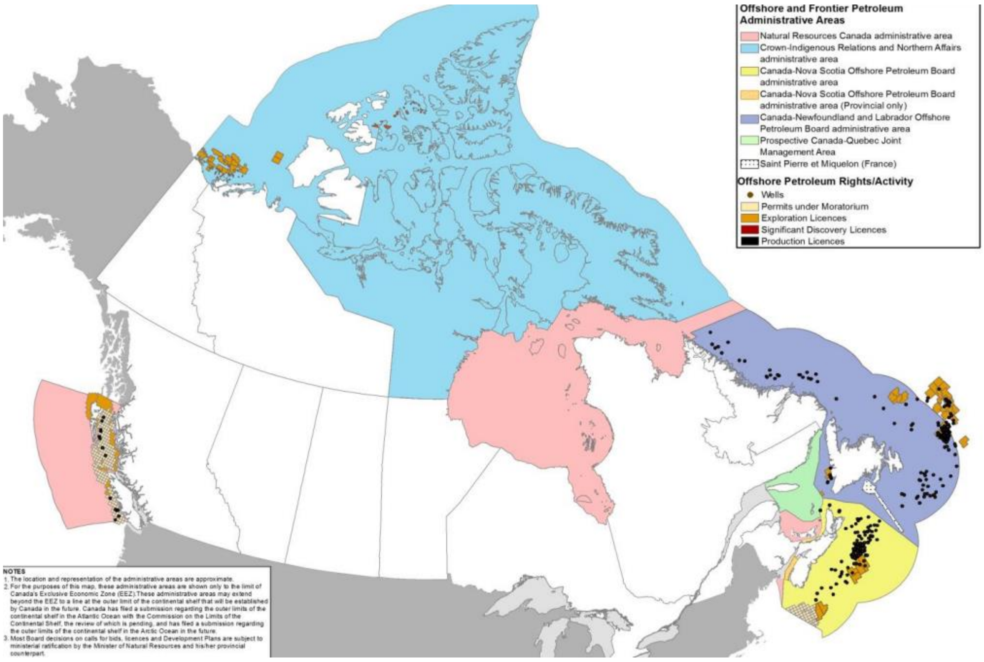

Figure 2.19 Canadian Offshore Oil and Gas Regimes

Source: [99]

In Mexico, the central niche is on the Gulf of Mexico [100], [101], as illustrated in Figure 2.20. In this figure, the darker blue represents more depth in the waters.

Figure 2.20 Offshore Extraction Sites in Mexico

Source: [93]

2.9.4. Marine Propulsion

Another application for SMRs is marine propulsion, for which their size is ideal. In 2014, the marine industry contributed 2 billion to the Canadian GDP for a mix of commercial and defense purposes. Around 50% of the sales are made to the Canadian Federal Government, and 6.5% of these are destined for ship power and propulsion [102]. In Mexico, the Navy plans to build 36 ships in the next four years [103], but aside from local builders of boats for tourists and fishing, there is very little boatbuilding in Mexico [104]. The United States is the largest supplier of this industry in Mexico. These trends in both Canada and Mexico reveal a good opportunity for the procurement of SMRs since the government helix would be the purchase decision-maker, and the pressure can be directed to procure SMRs as the propulsion option for these acquisitions.

2.9.5. Learning and Development

When SMR technologies have been introduced but not deployed, the institutions betting on this technology make great efforts behind the scenes. Institutions will work on strengthening their institutional capabilities to be prepared when the opportunity window arises. In this sense, institutions are malleable and responsive to their external conditions and pivot around finding the best practices that allow them to increase their chances of succeeding in their deployment endeavours. The knowledge generated by this learning process possesses great value as SMRs are to be deployed for the first time, and the policy surrounding their commercialization was not built for SMRs.

For example, the proposal for an SMR for research and development currently goes through the same pre-approval regulatory process as for a large nuclear project. The regulatory framework is rigid and does not reflect the wide gulf between the risks of the different models of nuclear technology, nor for those of commercial and non-commercial undertakings. Under this confining and long regulatory framework, there are no real incentives to prefer SMRs over larger nuclear projects for research and learning purposes.

This is especially relevant considering that the current regulation was created without considering the present urgency in deploying this type of technology due to the climate crisis and the importance of simultaneously increasing the number of specialized talent to carry the transition.

In contrast to the Canadian scenario, in Mexico, article 27 of the Mexican constitution, where nuclear power generation is centralized in the federal government, is believed to have also influenced and nudged the actors to professionalize this industry from the helix of Academia. This can be seen from the fact that the number of reactors in the country for learning, research and development purposes doubles the number of operational reactors. It is also important to mention that this centralization of all nuclear applications indicates that all institutions belong to a governmental or public structure, also applying to medical applications for research and development and producing radioisotopes. These, in particular, can go through an exhausting process of licensing and authorization (heavily influenced by Mexican bureaucracy, red tape, and assumed corruption), also in charge of the same central federal institutions. This, in turn, questions the capabilities of Mexican public institutions to propose, finance or implement a nuclear project for their territory, considering its long-term nature, significant investments and high uncertainty, as well as the panorama of economic, political and society of the country and its institutions. As well as the capabilities of these public institutions to reform themselves or trigger the creation of new institutions or specialized units within the existing structure responsive to potential market formation.

In addition to the procurement of brand-new SMRs for learning and development, another niche market is the replacement of learning and development reactors. In other words, when a reactor for this purpose has completed the years that the safety standards indicate that it can continue operating, these can be replaced with SMRs. This is the case, for example, with the reactor of the Saskatchewan Center for Cyclotron Sciences operated by the Fedoruk Centre. Under this category also stands out the innovation strategy of the province of New Brunswick, with a peculiar niche focused on research and development and the demonstration of this technology, activities that in turn contribute to the formation of specialized human capital that increases the province's competitiveness, and therefore, their deployment capabilities.

2.10 Social Networks

Innovation Ecosystems are social networks. Whether they are mapped, measured or managed, social networks exist and contain valuable information about how we interact, share information and decide to act, or not, towards a cause. Social networks are graphs that highlight the actors of a network and its interrelations. These graphs are constructed under a graph theory framework that utilizes matrices to communicate with specialized software whether a relationship exists between a given pair of actors or not.

These are composed by:

- Actors, technically referred to as nodes
- Connections, technically referred to as edges

The broader conception of actors is any individual or collective of individuals through institutions. Some literature focuses on "different kinds of firms, universities and research institutes, financiers, consultants, associations, private consumers and public facilities with different competencies, resources and strategies" [13] (p.1033), "Public Bodies, Influential Interest Organizations, and Organized Civil Society, among others."[105] (p.413). This research focuses on the institutional setting instead of an individual or multilevel approach, which combines the individual and institutional settings, adding complexity to the networks but containing deep and meaningful information.

Edges refer to the relational forms in which the nodes are connecting. A relational form is "a property of relations that exist independently of any specific context" [30] (p.11). A relational form differs from the content of a network as it provides a broader snapshot beyond purposes, interests or motives that group a series of actors or nodes. Some collaborations involve buyer-seller or university-industry links, professional networks/associations, public-private partnerships, co-patenting and co-publishing [105] (p.413). Other c relational forms can be between actors competing, suing or lobbying, as indeed, "conflicts and tensions are part and parcel of the dynamics of innovation systems"[105] (p.408). These relational forms were categorized by [30] into transaction, communication, boundary penetration, instrumental, sentiment, authority/power and kinship relations and for this research, the focus was mainly on transaction relations, whit a few exceptions in the authority/power relations elaborated in the boundary section of the methodology. Recalling that "Actors do not necessarily share the same goal, and even if they do, they do not have to work together consciously towards it (although some may be)." [105] (p.408). Non-consciously teamwork is a general characteristic of social networks, where the nodes are often not even aware of their affiliation to a social network or that their action or inaction impacts the broader set of institutions of a network. This unawareness is especially relevant as "network geometries are often invisible to those participating, nurturing or even harming the network" [31] (p.95).

These geometries were previously addressed as the structures or network compositions, which refer to the patterns that social network graphing recalls. These are technically referred to as the "topology" of a social network and are "crucial for deciphering everything about social change: how and when game-changing technological innovations take off (…)"[31] (p.27). This topology is especially relevant as it visually illustrates a distinction made by Granovetters in [31] between *weak* and *strong ties*. As shown in Figure 2.21, Centola highlights that firework displays showcase weak ties networks, while fishing nets reflect strong ties. It is important to emphasize that weak or strong ties do not necessarily translate into bad or good networks; each poses different characteristics that serve better distinct purposes.

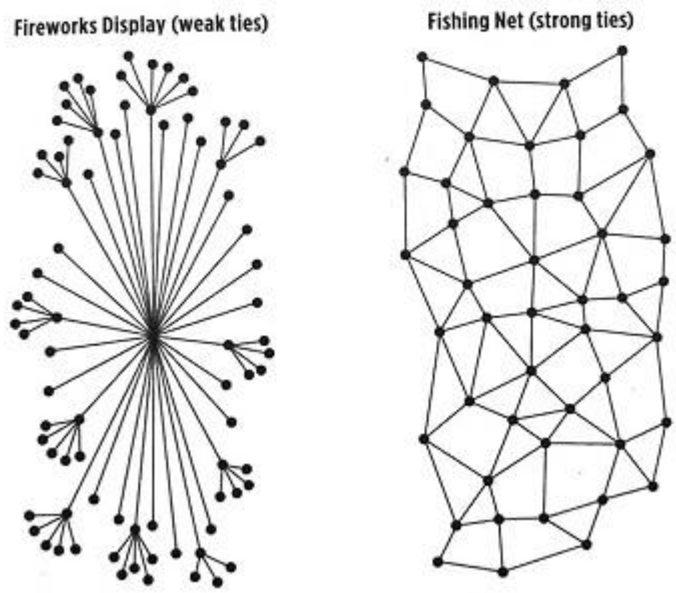

Figure 2.21 Network Geometry

Source: [31]

Moreover, Centola insists that the key to understanding the success behind social networks is "the pattern of network connections that underlie strong and weak ties" [31] (p.88). This combination is important as contrary to idealistic belief: "weak ties do not evolve to strong ones"[31] (p.41), and they are themselves the vehicles to deploy SMRs, both with their challenges and unfair advantages.

Translating this into SMR innovation ecosystems, policymakers should not try to replicate successes from developed to developing countries but work with their structural limitations and take advantage of their differences to remedy these limitations. In this sense, the further analysis of Canadian and Mexican SMR ecosystems does not mean comparing which one is better but highlighting how ecosystems can be addressed from a landscape managerial approach and strengths and weaknesses can be pointed out objectively towards SMR deployment.

Another important factor to consider is that the *centrality* of a node within a network determines the degree to which it can influence other institutions [29], [106]. Different measurements of a node's centrality in Social Network Analysis are explained in Table 2.4 Centrality Measures of a Network for both directed and undirected networks. It is worth remembering that all networks are undirected for this research.

Table 2.4 Node Level Centrality Measures of a Network

Network Measures	**Definition**
Betweenness Centrality	For undirected networks, betweenness centrality measures the extent to which "the actors fall on the geodesic paths between other pairs of factors in the network" Hanneman & Riddle, 2011, p. 366
Eigenvector Centrality	Commonly used for undirected networks, eigenvector centrality "count the number of nodes adjacent to a given node but weight each adjacent node by its centrality" Borgatti et al., 2013, p.168

Source: Adapted from [29]

In addition, Centola also highlights that *nodality* (the centrality of a node in the graph) is just the beginning of the analysis as this does not translate into adoption due to a very peculiar behavioural phenomenon: the effects of *redundancy*. Redundancy stresses that a well-connected node does not necessarily reflect a wider reach, which is the "key to success" [31] (p.110), as highly connected nodes often share the same connections, limiting the spread to the same interest group. To explain this, Centola emphasizes trust and strong ties, as "strong ties are often tied together" [31] (p.53). Although these findings challenge the previous assumptions on the statistical measures SNA provides, they also highlight a behavioural phenomenon that pushes us beyond our biases and cognitive limitations.

Moreover, I would like to invite the readers not to underestimate weak ties or fireworks networks because, as Granovetter [107] in [31] (p.97) states, "information spreads much faster in firework networks." Centola conducted experimental research with firework structures (weak ties) and fishing net structures (strong ties) to test both network structures. The experimental design involved six pairs of networks unaware of the invisible connections between each other or groups. These networks were provided with information regarding a health application, information about it, and hyperlinks to try the app themselves. In this sense, the patterns of information spreading and technology adoption could be monitored and tested.

Results in all six pairs of networks indicate the same results: on the one hand, firework networks (weak ties) spread information at a much faster pace but do not translate knowledge into action or its adoption. Centola highlights that "despite all the people who had been made aware of the innovation, actual uptake was lagging" [31] (p.96). On the other hand, fishing nets (strong ties) were "painfully slow at first" due to redundancy in the nodes; however, although a slow diffusion of information, it showcased a faster adoption spread. The conclusion was unanimous "although information spread faster in the firework networks, significantly more people adopted the innovation in the fishing nets."

Social Network Analysis often focuses its attention on social stars [31]. These are with the actor's centrality in the graph and are assumed to be catalyzers of large-scale spreading and influence among the network. However, they could also be consciously or unconsciously preventing it. These attributions are questioned in the literature to know if the "existence of a network actor is a strength (…) or a weakness" [105] (p.409). Although it is an interesting analysis, being able to answer it for certain would require a higher level of complexity, which is outside the scope of this document. However, actively invite readers to consider the central actors without falling into idolizing them objectively.

Furthermore, recent behavioural studies have also analyzed the differences between peripheral actors and social stars [31]. Results again challenge popular beliefs and indicate that highly connected nodes are not the drivers when it comes to social change, and in fact, "the network periphery is where all the action is" [31] (p.33). For this research, both central and peripheral actors will be exposed for each network, and it will be the discernment of the reader or policy maker where to allocate the resources according to the information presented here about both sets of nodes.

In addition to actor's centralization, another phenomenon allows identifying where there are important nodes for the network: bridges. These refer to the node connecting different social clusters or network communities that otherwise would not be connected. Bridges are then classified into narrow and wide bridges, which refer to the number of connections between the actors or clusters of a network. This is illustrated in Figure 2.22 below:

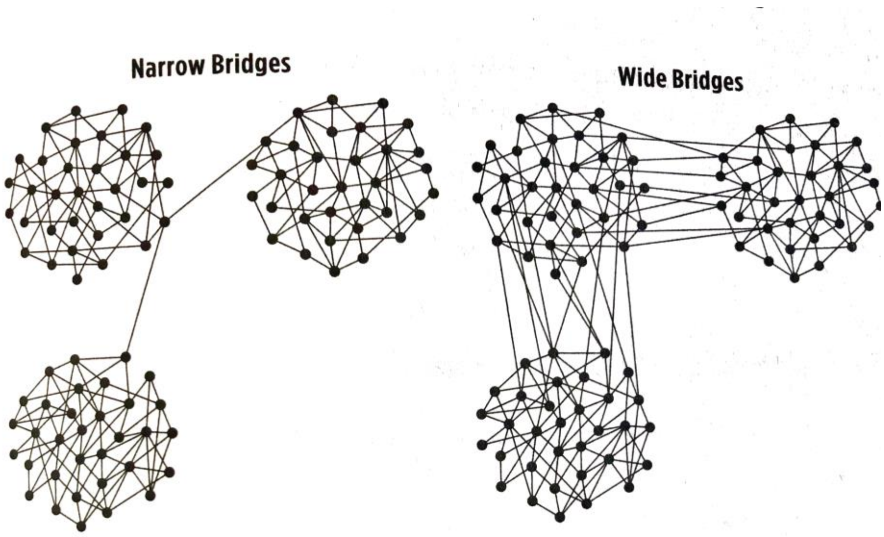

Figure 2.22 Narrow and Wide Brides

Source: [31]

The last relevant measure for the subsequent analysis is the density of a network; this “is calculated by summing the entire population of potential ties (n(n-1) where n=all nodes) as compared to the actual population of unidirectional links (m/n(m), where m= set of all edges or links).”[106] (p.24. A graphic visualization is presented below in Figure 2.23:

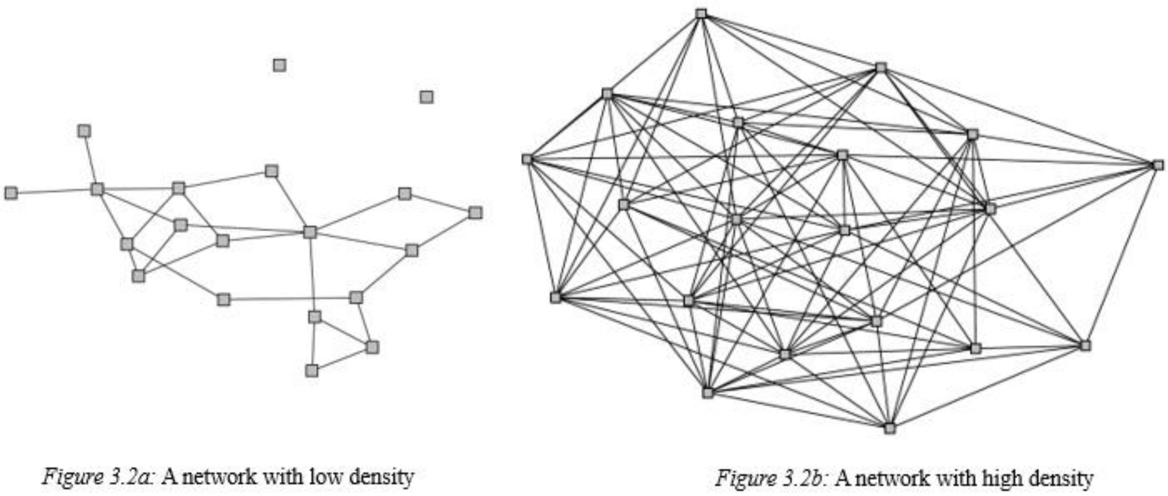

Figure 2.23 The Density of a Network

Source: [29]

Chapter 3. Methodology

SMR ecosystems are made of relational networks of heterogeneous actors that define the dynamics of a given market and are relevant to the governance of small modular reactors' technology and the policy behind their promotion and deployment. Three different snapshots of the network structure per country were developed through Social Network Analysis: a whole network, a key actors' network, and the whole network minus the five most centralized actors. The base for this research was the whole network as the key actor's snapshot, and eliminating the five most centralized actors in each country was taken out the same collected data for the whole network. The information collection period comprises the months of April and May 2022 and can be found in appendices 19 to 22.

3.1 Whole Networks

These actors are then mapped through a snowball sampling of affiliated organizations in the relational form of:

1. Transactional Relations

    1.1 Self-Declared Collaborations

2. Authority/Power Relations

    2.1 Hierarchical Subordination *

    *(only when they showcase new institutions formation as a consequence of the consolidation of the SMR ecosystem, these include SMR specialized units, the funding of a nuclear-related institution that responds in their governance to the funding institution or a joint venture that is considered to reflect the strengthening of the ecosystem)

The relations were assumed upon self-declared collaborations in the different information sources:

On the one hand, the initial institutions for the Canadian context are congregated on the website of the SMR Action Plan, with individual web pages for each participating institution explaining their role in the roadmap for the deployment of SMRs in Canada. All 119 institutions listed in the SMR Action Plan, including international actors, were considered for their explicit participation in the Canadian context. The SMR Action Plan provides information on the role of each institution in the deployment of SMRs in Canada and provides individual links to each participating organization's information, which served as input for a content analysis looking for self-declared collaborations. While collaborations can exist beyond what is described in each institution's description, this approach reduces the researcher's bias in delimiting inclusion or exclusion criteria, also known as boundaries in social network analysis.

On the other hand, there is no equivalent to the SMR Action Plan to start the mapping with officially recognized actors for the Mexican context. For this case, the information was collected primarily from the International Nuclear Information System (INIS) under the search of the words small modular reactors and Mexico, thoughtfully excluding the results alluding to New Mexico. Some variations included the abbreviation SMR or the equivalent in Spanish for *reactores modulares pequeños* or *RMP*. While the data collection for the Canadian context was more concentrated in the SMR Action Plan, it is important to mention that the information there had no structure for data collection or management and required a manual content analysis of the information there listed, while for the case of INIS for the Mexican context provided more curated data in terms of the participating institutions for each entry, which were considered as the collaborations for the data collection criteria. Furthermore, complementary searches were done in the broader google searches under the same word search criteria, which corresponded mainly to news about the federal government's plans towards SMRs in Mexico and also to a Doctoral thesis on an SMR design at the *Universidad Autónoma de Zacatecas*, which is by far the most relevant contribution of the Mexican ecosystem in the Research and Development of SMRs and which was not part of the INIS database.

For both countries, data collection Higher Education Institutions (HEI) were not considered when they were only mentioned to list where their employees graduated, which appeared repetitively on the content analysis and could be subject to further research. In addition, institutions only mentioned for reporting or hosting events are not considered without an evident collaboration stated throughout the content analysis. Likewise, although sometimes the location is expressed in the individual web pages, no connection is automatically assumed with their respective governments unless explicitly defined otherwise.

All institutions were registered in the node list regardless of the absence of self-declared collaborations, which was a recurring case for the Canadian context for six institutions of the 119 listed and non-existent for the Mexican context. In other words, they were registered in each country's node list (the spreadsheet page where the actors are enlisted), but isolates did not make it to their respective edge lists (the spreadsheet page where the relations are enlisted). These also respond to cleaning and preparing the information so that the software can analyze it. All networks are graphically represented in the form of undirected and unweighted ties, as the type of connection of self-declared collaboration implies mutuality in the relations. The networks were generated with the software Gephi 9.5, using a Force Atlas layout and with the only modifications to their initial setup in their repulsion strength from 200 to 10,000, as mentioned in the manual of use for improved visualizations [108]. The scope of this research focused only on inter-institutional collaborations and excluded the analysis of individuals

Each actor was assigned a unique identifier from 1 to 999 for Canada and from 1,000 onwards for Mexico. Although the information for each country was collected on different sheets of the same file, some actors have a presence in both ecosystems and respect the identifier given in the Canadian list. This is independently also in the variation of their institutional names in the corresponding languages. The scope of this research focused only on inter-institutional collaborations and excluded events or initiatives without institutional belonging. Under the collection process, some initiatives with very formal names were captured on the node list of each country, and they were removed from the edge list upon a further research on their individual web pages and confirming the lack of an institution behind these initiatives. Other exclusion criteria or out-of-boundaries for this research are decommissioned nuclear utilities as of July 2022 and in-depth uranium supply chain relations beyond the currently mapped organizations. In addition, media and social media were not considered part of the networks unless part of the SMR Action Plan.

The methodological boundaries were defined before the information collection and contemplated similar initial boundaries for both countries, with a slight variation in applying consequent limits for both countries, as illustrated in Figure 3.1. This figure illustrates the number of actors that stands out for their notable difference between the two countries and that guided the decision-making about the sampling boundaries, or the methodological decision before making any graph, to define the scope and limitations of each country, specifically with international institutions. While the information was scarcer in the case of Mexico, and the participation of international organizations has great weight for the country's nuclear innovation ecosystem, no exclusion was made under this criterion. In addition to not having a reference instrument such as the SMR Action Plan, it would represent a significant bias to define which institutions are considered and which are not with the current information available. In this sense, in the case of Canada, the SMR Action Plan validated which international institutions would be considered in the sample and which would not. This means these were only included if they were in the initial list of 119 institutions and not those mentioned as self-declared collaborations on their individual pages. Although this information was captured in their respective node lists, the information relevant to these nodes was deleted from the edge lists. These kept their unique identifier to ensure their connections were removed.

Country	SOURCE	DOMESTIC	INTERNATIONAL	TOTAL	
Canada	SMR Action Plan	✓	✓	119	339
	Individual 119 webpages of the SMR AP and their declared collaboration additional actors	✓		220	
Mexico	International Nuclear Information System (INIS)	✓	✓	55	87
	Complementary web searchers	✓	✓	32	

Figure 3. 1 Data Collection Boundaries per Country

3.2 Key Actor Networks

Furthermore, from the information collected for the whole network of each country, information was extracted to obtain a more detailed snapshot of the already available data.

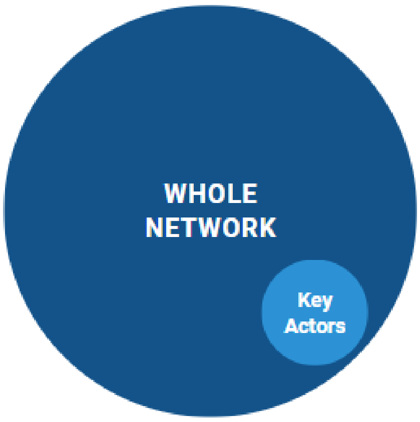

Figure 3. 2 Key Actors Network Rationale

The criteria to select which of these actors would correspond to key actors for each country are illustrated in figure 3.3 below. No SMR vendors are considered for the Mexican context as the designs are premature to be considered at a commercialization point. Furthermore, the current utilities and research and training rectors are only considered for Mexico due to the relevance of these public and centralized institutions for deploying SMRs in the country, and as such, dependence is not found in the Canadian context.

	CANADA	MEXICO
R&D	✓	✓
SMR VENDORS	✓	
Nuclear Utilities		✓
Training and Research Reactors		✓

Figure 3. 3 Selection Criteria for Key Actors

3.3 Whole Networks Minus their 5 Most Centralized Actors

The study on distributed governance[28], used the exercise of removing a certain number of the most central actors to measure the effect that such nodes have on the network composition. The effect of the loss of such actors reflects the rest of the network's vulnerability or resiliency to their removal. In these figures, the same general base of networks is used, with the difference that the five main centralized actors of each mapping are eliminated. This implies removing any relationship that these nodes occupy in the edge list of each country to get a new snapshot with Gephi under the same layout and setups as the whole original network.

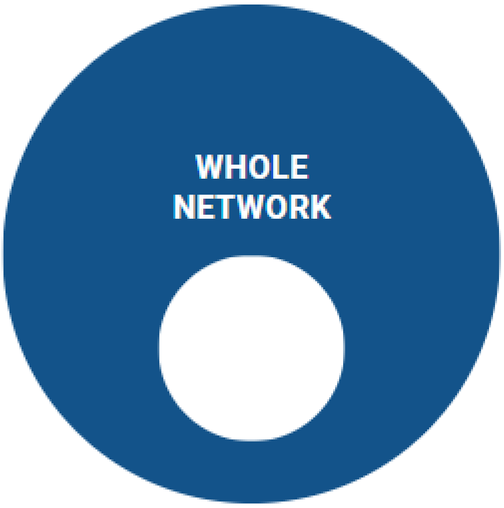

Figure 3. 4 Whole Network -5

Chapter 4. Results

Three snapshots per country were conducted: A whole network snapshot, a key actors snapshot and the elimination of the five most centralized actors from the whole initial network for comparison. The six networks' statistical analysis can be found at the end of this section.

Starting with the snapshots for the Canadian SMR ecosystem, figure 4.1 below belongs to the whole network of the Canadian ecosystem. This network comprises 339 nodes (actors) and 741 edges, with a network density of 0.022. The network structure is visually more similar to a fishing net display rather than a firework display, with intense activity conducted by the network's central actors but with a repeated pattern of branching on the peripheries of the network. This network has a diameter of 7, with an average path length of 3.198.

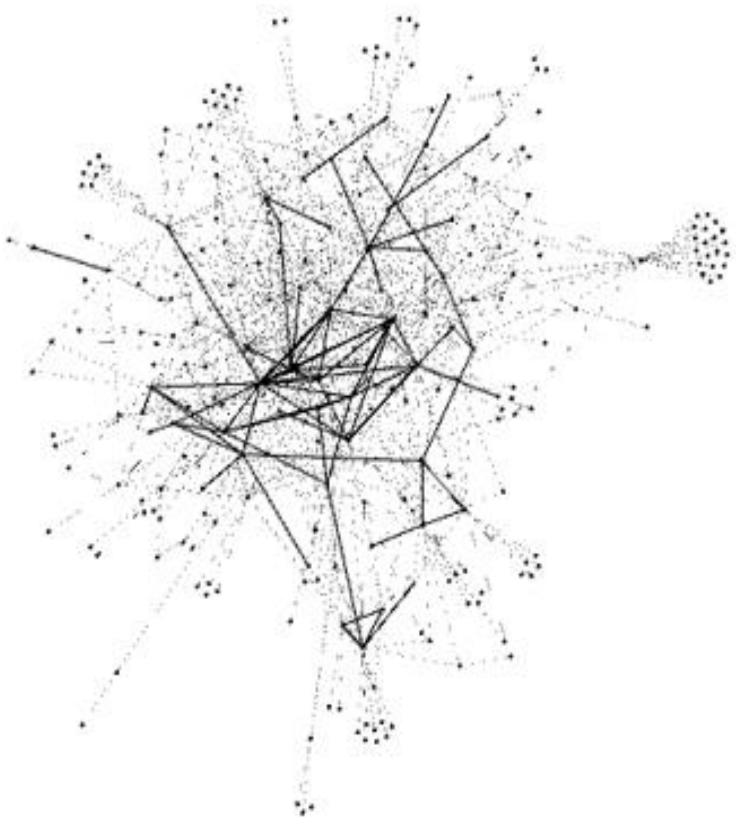

Figure 4.1 Canadian SMR Ecosystem; Whole Network

Figure 4.2 illustrates the key actor's snapshot of the Canadian ecosystem. This network comprises 59 nodes and 121 edges, with a network density of 0.58. The structure of this network repeats the fishing net pattern and the branching peripheries of the network.

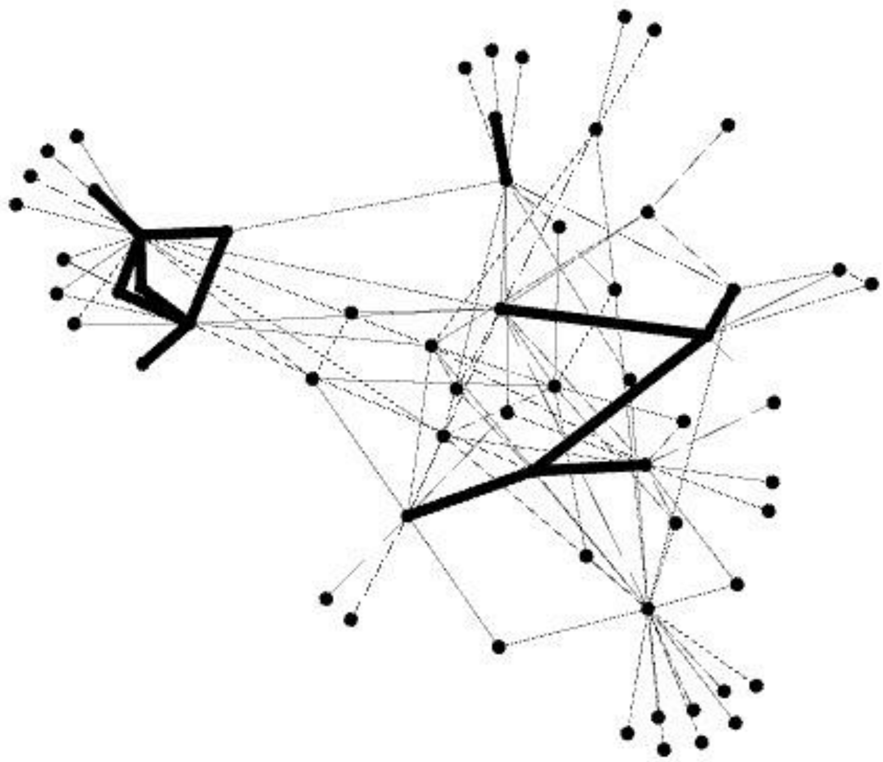

Figure 4.2 Canadian SMR Ecosystem; Key Actors

Figure 4.3 illustrates the removal of the five most centralized actors of the whole network snapshot of the Canadian ecosystem. This network comprises 334 nodes and 648 edges, with a network density of 0.021. The same fishing net structure and branching peripheries are also found in this snapshot.

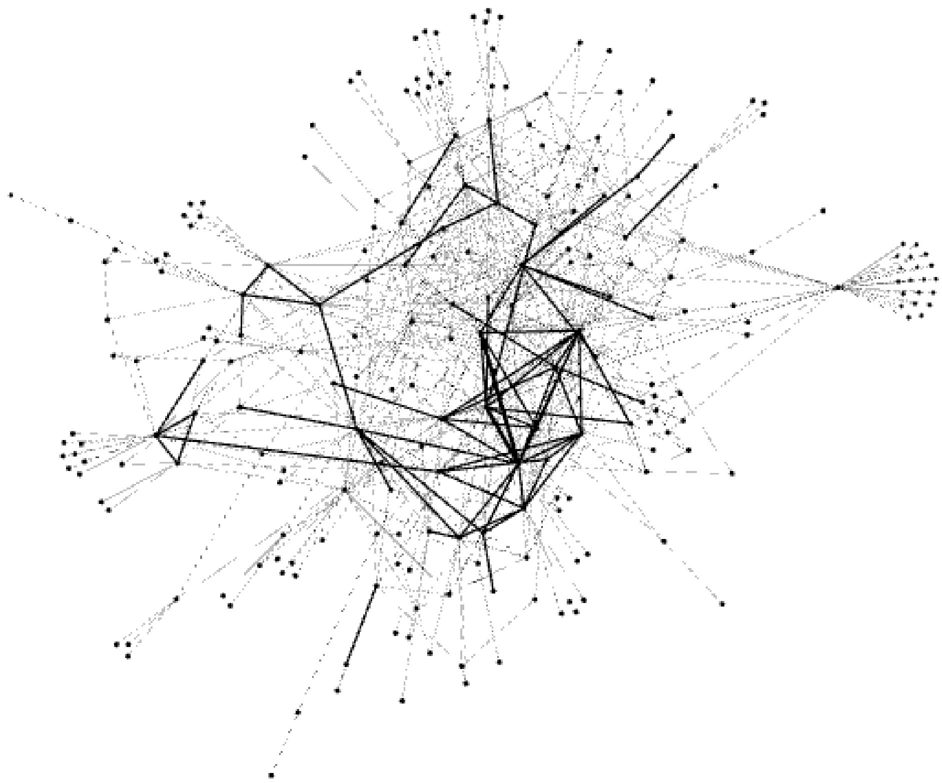

Figure 4.3 Canadian SMR Ecosystem; Whole Network -5 Centralized Actors

Following the Mexican snapshots, Figure 4.4 showcases the whole network of the Mexican SMR ecosystem. This network comprises 87 nodes and 740 edges, with a network density of 0.222. The structure of this network disrupts the fishing net pattern previously found in all the Canadian snapshots and showcases a less even distribution of actors, leaning more towards a firework display than a fishing net display. This snapshot has a clear tendency to verticality, with a “bottleneck” of two actors dividing the network into two sections. The upper section, although the irregularity of the rest of the network, illustrates a sub-system within the network that does follow a fishing net pattern. This sub-network represents 29.33% of the total nodes.

Figure 4.4 Mexican SMR Ecosystem; Whole Network

Figure 4.5 illustrates the key actor's snapshot of the Mexican ecosystem. This network comprises 28 nodes and 58 edges, with a network density of 0.13. The structure of this snapshot does not necessarily repeat a pattern found on the whole network, as this snapshot resembles more the fishing net pattern of network collaborations.

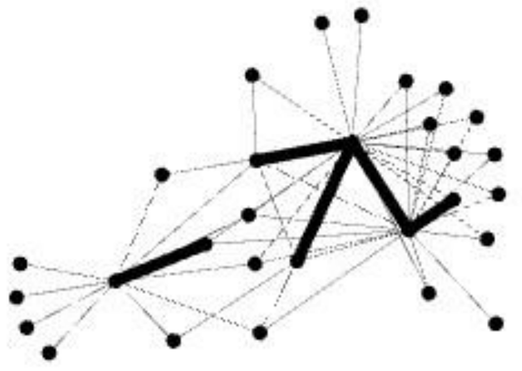

Figure 4.5 Mexican SMR Ecosystem; Key Actors

Figure 4.6 illustrates the removal of the five most centralized actors of the whole network snapshot of the Mexican ecosystem. This network comprises 84 nodes and 565 edges, with a network density of 0.215. The network structure follows a fisher net display.

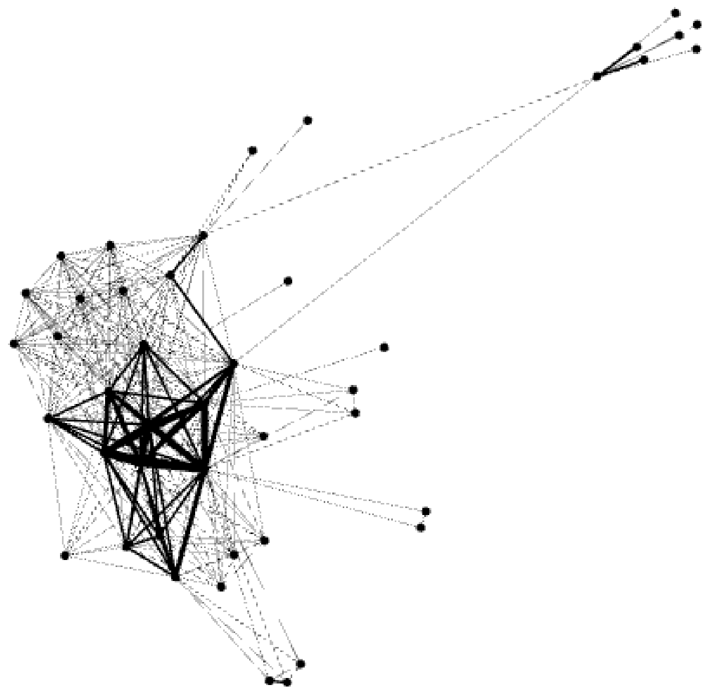

Figure 4.6 Mexican SMR Ecosystem; Whole Network -5 Centralized Actors

Table 4.1. General Network Analysis Statistics

	Nodes	Edges	Network Density	Network Diameter	Average Degree	Average Weighted Degree	Community Detection (Modularity)	Average Clustering Coefficient	Community Detection	Average Path Length
Canada Key Actors	59	121	0.58	4	3.508	3.967	.465	0.008	3	3.006
Mexico Key Actors	28	58	0.13	4	3.655	4.00	0.224	0.128	6	2.251
Canada Whole Network	339	741	0.022	6	5.365	5.952	0.402	0.297	11	3.198
Mexico Whole Network	87	740	0.222	4	16.4	19.68	0.416	0.88	4	2.042
Canada Whole -5	334	648	0.021	7	4.932	5.538	0.445	0.292	9	3.254
Mexico Whole -5	82	565	0.215	4	14.41	16.61	0.445	0.913	6	1.859

Table 4.2. Top Actors by Betweenness Centrality per Country; Whole Networks

	Canada	**Mexico**
1	Government of Canada	Westinghouse
2	Atomic Energy of Canada Limited	International Atomic Energy Agency
3	Business Development Bank of Canada	Mitsubishi Electric Co.
4	Canadian Commercial Corporation	Central Nucleoeléctrica Laguna Verde
5	Canadian Nuclear Safety Commission	Instituto Nacional de Investigaciones Nucleares

Chapter 5. Discussion

This research aimed to make visible the invisible to simple-sight collaboration patterns of the actors that constitute the innovation ecosystem for promoting and deploying small modular reactors in Canada and Mexico. Throughout this section, the implication of graphic representations and their patterns will be analyzed:

5.1 Whole Networks

Starting with the whole networks, there are some notable differences in the pattern of both networks. While Canada has a steadier distribution of actors under a fishing net display, Mexico's network is less even distributed with a display that tends more towards a firework display than a fishing net display. Alternatively, Canada's network's center (and majority) and the fishing net display are associated with strong ties [31] built on trust and illustrate a behavioural pattern for intra-organization collaborations. In addition, this mapping also shows some particular peripheral branches that will be further explored in this section.

Mexico's firework display is associated with weak ties, which are crucial for a faster and broader reach on a network, such as with information spreading, but lack the trust needed to engage in more formal types of collaboration [31]. In addition, this snapshot shows a pattern that tends towards verticality with a bottleneck that stands out as it separates the network into two sections. These sections represent different groups of community detection (modularity class), which refers to the measure of the strength of the division of a network into modules [109]. The visible upper network contains 29.33% of the total nodes (which also shows a fishing net display within an overall firework display), while the lower part constitutes 50.67% of the total nodes. The remaining nodes are divided 17.33% at both sides of the lower network, and 2.67% are attributable to offline nodes outside the Gephi display range. The two nodes responsible for the bottleneck in Mexico's snapshot are a US multinational in Mexico, belonging to the industry helix, and a public research center belonging to the government helix, which opens up the possibility to future research on whether the centralization effect of these nodes has either a positive or a negative impact on the network.

While Canada's network is mostly all evenly interconnected, showing no groups within the network besides minor ramifications on the periphery of the network and aligning with the strong ties associated with fishing net displays, Mexico showcases a clear case of narrow bridges, also consistent with the weak ties detected by the firework display. The differences in both network structures can be appreciated in Figure 5.1 below:

Figure 5.1 Comparison of Whole Networks

Although having a different number of nodes (actors), 339 for Canada and 87 for Mexico, both whole networks have similar edges, with 741 and 740, respectively. This apparent similarity explains one interesting difference in the collaboration patterns of both countries; while the collaboration patterns in Canada appear to be on a one-to-one case scenario, the Mexican pattern of collaboration showcases fewer collaborations with a broader number of participants in each collaboration project. In addition, this could also explain why the network density of the Mexican snapshot, of 0.222, is ten times higher than the Canadian network density of 0.022. This statistic reflects that although a more significant number of actors is usually associated with strengthening the SMRs ecosystem, the Canadian scenario is reduced to small collaborations or select groups that do not reflect the vast possibilities of interrelating with the entire ecosystem. In terms of cohesiveness besides the network density, Canada has a modularity of .402 with 11 communities detected, whereas Mexico shows a community detection (modularity) of 0.416 with only four communities detected. While the difference in the community detection is not that different for the pair of networks, the number of communities detected with such close community detection (modularity) is. To explain this, one can think of communities as a set of institutions that organically collaborate, just as students in a classroom are likely to group if no other conditions are expressed when giving the command. In this sense, a network's total can be divided as few or as many times, which describes potential collaboration patterns as actors not necessarily already collaborating with each other. Likewise, each network's cohesiveness is again confirmed with an average clustering coefficient of 0.297 for Canada and 0.880 for Mexico. Furthermore, each one of these communities could illustrate sets of institutions participating in a given niche when governing a network for SMR deployment.

Finally, on the cohesiveness approach, we have the average path length, which describes the mean distance of all pairs of nodes [110]. Explained in other words, we can think of the average path length as the equivalent of the famous sociology theory of the six degrees of separation [111] in [31]. This would be 3.198 for Canada and 2.042 for Mexico, indicating that a whole extra step is required in the Canadian context to cover the broad network in terms of connections. This can be explained both with the previously described density and clustering coefficient and, taking a step back, recalling the difference in the number of nodes per network and, therefore, their differences in diameter: 6 points for Canada and 4 points for Mexico.

In terms of the centrality measures of the network, we will focus on the broader networks instead of individual properties, as this is where the valuable information to understand collaboration patterns lies. However, the individual statistics for each node can be found in Appendices 16 to 19. In terms of between centrality, however, the statistics are presented only at an individual level as they refer to nodes only, and no average betweenness centrality or closeness centrality was found in network analysis literature. Only the average degree was found to depict general centrality.

In this sense, the average degree for both snapshots shows the average number of edges per node in a graph compared to the number of nodes [103], which is 5.365% for Canada and 16.4% for Mexico. This means each node for the Mexican context receives three times more edges or connections. This centrality statistic also aligns with the previously almost equal number of edges (741 and 740) despite the difference in the number of nodes (339 and 87) and their different collaboration patterns.

The overall higher centrality of the Mexican ecosystems in all the average degrees confirms what is already graphically visible with the bottleneck found in the whole Mexican network and the other network cohesiveness metrics. This bottleneck also separates the network in two groups, with the upper part of the network having a fishing net pattern, unlike the rest or the overall network. This almost perfect upper network also highlights a gap between the research being conducted on SMRs and the rest operating and supporting institutions.

In addition, the five most centralized actors by betweenness centrality per country are listed below in table 5.1, which highlights the presence of all five governmental actors in the Canadian context and whose Mexican equivalent consists of two governmental actors, two affiliates of the industry helix and an international organization. This is especially interesting as one could assume that, where the government helix dominates or even controls nuclear policy, we would find the most centralized network actors in this helix. Thus, we would expect to find this in Mexico and not in Canada, but the reverse is true. This highlights the extent of federal policy impact on SMR deployment in Canada and the importance of multinationals and international organizations for Mexico, although it also recognizes that Canada would not be as affected by these institutions disappearing as the Mexican network would be.

Table 5.1 Top Actors and their Helix per Country; Whole Networks

	Canada		**Mexico**	
	Betweenness Centrality	**Helix**	**Betweenness Centrality**	**Helix**
1st	Government of Canada	Government	Westinghouse	Industry
2nd	Atomic Energy of Canada Limited	Government	International Atomic Energy Agency	International
3rd	Business Development Bank of Canada	Government	Mitsubishi Electric Co.	Industry
4th	Canadian Commercial Corporation	Government	Central Nucleoeléctrica Laguna Verde	Government
5th	Canadian Nuclear Safety Commission	Government	Instituto Nacional de Investigaciones Nucleares	Government

For the analysis by country of affiliation of nodes to each helix, illustrated in Table 5.2 below, we can observe that for both countries, the industry helix led the participation on the networks; however, not with an overwhelming majority, but with a share of the 26.54% for Canada and 27.58% for Mexico. These percentages are also not that different from each other, as well as the share in the government helix; however, there are more significant differences when comparing the academia and civil society helix. Canada has substantially more in civil society and lower participation in academia than its Mexican counterpart. There are a couple of contextual facts that could explain the relation of these percentages:

Table 5.2. Helix Share per Country; Whole Network

	Canada	Mexico
Government	21.82%	20.68%
Industry	26.54%	27.58%
Academia	7.37%	20.68%
Civil Society	21.53%	12.64%

First, culturally Canada has a wider citizenship involvement in civil society with their preferred social causes in general [56], as well as a more acknowledged abusive past concerning their indigenous relations, which are far from being recognized and are often normalized in their Mexican equivalent. Although unfortunately recent, indigenous reconciliation in Canada has promoted the participation of organized indigenous groups not only as a desirable input in nuclear projects but as a must and even as a legal obligation when the mineral retrieving or plant construction is on their land jurisdiction. Mexican indigenous has not yet achieved that level of sovereignty neither on the de facto nor in their de jure power, and overall involvement of the general population with civil society organizations is lower culturally.

Secondly, I believe that the comeback of Mexico's percentages in academia can be attributed to the federal policy preventing other actors from arising in the ecosystem, as only the federal government is granted the faculty to generate energy from nuclear sources for commercialization and their research applications undergo high scrutiny to be approved under the same centralized federal institutions. In this way, the shaping of the Mexican SMR ecosystem could be attributed to the shift from enacting this policy and the response of the actors to derive the focus from commercialization purposes to R&D purposes. In addition, these percentages could also indicate that the Mexican SMR ecosystem is still young and, therefore, firmly based on their R&D stages.

In comparison, Canada has the inverse share distribution with a notorious wider civil society participation and a lower share in academia, although according to Philips & Castle, Higher Education Institutions perform 39% of the Canadian R&D, second to the industry with 52% share [54]. In this sense, the Canadian landscape within this academic helix could indicate how knowledge and expertise are being developed and strengthened in fewer universities. In addition, developments in this country's academic helix do not face the intrinsic limitation of the current Mexican policy. They can be further developed as spin-offs, startups or other legal ways of institution creation to pursue their development and potential future commercialization.

In addition, it is important to mention the presence of actors in both networks, which was the case for GE Hitachi, Westinghouse and Mitsubishi Electric from the industry helix and the

International Atomic Energy Agency as an international organization. Their presence highlights the role of multinational and international organizations in knowledge transmission among countries and within the country itself, which is especially relevant in the case of developing countries with more uncertainty towards nuclear energy policies for their important financing contributions.

One of the most admirable characteristics of innovation ecosystems is how the first actors pave the way and cause the formation of new institutions since, with their mere existence, unique needs arise and markets are being created. This market formation has positive economic consequences since it encourages creating of specialized jobs and entering new actors into the ecosystem. Creating specialized SMR departments or units within government offices is another example of institution-building out of new demand. These specialized units were found at the provincial and federal levels for the government helix. In the case of the civil society helix, the Canadian Nuclear Society introduced the Canadian Nuclear Industry Small Modular Reactor Secretariat to track the SMR roadmap and strategic action progress. Likewise, the formal creation of this specialization leaves a more solid precedent for imminent administration changes, which is a challenge to governmental institutions.

Furthermore, periphery actors and their aggrupation could also represent collaboration clusters due to the specialization of institutions that strengthens the ecosystem. It is important to emphasize that this level of specialization in the nascent institutions is not only the result of the constant professionalization of the ecosystem and that these consequences have an influence on the positioning of SMRs on the public agenda but also that their existence follows their time encouraging the creation of new institutions as market formation allow deeper specialization within the already existing institutions. In this sense, network structure and the related policy feed a constant loop that incentivizes each other to bridge the gaps as networks consolidate. For instance, the content analysis mentions several institution formations such as the Green Energy Park or the Clean Energy Development, Innovation and Research by the Canadian Nuclear Tech University, the facility Advanced Nuclear Reactors Laboratory (ANRL) by the University of New Brunswick. Other articulating institutions forthcoming are the Nuclear Innovation Institute, the SMR Learning Centre of Excellence by the First Nations Power Authority, the Indigenous Relations Supplier Network by Bruce Power, and the establishment of an SMR Construction innovation and worker training center by Bird in their Edmonton facilities.

Another clear example of these needs is the creation of institutions such as regulatory and safety bodies, specialized unions, industry worker associations or other supporting institutions created to respond to the emerging needs of the consolidated innovation ecosystem. It is essential to mention that this level of union specialization was notable from the data collection on the

Canadian ecosystem and barely present in the Mexican ecosystem, whose implications on the network resiliency are to be explored further in the document.

5.2 Key Actor Networks

As explained in the Methodology section, the focus on the Key Actors Network considered SMR vendors, developers or designers of the technology or, in the case of Mexico, also the actors in research and development areas. It is essential to highlight that first, the data collection of the entire network was carried out, and then new limit criteria were applied to obtain a narrower snapshot of each ecosystem. The visual comparison of the network structure can be found in Figure 5.2 below:

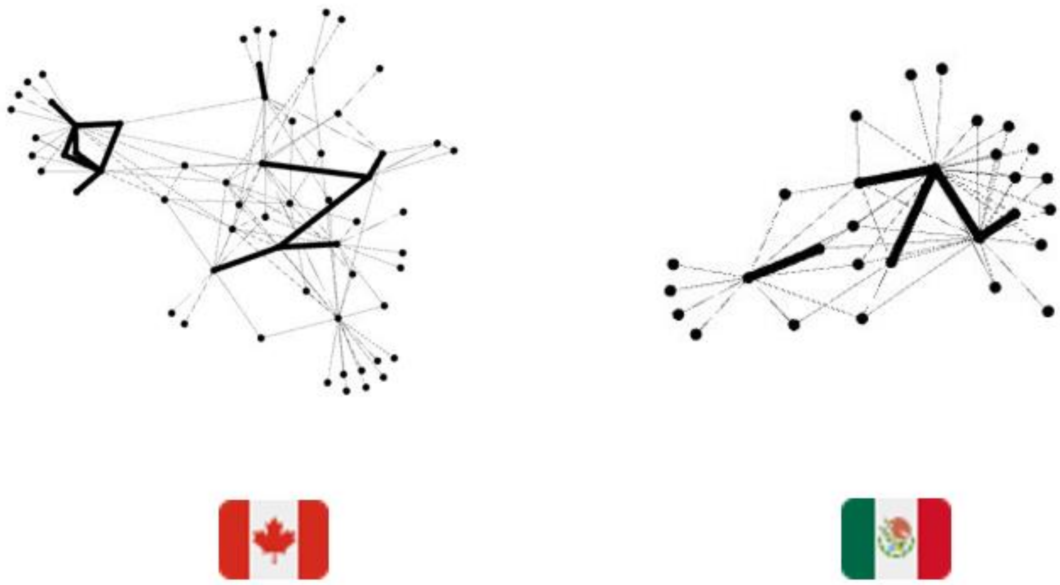

Figure 5.2 Comparison of Key Actor Networks

Compared with the first pair of snapshots, it stands out that these two network structures are not as different as their respective whole networks, which illustrated opposite network display scenarios. Here, both networks can be identified with a fishing net display, often associated with strong ties and more formal collaboration patterns. While this is not a surprise for the Canadian context, as it follows the previously shown pattern, it is a surprise for the Mexican context, which presented a different pattern in their whole network. This highlights, on the one hand, that the actors working more closely to the development of the technology have, in fact, a more formal collaboration pattern when analyzed as a separated ecosystem, and on the other hand, that supporting institutions, combined with the current limiting policy, play a role in having a faster-spreading network, but at the margin of real commitments and their accountability. In this sense, the fact that there is no Mexican equivalent to the SMR Roadmap, Action and Strategic Plan, nor a technology-specific policy supports the insight that the network displays indicate about their collaboration patterns.

These similarities are especially relevant considering that the Canadian snapshot has almost double the actors of the Mexican snapshot, with 59 and 29 nodes and 121 and 58 edges, respectively. Immediately we can also observe that the extremely similar number of edges per country found in the whole networks no longer appears on these networks, and this aligns with the difference in the collaboration patterns for the previously explained Mexican snapshots.

In addition, there is a significant change in the network densities. While on the previous set of snapshots, Mexico´s network density was ten times higher than the Canadian density, on these snapshots, Canada shows the higher density (0.58) of all networks, while Mexico´s (0.13) is a relatively lower density. The information behind these statistics tells us, on the one hand, about more cohesive collaboration patterns within this subnetwork of the whole Canadian ecosystem and, on the other hand, about a one-to-one collaboration pattern within this subnetwork of the whole Mexican ecosystem. Interestingly, both countries showcase the opposite scenarios of their previously analyzed whole networks on their key actor's networks, reinforcing the pertinence of contrasting both scenarios. These drastic changes in network density could also indicate, for further research, whether the presence of the existing group of supporting institutions is having a positive or negative impact on the network.

While their whole network's community detection (modularity) was not that different (0.402 for Canada and 0.416 for Mexico), the key actors' community detection (modularity) highlights a difference with .465 for Canada and 0.224 for Mexico, with three and six communities detected, respectively. It is important to mention that Canadian communities from the whole snapshot to this key actor´s snapshot are reduced (from 11 to 3), which is understandable due to the reduction of nodes. However, when contrasted with the changes in the Mexican context, it stands out that the number of communities increases (from 4 to 6). This increment of communities could indicate a negative influence of one of the removed actors, especially when this pattern repeats itself in the following exercise of removing the five most centralized actors. Furthermore, they present an average path length of 3.006 for Canada´s key actors and 2.251 for Mexico´s. These are not as different as their whole network counterparts, with Canada requiring almost a whole extra step to transit the entire network. As well as an average clustering coefficient of 0.008 for Canada and 0.128 for Mexico.

On the centrality measures, the average degree is 3.5% for Canada and 3.6% for Mexico, which stand out by being the closest in terms of average degree difference on the three pair of snapshots (with a 5.3%/16.4% for the whole network and a 4.9%/14.4% for the removal of the five most centralized actors). This indicates that the Mexican key actors themselves do not perpetuate the centralization that has been observed in the whole network and that it is about to be analyzed in the removal of the five most centralized actors, despite their removal. In addition, the five most centralized actors by betweenness centrality per country of this network are presented below in Table 5.3 This table stands out to have two actors from the government helix and three from the industry helix (two of them being startups and SMR vendors) for the Canadian context, and three actors from the academia helix and two from the government, one being the only commercial nuclear generator and the other one, a public research institute.

Table 5.3 Top Actors by Betweenness Centrality per Country; Key Actor Networks

	Canada	**Mexico**
1	NUSCALE	Universidad Nacional Autónoma de México
2	Canadian Nuclear Safety Commission	Universidad Autónoma de Zacatecas
3	ARC Nuclear Canada Inc	Central Nucleoeléctrica Laguna Verde
4	GE Hitachi	Instituto Nacional de Investigaciones Nucleares
5	Nuclear Waste Management Organization	Instituto Politécnico Nacional

A comparison of the percentage of nodes identified according to their helix is presented below, where a considerable difference stands out in the academia helix, where Mexico exceeds Canada by almost ten percentage points, and in the civil society helix, where Canada exceeds Mexico by more than 14 percentage points. Repeating, however, the pattern of the whole network analysis.

Table 5.4. Helix Share per Country; Key Actors

	Canada	**Mexico**
Government	22.03%	25%
Industry	44.06%	39.28%
Academia	10.16%	25%
Civil Society	22.03%	7.14%

Whole Networks Minus the 5 Most Centralized Actors

Once networks and their centrality measures are obtained, the exercise of removing a certain number of actors with the highest degree of centrality illustrates the vulnerability or resilience that a network possesses, how it is maintained or dissolved if the influence and connection of a certain actor are taken out of the picture. Although this is an estimate, the changes in the networks do reflect an essential indication of the differences between the two countries when I removed their respective five most centralized actors. However, these changes can be perceived at simple sight by comparing the two networks. In addition, the statistics of the loss effect are illustrated in tables 5.5 and 5.6 below:

Table 5.5 Vulnerability Estimation of the Canadian SMR Ecosystem

	Whole Network	Whole Network -5	% of Loss Effect
# nodes	339	334	-1.47%
# edges	741	648	-12.55%
Density	0.022	0.021	-4.54%
Average Degree	5.365	4.932	-8.08%
Community Detection (Modularity)	0.402	0.445	+10.69%
Community Detection	11	9	-18.19%
Average Clustering Coefficient	0.297	0.292	-0.68%
Eigenvector Centrality	0.003	0.004	+33.33%
Average Path Length	3.172	3.253	+2.55%
Statistical Inference of Assortative Community Structures	2861.228	2527.961	-11.65%

Source: Adapted from [28]

From this table, two of the three positive results stand out since it could be expected that the effect of the loss of these actors would be reflected negatively in all the measures in their respective proportionality. These pertain to community detection (modularity), which refers to the membership of each actor in a group and illustrates the change in behavioural dynamics in the question of greater grouping and to eigenvector centrality: the measures that "count the number of nodes adjacent to a given node but weight each adjacent node by its centrality"[29] and indicate that the nodes are closer to the center of the graph with the loss of the other five actors.

The average path length is also positive, but this measure refers to the distance between the nodes or the average steps between them, indicating that the steps need to be increased with the loss of the actors. The visual differences in the network can be observed in Figure 5.3:

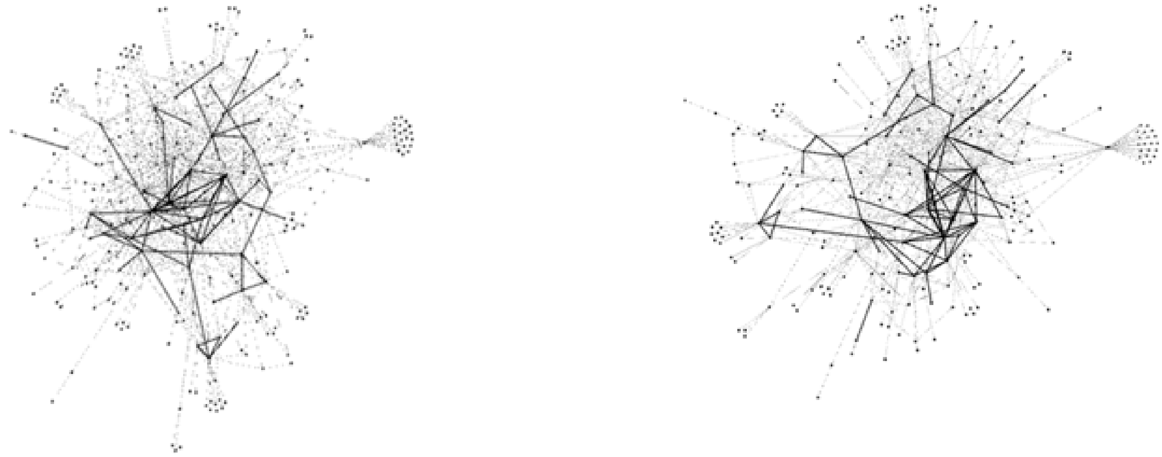

Figure 5.3 Comparison of Canada´s Whole Network and Whole Network -5

Mexico´s loss effect of their five most centralized actors is shown in Table 12 below.

Table 5.6. Vulnerability Estimation of the Mexican SMR Ecosystem

	Whole Network	Whole Network -5	% of Loss Effect
# nodes	87	82	-5.75%
# edges	740	565	-23.65%
Density	0.222	0.215	-3.16%
Average Degree	16.4	14.41	-12.14%
Community Detection (Modularity)	0.416	0.5	+20.19%
Community Detection	4	6	+50%
Average Clustering Coefficient	0.88	0.913	+3.75%
Eigenvector Centrality	0.004	0.0164	+310%
Average Path Length	2.042	1.859	-8.97%
Statistical Inference of Assortative Community Structures	1533.822	992.018	-35.33%

Source: Adapted from [28]

The percentages of changes in this table are higher than those found in the Canadian context, which already reflects a Mexican ecosystem that is much more vulnerable to eliminating main actors. In this table, three measures appear positive again, and although community detection (modularity) and eigenvector centrality are repeated, the other is the average clustering coefficient, which refers to the degree to which nodes tend to group and form clusters. It also highlights that the average path length is reduced by eliminating these actors, two visibly acting as unique connectors or possible bottlenecks in the graph.

The visual differences in the network can be observed in Figure 5.4, where the dramatic change in the network composition stands out, reflecting the country´s vulnerability to losing its central institutions. Only two of these are governmentally centralized, but multinationals seem to have a similar centralizing effect. We can also observe how the division of the northern and southern networks seen in the left image practically disappears with the loss of such centralizing institutions. Problems arise when we recall that the loss of these particular institutions would open up a gap between research on SMRs and other operating and supporting institutions and the network. It is likely that the loss of these five actors would reduce the effectiveness of the network in research, both on new SMR designs and on the feasibility of their deployment in Mexico. The impact on such loss would be also in the policy opportunities that come with this research and development stages, leaving, therefore, institutions advancing without clear vision and expectations, but merely surviving.

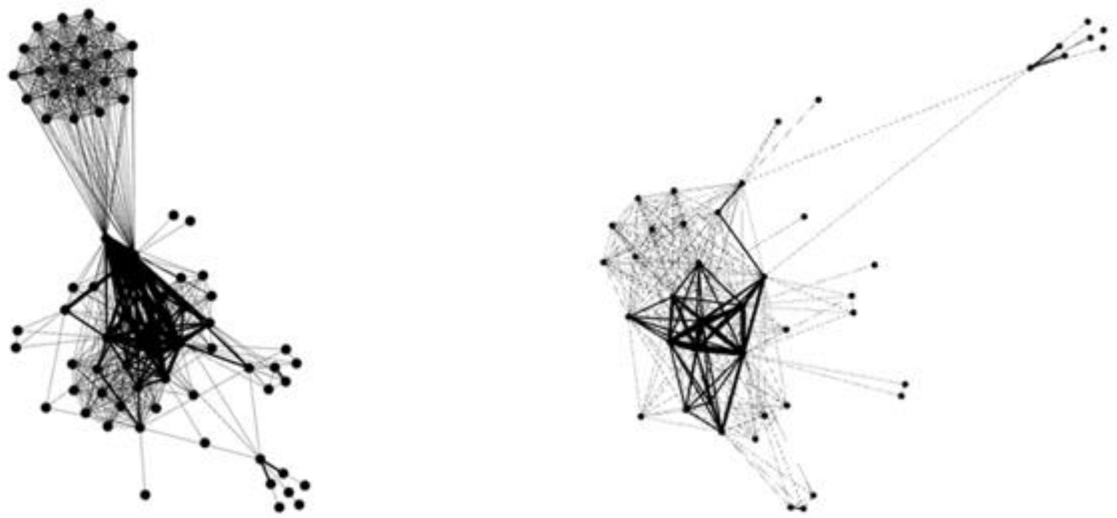

Figure 5.4 Comparison of Mexico´s Whole Network and Whole Network -5

From the analysis of the three snapshots per country and the contextual exposure of each one, the relational situation between policy, network structure and SMR deployment presented in the conceptual model for this research is applied to Canada in Figure 5.5 and Mexico in Figure 5.6.

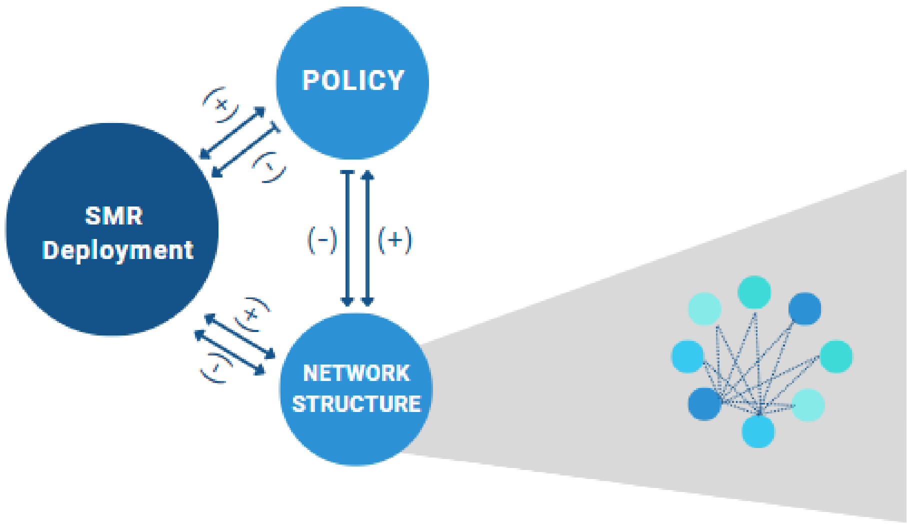

Figure 5.5 Relational Diagram Applied to Canada

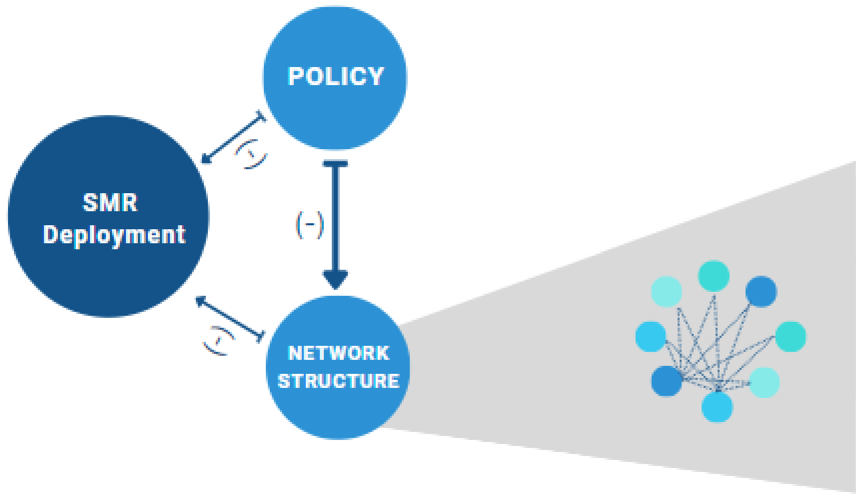

Figure 5.6 Relational Diagram Applied to Mexico

From the analysis of the three snapshots per country and the contextual exposure of each one, the relational situation between policy, network structure and SMR deployment presented in the conceptual model for this research is applied to Canada in Figure 5.5 and Mexico in Figure 5.6. Figure 5.5, applied to Canada, shows a more optimistic scenario of constant feedback between policy, network structure and SMR development, where there is a positive bidirectionality between the network structure and the country's policy, as well as a unidirectionality of the policy towards the country's network structure, but not the other way around. This suggests that as long as there is a supportive policy, the network structure seems to have a catapult effect that encourages the creation of more public policies in this regard. Still, the absence of a consolidated ecosystem does not have the power to regress the gained ground on the policy aspect, probably attributable to the country's commitments to reduce carbon emissions agreed in the Paris Agreement and otherwise reversible or subject to budget reduction or related setbacks. The same happens between the policy and the SMR deployment, where a positive feedback loop flows in both directions, and negative aspects flow from the policy to the SMR deployment. This graphic element explains that although a policy encourages SMR deployment, such as specialized federal funds for SMRS, another policy, such as the applicable regulation, was not created for this technology's specificities but for large projects' nukes.

Unlike the two former cases, the relationship between network structure and SMR deployment shows bidirectionality in both its positive and negative aspects. This explains that a weak infrastructure can undermine SMR deployment efforts but that SMR deployment, a positive feature by nature, could negatively influence the network structure by creating lock-in effects, for example, when it happens with a single SMR vendor that centralizes or monopolize the network, and that does not allow competition and its corresponding learning feedback from deploying new technology such SMRs.

In contrast, the current situation of the Mexican ecosystem only illustrates negative effects with a specific direction, with the negative relationship from policy to network structure being the most determined of them, concerning the policy that limits and centralizes the nuclear sector to a couple of institutions with government influence and that rules out beforehand the potential creation of institutions to exploit both commercial and research applications. This is also supported by the vulnerability and disruption in the institutional ecosystem that the Mexican network demonstrated by removing its five most centralized actors. Two are institutions in the government helix, two are multinationals belonging to the industry helix, and one is an international organization. In this sense, it could be assumed as a hypothesis for future exploration in which each institution has a positive or negative effect on the network.

Conclusions

This research explored through Social Network Analysis the invisible to simple sight collaboration patterns of the SMR innovation ecosystems in Canada and Mexico to better understand the challenges and opportunities for SMR deployment. The document takes readers through all those puzzle pieces that make up this complex ecosystem. Although no section of this research work is in itself a novelty discovery, these pieces are rarely contrasted with each other and less often analyzed as a whole. My research then attempts to clarify to non-experts the diverse nature of the challenges for deploying SMRs. It recognizes the technical barriers that policymakers often face by being presented with a wide diversity of sectoral policies resulting from a diverse public agenda and constantly emerging new needs.

This research contained the main question led to three specific questions. My main research question: What is the current structure of the innovation ecosystem in Canada and Mexico for the deployment of small modular reactors, is answered with a pair of three different network snapshots for each country. Results highlight a visually different snapshot for each country, showing two SMR innovation ecosystems with different degrees of consolidation-specialization and vulnerability that appear to be mutually exclusive. My first specific question: which is the helix of the actors dominating each SMR innovation ecosystem, is answered in Tables 5.2 and 5.4, where both tables showcase the industry helix as the major share in both countries and illustrate an interesting distribution among the academy and the civil society helices. Mexico has notorious broader participation in academia and a precarious one in civil society. The second specific research question is: who are the central actors connecting the innovation ecosystem? is answered in Tables 4.2 for the whole networks and Table 5.3 for the key actor's networks. In addition, the list of central, peripheral and actors connecting the center with the peripheries of the whole and key actor networks can be found in the Appendix section of this document. Except for the central actors, the other lists are presented in chronological order of the institution creation where relevant, and their respective helix is also noted. These tables give us a sense of historical perception of the SMR innovation ecosystem consolidation and each country's ruling patterns or trends that have the potential to be explored in further research. In addition, a timeline for the perspective of the historical reactor building in each country, contrasted with the institution formation (of the institutions mapped for this research), is illustrated in Appendix 15.

This research approach aligned with the systematic approach required to leverage SMRs deployment, focusing on a broader decision-making process towards this technology rather than an individual behavioural pattern often used for technologies whose business model relies on individual purchasing decision-making. This needed systematic approach, combined with the risk and complexity components of the nuclear energy field itself, indicates that to achieve prompt deployment, the networks might require active managing through controlled interventions.

This research highlighted a great learning opportunity from even considering an intervention with a protected space, as Strategic Niche Management proposes. In this scenario, even the simulation of a different case of intervention scenario generate knowledge not yet available to policy and decision-makers to make informed decisions on procuring SMRs as a sustainable technology, and therefore, the key to playing a role in reducing carbon emissions in the level needed within the urgency of the climate crisis.

This is especially relevant when we connect it with the regime approach used in the SNM, and we understand regimes as unique and collectively cohesive. In addition, this framework suggests regime monitoring as part of a comprehensive approach in the broader deployment of SMRs, rather than isolated projects to gain ground in their respective energy mix participation percentage. In this sense, niches, and then regimes, are a bottom-to-top approach to gaining a bigger percentage of the market share and help with a less frictional energy transition management strategy, and regimes are an undeniable variable for the success or failure of a niche. For instance, throughout this document, we can observe two very different national landscapes for Mexico and Canada, the difference in the consistency of the message, the actions subsequent to the speech at the federal level, and how it permeates at the provincial level in the case of Canada. With the actors belonging to other helices, but especially towards the SMR vendors and institutions focused on research and development for both countries. Alternatively, the inconsistent and rarely backed-up action when the Mexican federal government has expressed their support or interest in procuring SMRs creates a rather uncertain landscape for institutions to decide to invest any kind of resources towards this endeavour in nature already risky and expensive.

Understanding collaboration patterns is crucial for network learning and development, but network governance as their helix affiliation constitutes strengths and weaknesses and can also provide feedback on what combination of institutions can minimize unnecessary constraints and speed deployment. In this sense, SMRs are a modular technology and require a modular approach to make the most impact with their deployment. The feedback loop that the evolutionary approach of SMR deployment also provides the basis for monitoring and development, a crucial part of any policy intervention that allows validating or pivoting accordingly towards the best scenario possible for successful and timely technology deployment.

In addition, the ground gained to date, making it possible to open the debate about having protected niche spaces for SMR deployment, legitimizes both the technology and the institutions part of the innovation ecosystem. Considering a Strategic Niche Management approach to this technology opens the debate about where? And with who? and not why nuclear technology as that has been already demonstrated by the scientific community and environmental activists [6], [8], [112], leaving to evidence the decisions about site location and the mix of actors that best fulfill the needs of each niche market. In this sense, this research provides some ground information on two economically, politically and culturally different countries and their strengths and weaknesses regarding SMR deployment.

Now knowing who the actors that are counted on to carry out the deployment of SMRs in each country and answer the basic question of with whom, further research can now focus on what are the challenges that these actors have encountered and which of them could be addressed by the different institutions immediately and which are not are. This managerial approach is particularly relevant as resources are finite and "successful innovation comes from social networks that balance coordination with creativity" [31] and not solely by the existence of a superior technology like SMRs are.

In this coordination focus, counting with such a wide pool of niche markets in each country allows one to strategically target those with fewer market entry barriers, such as remote areas where competitors do not need to be displaced. Achieving this is an initial deployment with the least possible friction that allows legitimizing the technology and the actors behind the technology. This is particularly relevant as "innovations that face entrenched opposition from established norms can spread more effectively when early adopters have less exposure to the entire network. It is a matter of balance between being protected and being connected" [31] (p. 296). These early adopted niches would set a precedent and contribute to the ground opening for this technology in the market share to leverage towards a successful and timely deployment. While some innovation approaches suggest different metrics to predict success (the 25% tipping point [31], the chasm (16% of the market share) [69]), the ongoing consolidation of this technology on its way to the market suggests this technology is likely to create their own metrics for success.

Unlike other technologies, SMRs are not expected to displace all other competitors but to partner with other energy generation sources in the country's energy mix. In this sense, the sole focus of SMRs of this research does not suggest a premature lock-in of this technology but one that recognizes the role of nuclear technologies in achieving the Paris Agreement national commitments and in the human race against the rapidly accelerating climate crisis [8]. In addition, due to the inevitable weight of the social perception regarding nuclear projects, SMRs face an extra burden of legitimization for their deployment, and literature suggests that "when the legitimacy of a movement of innovation is the crucial factor for its diffusion, diversity –not similarity- will be the primary principle for adoption" [31] (p.152). In this sense, diversity is considered a strength in the energy mix, in the number of SMR designs available, as well as in the institutional structures behind these designs.

Throughout the document, I found a recurring "we can't have it all" dilemma, from the public versus private and centralization versus decentralization institutional mix perspective to strong versus weak ties, peripheral versus centralized actors, and a wider reach versus a redundant stronger contact. These characteristics reinforce the importance of a tailored mix within countries to promote deployment and highlight what combination of institutions might serve each jurisdiction better according to their needs and deployment capabilities. However, once the optimal share of apparently opposing forces is explored, it is possible to take advantage of their strengths and correct their weaknesses, for example, through public-private partnerships, with a governance goal aligned to promoting the deployment of SMRs in an integral way.

Each country has their strengths and weaknesses and its own infrastructure for innovation, and each participating institution possesses its own advantages and limitations, vision, direction and organizational culture. This research highlights the value of comparative policy analysis and recognizes the value of the information generated by the actors in the SMR innovation ecosystems, including the know-how and unstructured information. In this sense, dedicating efforts to capturing this valuable information can help carry out comparative analyses with the information being generated with the deployment of this technology.

I can, however, conclude that while both countries have very different starting lines and obstacles to overcome, both also have the potential to benefit from SMRs. In fact, diversity between and within countries is a strength for SMR deployment. In this sense, interventions with protected spaces, such as the ones proposed by the Strategic Niche Management framework, are possible for both countries and are more likely to become a reality the more consolidated the innovation ecosystem is and could serve as an indicator for country readiness towards SMR deployment.

Further Research

Social Network Analysis is a robust method, little explored and with great potential to continue deepening groups' behaviour patterns according to researchers' concerns. While one of the great strengths of this research is the exclusion of social bias from person-to-person nomination for building personal networks, further research can benefit from the qualitative and rich perspectives of conducting interviews to acquire the collaboration nominations.

It is important to mention that, although it exceeds the scope of this research, the influence that other global public, diplomatic and economic policy events have on the deployment of this technology and the consolidation of its innovation ecosystem cannot be denied. A timeline can be found in Appendix 14, which puts into perspective the consolidation of ecosystems for each country, emphasizing the helix that governs the construction of nuclear reactors and whether their purposes are commercial or research with circles and with rectangles the creation of support institutions emerging from new needs and the consolidation of new markets.

Further research could include individuals in a more complex multi-level Social Network Analysis, forecasting timing frames for niche protection or deployment. Different relational forms, such as a sole focus, on funding or lobbying, could also be an exciting topic for further discussion.

Great opportunity for further research arises when considering changes to the boundaries or inclusion/exclusion criteria for the actors, for example:

- Focusing solely on the role international institutions have in the national ecosystem for each country, highlighting the difference in the collaboration dynamics of these organizations with developed and developed countries.
- Analyzing institutional creation and decay historically and their effects on the network composition as institute formation triggers job creation and the creation of SRM-specific higher education programs or research funds allows to attract human talent to the institutions driving and promoting the deployment of SMRs.
- To track down how human talent makes its way from the higher education institutions to the diverse career opportunities in different institutions, contributing this way to the transmission of knowledge among institutions.
- Going beyond self-declared collaborations would open the floor to isolated nodes in the network. This apparently "solo" work becomes relevant, especially when breakthroughs are made in an academy setting, for example, with the doctoral thesis of a new SMR design.
- Another relational criterion for the boundaries set. As they could involve, for example, mapping only those collaborations that have provided funding to SMR vendors. Or joint collaborations in the R&D stages only. Or track back down the institutional collaborations that a given SMR vendor did to reach a minimum viable product. Although this methodology allows for expanding and specializing interests according to the purpose of the research, the general analysis of these network patterns for the present investigation requires a broader approach as a baseline. (Remembering

collaboration patterns are often invisible to simple sight, and no record was found of previously applied social network analysis in this field for either country)

- And last but not least, in accordance with the behavioural component this research entails regarding the public acceptance of nuclear technologies, the contrast of the network's transmission of pro and anti-nuclear information with the actual networks available for deployment as "social networks that accelerate the spread of an infectious disease can slow down the diffusion of its cure" [113].

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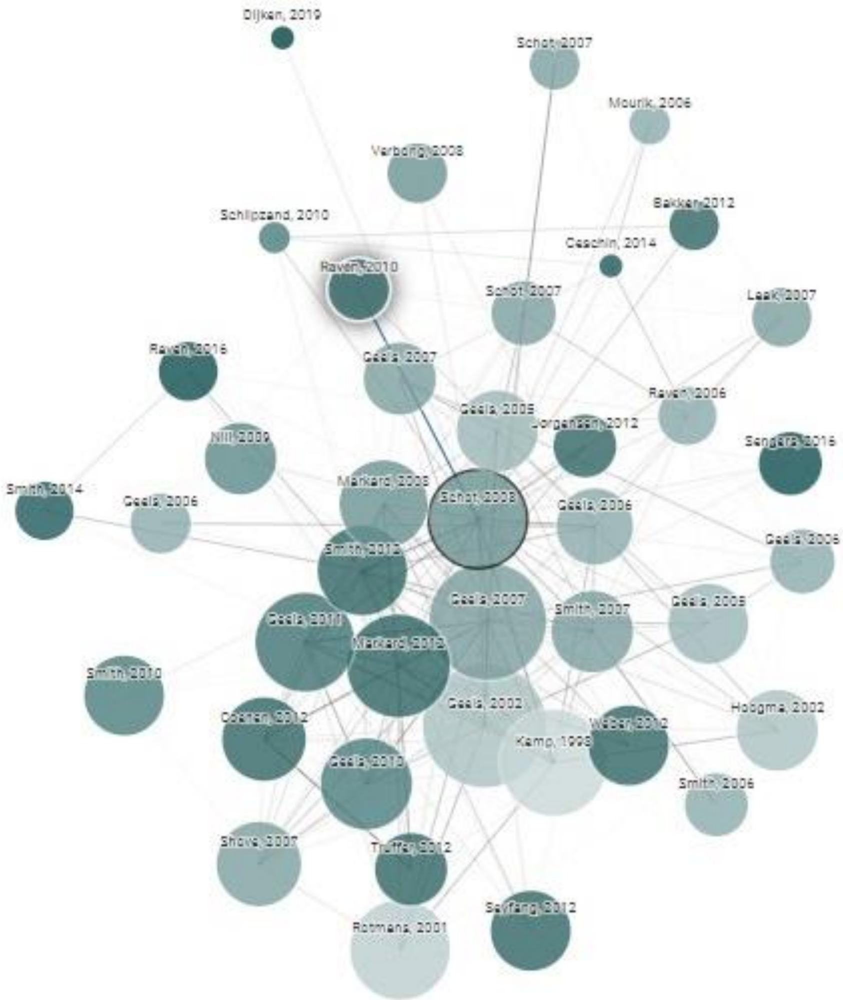
Appendices

Appendix 1. Connected Papers; "Strategic Niche Management" & "Nuclear Technologies". Source: [114]

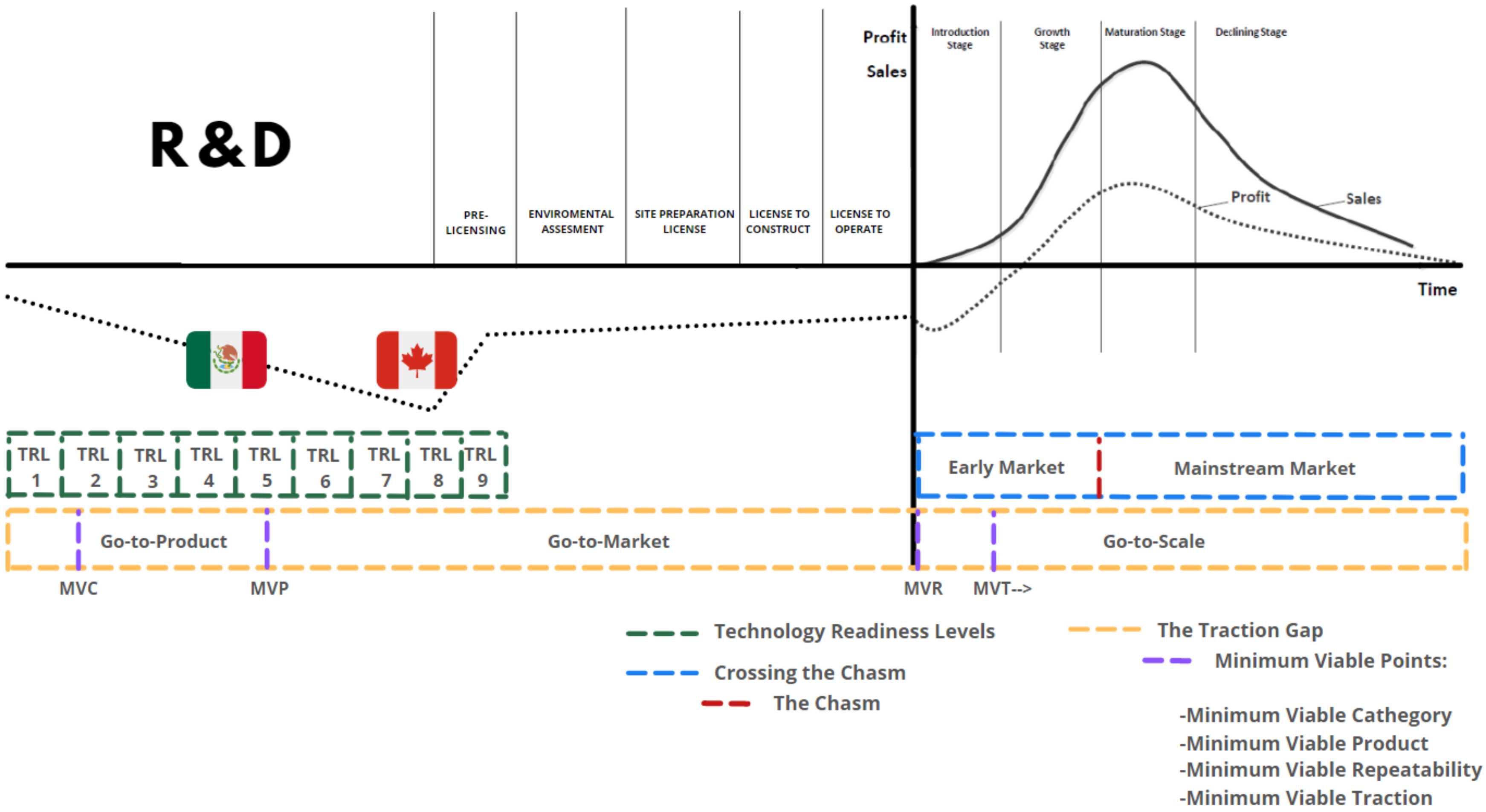


Appendix 2. Applicable Legal Framework

	Legal Framework	Relevant Institutions	Helix
International	Treaty on the Non-Proliferation of Nuclear Weapons	United Nations	International NGO
	Tlatelolco Treaty (applicable to Latin America)	International Atomic Energy Agency (IAEA)	International NGO
	Nuclear Safety Convention *		International NGO
Canada	-Nuclear Safety and Control Act	Canadian Nuclear Safety Commission (CNSC)	Government
	-Nuclear Fuel Waste Act	Nuclear Waste Management Organization (NWMO)	Government
	-Nuclear Liability and Compensation Act *	Natural Resources Canada	Government
	-Canadian Environmental Assessment Act	Canadian Standards Association (CSA)	Civil Society (Non for Profit)
		International Standards Organization (ISO)	International NGO
Mexico	Constitutional Articles 27 and 73	National Commission of Nuclear Safety and Safeguards (CNSNS)	Government
	Ley de Responsabilidad Civil por Daños Nucleares *	Energy Regulatory Commission (CRE)	Government
	Ley General del Equilibrio Ecológico y la Protección al Ambiente	Ministry of Energy (SENER)	Government

Source: [115][116]

Appendix 3. SMR Integrated Lifecycle



Appendix 4. Top Five Actors per Betweeness Centrality; Canada

	Betweenness Centrality	
1st	Government of Canada	4888,296504
2nd	Atomic Energy of Canada Limited	4253,049844
3rd	Business Development Bank of Canada	3670,469171
4th	Canadian Commercial Corporation	3664,139727
5th	Canadian Nuclear Safety Commission	3262,776188

Appendix 5 Top Five Actors per Betweeness Centrality; Mexico

	Betweenness Centrality	
1st	Westinghouse	881.919
2nd	International Atomic Energy Agency	414.109
3rd	Mitsubishi Electric Co.	411.2
4th	Central Nucleoeléctrica Laguna Verde	411.109
5th	Instituto Nacional de Investigaciones Nucleares	246.081

Appendix 6. Actors Connecting Periphery Ramifications in the Canadian SMR Ecosystem; Key Actors

ID	Foundation Year	Actor	Helix	Extra Tags
111	1910	GE Hitachi	Industry	SMR Vendors
110	1950	Candu- An SNC-Lavalin Technology	Industry	SMR Vendors
112	1986	Holtec International	Industry	SMR Vendors
109	2006	ARC Nuclear Canada Inc.	Industry	SMR Vendors
114	2007	NUSCALE	Industry	SMR Vendors - Startups
116	2008	UBattery Local Modular Energy	Industry	SMR Vendors
117	2015	USNC Ultra Safe Nuclear	Industry	SMR Vendors

Appendix 7. Periphery Actors in the Canadian SMR Ecosystem; Key Actors

ID	Foundation Year	Actor	Helix	Extra Tags
126	1842	Natural Resources Canada	Government	
60	1871	Canadian Manufacturers & Exporters	Civil Society	Unions, Professional or Industry Associations
50	1887	McMaster University	Academia	
37	1896	International Union of Operating Engineers	Civil Society	Unions, Professional or Industry Associations
168	1907	University of Saskatchewan	Academia	Public University
108	1912	Fluor	Industry	
27	1929	SaskPower	Government	Provintial/ Territorial/ Statal Crown Corporation
143	1944	CNL – Chalk River Laboratories (main)	Government	GOCO- Government Owned, Contractor Operated
99	1950	SNC-LAVALIN	Industry	Enterprises
	1952	Atomic Energy of Canada Limited	Government	Federal Crown Corporation
192	1963	University of Moncton	Academia	
29	1977	Canada´s Building Trades Union	Civil Society	Unions, Professional or Industry Associations
35	1981	International Brotherhood of Electrical Workers FIOE	Civil Society	Unions, Professional or Industry Associations
162	1983	Point Lepreau Nuclear Generating Station	Government	Provintial/ Territorial/ Statal Crown Corporation- Power Utilities
16	1987	North Shore Micmac Distric Council	Civil Society	Non-for-Profit
169	1991	Des Nedhe Group	Industry	Indigenous Governance
189	1994	Nuclear Energy Institute	International	
48	2002	Ontario Tech University	Academia	
336	2002	Ontario Institute of Technology	Academia	
154	2015	Opportunities New Brunswick	Government	Provintial/ Territorial/ Statal Crown Corporation

142	2019	Global First Power	Industry	Joint Venture
8	-	Government of Ontario	Government	Provintial/ Territorial/ Statal Government
10	-	Government of Saskatchewan	Government	Provintial/ Territorial/ Statal Government
45	-	Women in Nuclear Canada	Civil Society	Non-for-Profit-International
103	-	Urenco	Industry	
337	-	Global First Power Limited Partnership	Industry	Joint Venture
84	-	Canadian Power Utility Services Ltd	Industry	Power Utilities
90	-	IDOM Consulting, Engineering, Architecture SAU	Industry	

Appendix 8. Actors Connecting Periphery Ramifications in the Mexican SMR Ecosystem; Key Actors

ID	Foundation Year	Actor	Helix	Extra Tags
1010	1910	Universidad Nacional Autónoma de México *	Academia	Public University
1062	1968	Universidad Autónoma de Zacatecas	Academia	Public University
1001	1995	Central Nucleoeléctrica Laguna Verde	Government	Independent Federal Government Agency-Nuclear Power Utilities

*This Public University is the recipient of the donated Nuclear Reactor Siemens Sur-100 by the Federal German Republic

Appendix 9. Specific Network Analysis Statistics: Mexican Key Actors Network

ID	Foundation Year	Actor	Helix	Extra Tags
331	1921	Mitsubishi Electric Co.	Industry	
1084	1947	Ingenieros Civiles Asociados	Industry	
1024	1956	Universidad Autónoma de Nuevo León	Academia	Public University
130	1957	International Atomic Energy Agency	International Organization	
1029	1960	Nukem	Industry	
1061	1975	Instituto de Investigaciones Eléctricas	Government	Independent Federal Government Agency
1028	1986	Tenex	Industry	
1030	1988	Vertek Industrial Supply	Industry	
1033	1992	Iberdrola, Ingeniería y Construcción	Industry	
1025	1993	Nvidia	Industry	
1065	1994	Bartlett de México	Industry	
1077	2003	Asociación de Jóvenes por la Energía Nuclear en México	Civil Society	
1011	2017	Women in Nuclear México	Civil Society	Non-for-Profit-International
1063	-	Gobierno del Estado de Yucatán	Government	Statal/Provintial Government
1083	-	Germany Government*	Government	Federal Government

***** Donation of the Nuclear Reactor Siemens Sur-100 for Research and Training to the UNAM

Appendix 10. Actors Connecting Periphery Ramifications in the Canadian SMR Ecosystem; Whole Network

ID	Foundation Year	Actor	Helix	Extra Tags
126	1842	Natural Resources Canada	Government	Federal Government
55	1845	Queen´s University	Academia	Public University
50	1887	McMaster University	Academia	Public University
102	1905	United	Industry	
108	1912	Fluor	Industry	
78	1957	AECON	Industry	
75	1974	Saskatchewan Mining Association	Civil Society	Unions, Professional or Industry Associations
35	1981	International Brotherhood of Electrical Workers FIOE	Civil Society	Unions, Professional or Industry Associations
40	2006	National Electrical Trade Council	Civil Society	Non-for-Profit
109	2006	ARC Nuclear Canada Inc.	Industry	SMR Vendors
49	2011	Sylvia Fedoruk Canadian Center for Nuclear Innovation	Civil Society	Non-for-Profit/ Academic Research Center
70	2012	Canada's Oil Sands Innovation Alliance	Civil Society	Fundations
57	-	Atlantic Clean Energy Alliance		
45	-	Women in Nuclear Canada	Civil Society	Non-for-Profit/ International Organization

Appendix 11. Periphery Actors in the Canadian SMR Ecosystem; Whole Network

ID	Foundation Year	Actor	Helix	Extra Tags
229	1874	Royal Military College	Academia	Military Applications
286	1891	Capital Power	Industry	
127	1894	Trade Commissioner Service	Government	
279	1904	EnNMAX	Industry	
123	1909	Global Affairs Canada	Government	
283	1911	TransAlta-Sunday 7 Energy Centre	Industry	
291	1912	ArcelorMittal Dofasco	Industry	
218	1916	National Research Council Canada	Government	Independent Federal Government Agency / Funding Agency
76	1917	SUNCOR Energy	Industry	
124	1919	Health Canada	Government	
74	1932	Prospectors & Developers Association of Canada	Civil Society	Unions, Professional or Industry Associations
3	1944	Business Development Bank of Canada	Industry	
298	1944	Hydro-Québec	Industry	Public Enterprise-Govt control
183	1944	Society of Energy Professionals	Civil Society	Unions, Professional or Industry Associations
284	1951	TransCanada	Industry	
230	1957	University of Waterloo	Academia	
228	1959	McMaster Nuclear Reactor	Academia	Research Center/ Nuclear Reactor
181	1960	Laurentian University	Academia	
275	1961	BC Hydro	Industry	
122	1971	Environment and Climate Change Canada	Government	
299	1976	Coleson Cove Generating Station	Government	Provintial/ Territorial/ Statal Crown Corporation
277	1980	New Gold	Industry	
120	1987	Canada's Regional Development Agencies	Government	
72	1987	Mining Innovation Rehabilitation and Applied Research Corporation	Civil Society	Non-for-Profit/ Private Research Center
287	1988	ATCO Power	Industry	

89	1988	Henderson Robb Marketing	Industry	
215	1988	Western Economic Diversification	Government	Federal Government / Funding
121	1989	Canadian Space Agency	Government	
201	1989	Skills Ontario	Civil Society	Non-for-Profit
301	1991	Des Nehde Development	Industry	Indigeneous
202	1994	Skills Canada	Civil Society	Non-for-Profit
280	1996	Alberta Electric System Operation	Civil Society	Non-for-Profit
318	1998	Spirit Omega Staffing	Industry	
274	1999	Hydro One	Industry	
225	2001	McMaster Manufacturing Research Institute	Academia	Academic Research Center
289	2001	Canadian Solar	Industry	
94	2001	McCallum Environmental Ltd.	Industry	
319	2008	Pride at Work Canada	Industry	
210	2009	Innovation Saskatchewan	Government	Provintial/ Territorial/ Statal Government
101	2009	Thomas Thor Associates	Industry	
302	2011	George Gordon Developments Ltd.	Industry	
106	2013	North American Helium	Industry	
278	2013	Kineticor	Industry	
211	2015	Saskatchewan Centre for Cyclotron Sciences	Academia	Academic Research Center
269	2015	Aecon Six Nations	Industry	
314	2017	Canadian Infrastructure Bank	Industry	
313	2017	Allied Canada Nuclear Operations	Industry	
267	2019	Chipewyan Prairie-Aecon Joint Venture	Industry	Joint Venture
268	2019	Enoch-Aecon Joint Venture	Industry	Joint Venture
288	2021	City of Medicine HAT - 17 Power Plant	Government	Provintial/ Territorial/ Statal Government

Appendix 12. Actors Connecting Periphery Ramifications in the Mexican SMR Ecosystem; Whole Network

ID	Foundation Year	Actor	Helix	Extra Tags
118	1886	Westinghouse	Industry	
1002	1956	Instituto Nacional de Investigaciones Nucleares	Government	Independent Federal Government Agency
1001	1995	Central Nucleoeléctrica Laguna Verde	Government	Independent Federal Government Agency
1011	2017	Women in Nuclear México	Civil Society	International Organization

Source: Own Elaboration

Appendix 13. Upper Network Periphery Actors in the Mexican SMR Ecosystem; Whole Network

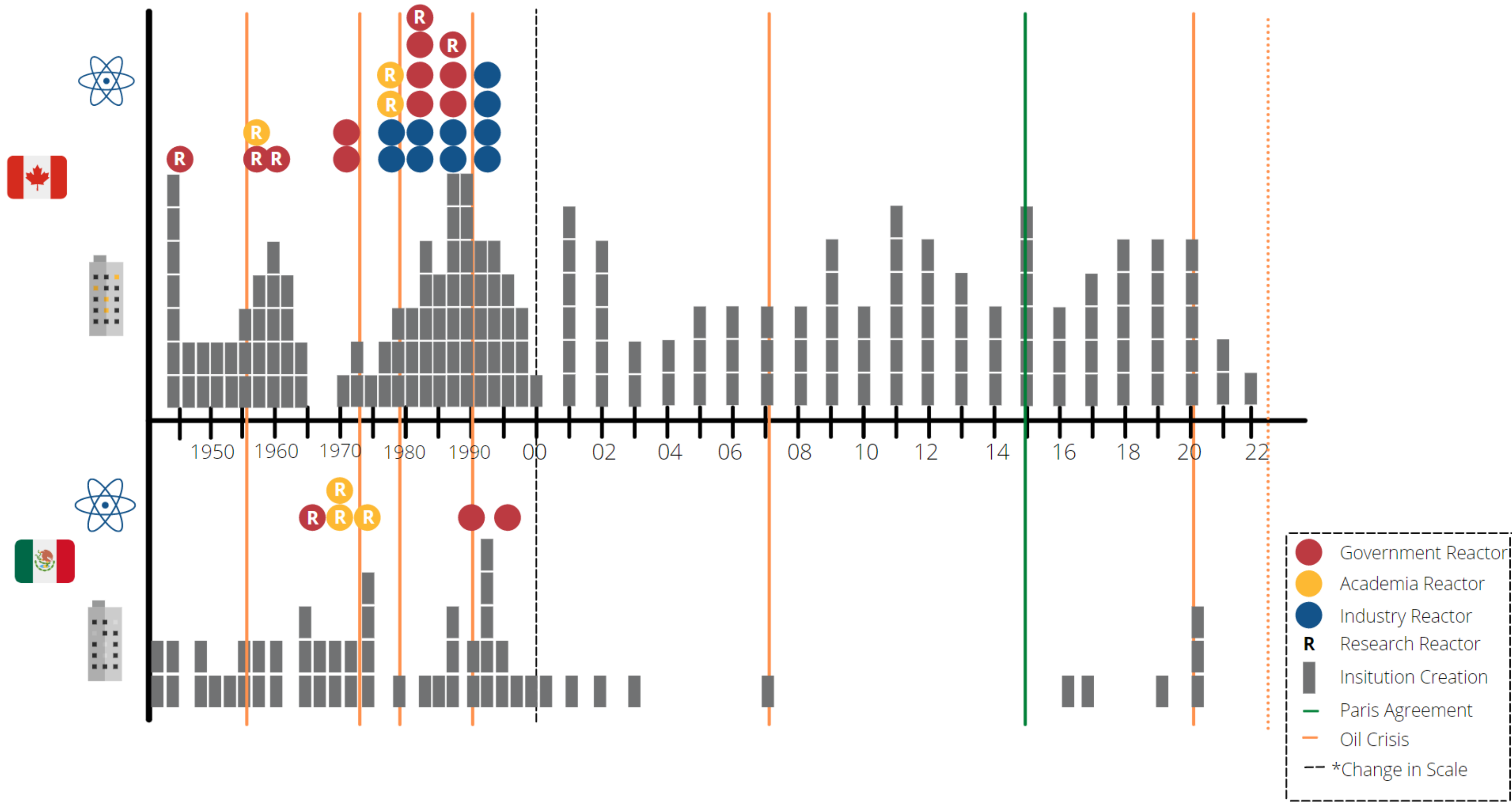
ID	Foundation Year	Actor	Helix	Extra Tags
1053	1303	University of Rome	Academia	Public University
1051	1343	University of Pisa	Academia	Public University
1050	1669	University of Zagreb	Academia	Public University
1056	1794	University of Tennessee	Academia	Public University
1038	1853	Ansaldo Energía	Industry	
1052	1859	Polytechnic University of Turin	Academia	Public University
1047	1863	Polytechnic di Milano	Academia	Public University
1048	1868	University of California Berkeley	Academia	Public University
1057	1870	Ohio State University	Academia	Public University
1049	1881	Tokyo Institute of Technology	Academia	Public University
1054	1885	Georgia Institute of Technology	Academia	Public University
1043	1943	Oak Ridge National Laboratory	Government	Public Research Center
1042	1945	OKBM Afrikantov	Industry	
1059	1945	Sandia Lab- University of Michigan	Government	Public Research Center
1058	1947	Ames Lab- Iowa State University	Government	Public Research Center
1046	1952	National Agency for New Technologies, Energy and Sustainable Economic Development	Government	Public Body
1044	1954	Comissao Nacional de Energia Nuclear	Government	Independent Federal Government Agency
1040	1973	Equipos Nucleares ENSA	Industry	

1041	1975	Nuclep	Industry	
1055	1997	Elletrobas Electronuclear	Government	
1045	2000	Lithuanian Energy Institute	Government	Independent Federal Government Agency
1039	-	Ansaldo Camozzi	Industry	

Appendix 14. Rest of the Periphery Actors in the Mexican SMR Ecosystem; Whole Network

ID	Foundation Year	Actor	Helix	Extra Tags
1035	1861	Massachusetts Institute of Technology	Academia	Private University
1007	1902	Organización Panamericana de la Salud	International Organization	
331	A921	Mitsubishi Electric Co.	Industry	
1084	1947	Ingenieros Civiles Asociados	Industry	
130	1957	International Atomic Energy Agency	International Organization	
1003	1965	International Radiation Protection Association	International Organization	
1036	1965	Comisión Chilena de Energía Nuclear	Government	Independent Federal Government Agency
1081	1974	Instituto Técnico de Toluca	Academia	Public University
1006	1993	Federación de Radio Protección de América Latina y el Caribe	International Organization	
1012	1994	Secretaría de Energía	Government	Federal Government
1034	2002	Iberdrola MX	Industry	
1072	2017	Omniciencia	Civil Society	Organized Society
1073	2019	Ciencia Juvenil Mexicana	Civil Society	Organized Society
1075	2020	Standup for Nuclear	Civil Society	International Organization
1071	2020	Radio Nuclear Team	Civil Society	Organized Society
1070	2020	Astra Navis	Civil Society	Organized Society
1076	-	Asociación Estudiantil de Ingeniería Física	Civil Society	Unions, Professional or Industry Associations
1083	-	Germany Government	Government	Federal Government

Appendix 15. Timeline for Perspective: Historical Reactor Building and Supporting Institutions Creation per Country.



Source: Adapted from [65], [116], [117]

Appendix 16. Specific Network Analysis Statistics: Canadian Whole Network

ID	Degree	Weight	Eccentricity	Closeness Centrality	Harmonic Closeness Centrality	Betweness Centrality	Bridging Coefficient	Clustering Coefficient	Modularity Class	Clustering	Triangles	Statistical Inference Class	Eigen Centrality
1	25	26	4	0,4202401372	0,4721088435	2784,019483	0,09089785435	0,00372654565	0,0003387350037	3	9	0,08333333333	25
2	19	19	4	0,4188034188	0,4632653061	837,133191	0,02733228389	0,0206121093	0,0005633760229	2	8	0,2339181287	40
3	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
4	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
5	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
6	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
7	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
8	2	2	5	0,299877601	0,3189795918	10,20833333	0,0003333006835	1,724137931	0,0005746563508	3	9	0	0
9	26	26	4	0,421686747	0,4755102041	2428,509455	0,07929050067	0,005109892801	0,0004051659586	0	2	0,06153846154	20
10	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
11	15	16	5	0,3840125392	0,4280272109	1084,681937	0,03541471649	0,01494797035	0,0005293781321	1	2	0,1904761905	20
13	8	9	5	0,3792569659	0,4123809524	75,07895116	0,00245131746	0,2403099783	0,0005890760455	1	2	0,5714285714	16
14	10	12	4	0,3957996769	0,4282312925	283,4138397	0,009253423002	0,1212148122	0,001121651931	2	7	0,3333333333	15
15	39	40	4	0,4605263158	0,524829932	3262,776188	0,1065291951	0,003673847727	0,0003913720413	2	6	0,1147098516	85
16	42	50	4	0,483234714	0,5459183673	3670,469171	0,1198403151	0,005136446704	0,0006155533916	2	6	0,1742160279	150
17	41	47	4	0,49	0,5493197279	4253,049844	0,1388614942	0,002748225816	0,0003816227432	10	3	0,1426829268	117
18	18	23	4	0,4438405797	0,4829931973	1778,808547	0,05807785515	0,04320973663	0,002509528825	4	3	0,3594771242	55
19	30	44	4	0,447080292	0,5020408163	1743,659028	0,05693022815	0,007763694644	0,0004419889074	2	5	0,2206896552	96
20	2	2	5	0,299877601	0,3186394558	4,402777778	0,0001437500907	2,083333333	0,0002994793556	3	9	0	0
21	2	2	5	0,299877601	0,3186394558	4,402777778	0,0001437500907	2,083333333	0,0002994793556	3	9	0	0
22	1	1	5	0,2962515115	0,3127891156	0	0	25	0	3	9	0	0
23	7	8	4	0,3876582278	0,4193877551	264,4178599	0,008633206865	0,4517200108	0,003899792298	4	9	0,4285714286	9
24	2	2	5	0,3301886792	0,3531972789	16,49330519	0,0005385041526	7,6171875	0,0041018871	3	9	0	0
25	2	2	5	0,3006134969	0,3196598639	4,18030303	0,0001364863207	2,419354839	0,0003302088404	3	9	0	0
26	2	2	5	0,3227931489	0,3450340136	0	0	6,818181818	0	3	9	1	1
27	1	1	5	0,2955367913	0,3103401361	0	0	19	0	2	8	0	0
29	9	9	4	0,3786707883	0,4088435374	64,35527488	0,0021011909	0,1061566859	0,0002230554624	2	8	0,5555555556	20
30	39	41	4	0,447080292	0,512585034	3664,139727	0,1196336596	0,002057214566	0,0002461121071	1	9	0,08819345661	62
31	33	42	4	0,4478976234	0,506462585	2521,235848	0,08231800469	0,004923894048	0,0004053251334	2	8	0,1628787879	86
32	9	12	5	0,3816199377	0,4144217687	23,14887355	0,000755807547	0,2692501985	0,000203501332	4	3	0,6944444444	25
33	15	21	5	0,3888888889	0,429047619	261,6237956	0,008541981049	0,04764470961	0,0004069802066	4	3	0,3714285714	39
34	15	19	5	0,3983739837	0,4399319728	965,8858762	0,03153604141	0,02352915209	0,0007420163146	4	3	0,3428571429	36
35	21	27	4	0,409015025	0,4568027211	1261,870688	0,04119990492	0,008396029278	0,0003459156079	4	5	0,2571428571	54
36	15	19	4	0,3882725832	0,4278911565	689,584034	0,02251482415	0,02981643975	0,0006713118977	5	5	0,219047619	23
37	11	15	4	0,3740458015	0,4095238095	100,8772174	0,003293627315	0,07277541808	0,0002396951049	2	5	0,3636363636	20
38	2	3	5	0,3149100257	0,334829932	0	0	5,372093023	0	5	5	1	1
39	22	28	4	0,4188034188	0,4693877551	1525,470367	0,04980639831	0,00966977513	0,0004816166717	5	5	0,1645021645	38
40	13	14	5	0,3888888889	0,4273469388	657,343857	0,02146218679	0,02595041523	0,0005569526591	5	5	0,2820512821	22
41	1	1	5	0,290628707	0,3063945578	0	0	21	0	4	5	0	0
42	3	3	5	0,3402777778	0,3641496599	5,69047619	0,0001857932673	2,807854137	0,0005216803943	5	5	0,6666666667	2
43	1	1	5	0,290628707	0,3063945578	0	0	21	0	4	5	0	0
44	1	1	5	0,290628707	0,3063945578	0	0	21	0	4	5	0	0
45	11	11	5	0,3651266766	0,403877551	213,5833495	0,006973467074	0,08338243205	0,0005814646445	8	9	0,2	11
46	8	8	5	0,3417015342	0,372585034	59,13727065	0,001930823777	0,09220820693	0,0001780377984	2	8	0,1071428571	3
47	9	9	5	0,3374655647	0,3705442177	57,93474896	0,001891561609	0,143373796	0,0002712003682	5	5	0,3611111111	13
48	3	3	5	0,3013530135	0,3205442177	244	0,00796656654	0,2991452991	0,002383160931	4	3	0,3333333333	1
49	1	1	6	0,2317880795	0,2410204082	0	0	3	0	4	3	0	0
50	5	5	5	0,3402777778	0,366462585	27,22170975	0,0008887850905	0,4015645372	0,0003569045735	8	2	0,4	4
51	1	1	5	0,3093434343	0,326122449	0	0	30	0	2	5	0	0
52	1	1	6	0,2852153667	0,2997959184	0	0	15	0	4	3	0	0
53	1	1	6	0,2852153667	0,2997959184	0	0	15	0	4	3	0	0
54	21	25	4	0,3804347826	0,4306122449	2309,394975	0,07540142924	0,004697309586	0,0003541838564	6	4	0,07142857143	15
55	4	5	5	0,3293010753	0,3550340136	60,83035107	0,001986102621	0,9773024167	0,001941022891	6	4	0,3333333333	2
56	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
57	1	1	5	0,296969697	0,3140816327	0	0	26	0	0	2	0	0
58	4	4	4	0,3689759036	0,3931972789	26,06750899	0,0008511005939	1,742553191	0,001483088056	0	3	0,3333333333	2
59	2	2	5	0,3125	0,3340136054	36,07037837	0,001177692908	0,9512195122	0,001120244473	9	4	0	0
60	2	2	6	0,2885747939	0,3059863946	10,53161376	0,000343855745	0,8947368421	0,0003076604034	9	4	0	0
61	6	6	4	0,3645833333	0,3911564626	74,19227845	0,002422367718	0,2198936778	0,0005326633464	2	5	0,2	3

62	35	41	4	0,4351687389	0,5013605442	2218,512033	0,07243411366	0,006981893536	0,0005057272699	10	0	0,131092437	78
63	2	2	1	1	1	1	,0000326498628	0,25	,00000816246571	7	1	0	0
64	1	1	2	0,6666666667	0,75	0	0	2	0	7	1	0	0
65	1	1	2	0,6666666667	0,75	0	0	2	0	7	1	0	0
66	2	2	5	0,3271028037	0,347755102	0,718866926	,0000234709065	7,032786885	0,0001650658838	2	7	0	0
67	22	22	4	0,3977272727	0,4510204082	673,1932017	0,02197966572	0,01492723706	0,0003280956807	2	7	0,1385281385	32
68	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
69	3	3	5	0,327978581	0,3494557823	244	0,00796656654	0,2990291262	0,002382235432	8	9	0,3333333333	1
70	1	1	6	0,2472250252	0,2570748299	0	0	3	0	8	9	0	0
71	1	1	6	0,2076271186	0,2153741497	0	0	2	0	2	8	0	0
72	2	2	5	0,2617521368	0,2755782313	244	0,00796656654	0,4166666667	0,003319402725	2	8	0	0
73	3	3	5	0,3211009174	0,3446938776	5,271099514	0,000172100676	1,273469388	0,0002191649429	2	8	0,3333333333	1
74	21	26	4	0,424610052	0,4697278912	612,4032427	0,0199948819	0,03395420563	0,0006789103315	4	3	0,380952381	80
75	26	32	4	0,4328621908	0,4840136054	945,2893514	0,0308635677	0,01706910039	0,0005268133353	2	0	0,2707692308	88
76	24	24	5	0,4124579125	0,4654421769	1034,653858	0,03378130659	0,01657304312	0,000559859051	1	2	0,1449275362	40
77	2	3	5	0,3297442799	0,3480952381	0	0	0,9534883721	0	10	3	1	1
78	2	2	5	0,3297442799	0,3480952381	0	0	0,9534883721	0	10	3	1	1
79	18	20	4	0,4063018242	0,4496598639	1649,124749	0,0538436969	0,008526262992	0,0004590855202	9	4	0,1307189542	20
80	2	2	5	0,3333333333	0,3521768707	40,52594144	0,001323166431	1,822222222	0,002411103274	5	5	0	0
81	14	15	4	0,3901273885	0,4268707483	466,9470583	0,01524575742	0,02904479626	0,0004428099182	10	2	0,1978021978	18
82	1	1	5	0,3293010753	0,3460544218	0	0	41	0	10	3	0	0
83	4	4	5	0,3383977901	0,3617006803	1,66025641	,0000542071441	0,684370258	,000037097757	10	3	0,5	3
84	1	1	5	0,3293010753	0,3460544218	0	0	41	0	10	3	0	0
85	1	1	5	0,3293010753	0,3460544218	0	0	41	0	10	3	0	0
86	1	1	5	0,3293010753	0,3460544218	0	0	41	0	10	3	0	0
87	2	2	5	0,330634278	0,353537415	2,637413187	,0000861111788	8,47826087	0,0007300730385	1	9	0	0
88	12	16	4	0,3757668712	0,4170068027	315,6954623	0,01030741355	0,06651551025	0,0006856028718	9	4	0,2424242424	16
89	7	7	5	0,3576642336	0,390952381	132,6339464	0,004330480161	0,2222946545	0,0009626425911	8	7	0,1904761905	4
90	6	8	4	0,3662182362	0,3921768707	23,82017817	0,000777725550	0,2567270085	0,0001996631541	2	8	0,6	9
91	4	4	5	0,2927120669	0,3144217687	20,74557062	0,000677340035	0,2097902098	0,0001420993082	5	5	0,1666666667	1
92	8	9	4	0,3441011236	0,3761904762	580,3171708	0,01894727605	0,07178676925	0,001360163734	5	2	0,07142857143	2
93	2	2	5	0,2819332566	0,2982993197	0	0	1,578947368	0	5	5	1	1
94	7	7	5	0,3525179856	0,3817687075	333,2610183	0,01088092655	0,07913279799	0,0008610381625	5	5	0,2857142857	6
95	2	2	5	0,2842227378	0,3010204082	1,357854406	,0000443337601	2,386363636	0,0001057964731	5	5	0	0
96	1	1	6	0,2609158679	0,2727210884	0	0	7	0	5	5	0	0
97	2	2	4	0,3319783198	0,3537414966	0	0	8,9375	0	2	8	1	1
98	3	3	4	0,3262316911	0,3506802721	1,077493656	0,0000351800201	2,19939577	0,000077374787	0	2	0,6666666667	2
99	1	1	5	0,296969697	0,3140816327	0	0	26	0	0	2	0	0
100	2	3	5	0,2565445026	0,2711564626	0	0	0,8	0	5	2	1	1
101	2	2	5	0,2565445026	0,2711564626	0	0	0,8	0	5	2	1	1
102	5	5	5	0,3141025641	0,3400680272	22,871913	0,0007467648231	0,4300905868	0,000321176521	1	2	0,4	4
103	6	6	4	0,3393351801	0,3680272109	64,71679681	0,002112994541	0,3580519968	0,0007565619147	5	5	0,3333333333	5
104	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
105	1	1	5	0,2809633028	0,293877551	0	0	14	0	10	2	0	0
106	8	10	5	0,3618906942	0,3936734694	63,37962263	0,002069335988	0,2398273287	0,0004962833221	9	7	0,3214285714	9
107	4	4	5	0,3576642336	0,3831292517	1,822670807	,0000595099519	1,634396355	0,000097262848	10	2	0,8333333333	5
108	2	2	5	0,3271028037	0,347755102	0,718866926	,0000234709065	7,032786885	0,0001650658838	2	7	0	0
109	1	1	5	0,290628707	0,3063945578	0	0	21	0	4	5	0	0
110	1	1	6	0,2777777778	0,2934693878	0	0	15	0	1	2	0	0
111	1	1	6	0,2777777778	0,2934693878	0	0	15	0	1	2	0	0
112	2	2	5	0,3137003841	0,3352380952	3,135854342	0,000102385214	2,6	0,000266201557	2	9	0	0
113	11	12	4	0,3945249597	0,4282312925	61,68538275	0,002014019288	0,1462685552	0,0002945876913	1	8	0,4181818182	23
114	6	6	4	0,3431372549	0,3744897959	211,8137376	0,006915689488	0,304964431	0,00210903931	6	4	0,1333333333	2
115	19	21	4	0,4260869565	0,469047619	1337,781797	0,04367839222	0,01616006018	0,0007058454469	9	7	0,2046783626	35
116	11	11	4	0,3540462428	0,3891156463	434,594539	0,0141894521	0,03833101806	0,0005438961448	9	7	0,2	11
117	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
118	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
119	8	10	5	0,3388658368	0,3702040816	183,2086658	0,005981737814	0,1063470628	0,000636140247	6	4	0,2142857143	6
120	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
121	10	12	4	0,3566229985	0,3955782313	711,664874	0,02323576055	0,03180360769	0,0007389810128	6	4	0,1555555556	7
122	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
123	3	4	5	0,330634278	0,354829932	48,82428796	0,001594106307	2,194467728	0,003498214846	5	4	0,3333333333	1
124	3	3	5	0,3066332916	0,33	52,80479551	0,001724069332	0,7579617834	0,001306778666	9	4	0	0
125	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
126	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
127	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
134	1	1	5	0,2759009009	0,2928571429	0	0	21	0	6	4	0	0
139	3	3	5	0,3017241379	0,3242857143	47,8842036	0,001563412681	0,5283018868	0,0008259538693	6	4	0	0
140	2	2	5	0,2651515152	0,2795238095	1,078737542	0,000035220632	1	0,0000352206328	6	4	0	0
141	1	1	5	0,2892561983	0,303877551	0	0	18	0	9	4	0	0
142	1	1	5	0,2892561983	0,303877551	0	0	18	0	9	4	0	0
143	1	1	5	0,2892561983	0,303877551	0	0	18	0	9	4	0	0
145	17	20	5	0,3945249597	0,4378911565	1530,584645	0,04997337878	0,01032115563	0,0005157830195	9	4	0,08088235294	11
149	1	1	5	0,2892561983	0,303877551	0	0	18	0	9	4	0	0

155	1	1	5	0,2892561983	0,303877551	0	0	18	0	9	4	0	0
158	3	3	5	0,293764988	0,3127210884	16,78423259	0,0005480028925	0,375	0,0002055010847	9	4	0	0
159	2	2	6	0,2838933951	0,3008843537	4,156159541	0,0001356980391	1,275	0,0001730149998	9	4	0	0
160	3	3	5	0,3388658368	0,3610204082	17,58660626	0,0005742002827	0,806557377	0,0004631254739	10	4	0,3333333333	1
161	2	3	5	0,312899106	0,3327891156	0	0	4,794871795	0	9	4	1	1
162	1	1	5	0,2955367913	0,3121768707	0	0	22	0	5	5	0	0
163	1	1	5	0,2955367913	0,3121768707	0	0	22	0	5	5	0	0
164	13	14	4	0,3913738019	0,4272108844	225,7726328	0,007371445501	0,06767958162	0,0004988963474	1	2	0,3076923077	24
165	1	1	5	0,2631578947	0,2781632653	0	0	10	0	6	4	0	0
166	1	1	5	0,2631578947	0,2781632653	0	0	10	0	6	4	0	0
167	2	2	5	0,2762119504	0,2934013605	0	0	2,222222222	0	6	4	1	1
168	11	11	4	0,3951612903	0,4292517007	836,3861725	0,02730789384	0,02685833889	0,0007334446672	9	4	0,2909090909	16
169	1	1	5	0,2835648148	0,2959863946	0	0	11	0	9	4	0	0
171	1	1	5	0,2835648148	0,2959863946	0	0	11	0	9	4	0	0
172	1	1	5	0,2835648148	0,2959863946	0	0	11	0	9	4	0	0
173	1	1	6	0,2832369942	0,2981632653	0	0	17	0	9	4	0	0
174	9	9	4	0,3786707883	0,4102040816	121,3003632	0,003960440225	0,1870559112	0,0007408237551	1	8	0,3611111111	13
179	1	1	6	0,2832369942	0,2981632653	0	0	17	0	9	4	0	0
181	1	1	6	0,2832369942	0,2981632653	0	0	17	0	9	4	0	0
182	1	1	6	0,2803203661	0,2941496599	0	0	13	0	5	5	0	0
183	1	1	6	0,2803203661	0,2941496599	0	0	13	0	5	5	0	0
184	3	3	5	0,3211009174	0,3453061224	16,2289028	0,000529871451	0,7595993322	0,0004024900004	10	4	0	0
185	2	2	5	0,3125	0,3327891156	2,931219176	,0000957039041	3,219512195	0,0003081198865	2	8	0	0
186	5	5	4	0,3485064011	0,3755102041	254,7415255	0,008317275874	0,1701597195	0,00141526533	0	5	0,1	1
187	1	1	5	0,2587117212	0,2700680272	0	0	5	0	0	5	0	0
189	1	1	5	0,2617521368	0,2750340136	0	0	11	0	9	7	0	0
190	1	1	5	0,3097345133	0,3273469388	0	0	33	0	2	8	0	0
192	1	1	5	0,296969697	0,3140816327	0	0	26	0	0	2	0	0
193	11	12	4	0,3798449612	0,4153061224	107,8619747	0,003521678681	0,09757775196	0,0003436374888	2	7	0,2363636364	13
197	8	9	4	0,3571428571	0,3880952381	740,1744193	0,02416659329	0,03767860638	0,0009105635561	4	9	0,1785714286	5
199	5	5	4	0,3530259366	0,380952381	527,395543	0,01721939216	0,1822595818	0,003138399214	2	8	0,1	1
200	12	13	4	0,3786707883	0,4153061224	581,082741	0,01897227181	0,02868635225	0,0005442452722	10	3	0,1515151515	10
201	6	6	4	0,3561046512	0,3853741497	319,550359	0,0104332754	0,2095148078	0,002185925691	6	4	0,06666666667	1
202	6	6	4	0,3635014837	0,3918367347	17,03793357	0,0005562861947	0,3601764885	0,0002003612082	10	3	0,6	9
210	5	6	4	0,3520114943	0,3772108844	106,163032	0,003466208437	0,1748449269	0,0006060489607	3	9	0,2	2
211	4	5	4	0,3667664671	0,3914965986	0,7134099617	,0000232927374	2,27056962	0,0000528877819	10	3	0,8333333333	5
212	4	6	5	0,3262316911	0,3495238095	247,5555097	0,008082653443	0,1966292135	0,001589285789	10	7	0,1666666667	1
213	7	7	4	0,3555878084	0,387414966	556,0697969	0,01815560261	0,05419318164	0,0009839098702	0	2	0,09523809524	2
215	1	1	5	0,2625937835	0,2753741497	0	0	7	0	0	2	0	0
216	1	1	5	0,2625937835	0,2753741497	0	0	7	0	0	2	0	0
217	2	2	5	0,3051058531	0,324829932	0	0	2,757575758	0	0	2	1	1
218	1	1	5	0,296969697	0,3140816327	0	0	26	0	0	2	0	0
219	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
220	5	5	5	0,3117048346	0,332585034	731,2336563	0,02387467861	0,06206896552	0,001481876603	6	3	0	0
221	1	1	6	0,2378640777	0,2472789116	0	0	5	0	6	3	0	0
222	1	1	6	0,2378640777	0,2472789116	0	0	5	0	6	3	0	0
223	1	1	6	0,2378640777	0,2472789116	0	0	5	0	6	3	0	0
224	2	2	4	0,3288590604	0,3520408163	60,51578947	0,001975832228	7,070175439	0,01396948049	0	9	0	0
225	1	1	5	0,2634408602	0,2756462585	0	0	8	0	4	9	0	0
228	1	1	5	0,2634408602	0,2756462585	0	0	8	0	4	9	0	0
229	1	1	5	0,2634408602	0,2756462585	0	0	8	0	4	9	0	0
230	2	2	4	0,3153153153	0,3346938776	0	0	2,171052632	0	2	8	1	1
231	1	1	5	0,2749719416	0,2883673469	0	0	12	0	10	3	0	0
232	1	1	5	0,2749719416	0,2883673469	0	0	12	0	10	3	0	0
233	31	31	5	0,409015025	0,4732653061	4888,296504	0,1596022105	0,001507839112	0,0002406544554	8	9	0,02580645161	12
234	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
235	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
236	3	3	5	0,3525179856	0,3780272109	41,41042855	0,001352044813	3,459227468	0,004677030556	8	9	0,3333333333	1
241	9	9	4	0,3858267717	0,4166666667	221,3377046	0,007226645704	0,1447496531	0,001046054459	1	7	0,2222222222	8
242	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
243	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
244	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
245	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
246	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
247	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
248	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
249	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
250	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
251	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
252	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
253	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
258	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
260	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
261	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
262	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
264	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
265	1	1	6	0,290628707	0,310952381	0	0	31	0	8	9	0	0
267	4	4	4	0,3266666667	0,3510204082	13,88873186	0,000453465190	0,5774544115	0,0002618554747	2	7	0,3333333333	2
268	4	4	5	0,3232189974	0,3480952381	17,30132588	0,000564885917	0,3926174497	0,0002217840682	2	7	0,1666666667	1
269	4	4	4	0,3365384615	0,3608843537	42,5733104	0,001390012747	0,4107115992	0,000570894358	3	9	0,3333333333	2
271	3	3	5	0,3202614379	0,3447619048	2,908134921	,0000949502063	1,514563107	0,0001438080795	1	7	0,3333333333	1
272	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0

273	2	3	5	0,3206806283	0,3423129252	0	0	4,29	0	2	5	1	1
274	1	2	6	0,2462311558	0,2566666667	0	0	4	0	10	7	0	0
275	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
277	1	1	5	0,3157216495	0,3344897959	0	0	39	0	2	6	0	0
278	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
279	4	4	5	0,3190104167	0,3423129252	15,20000293	),0004962780111	0,4372197309	0,0002169825385	8	2	0,1666666667	1
280	4	4	5	0,3374655647	0,3606802721	67,01155114	0,002187917956	0,2889173607	0,0006321274811	8	2	0,1666666667	1
283	6	6	5	0,3729071537	0,3994557823	61,87361061	0,002020164902	0,2480428485	0,0005010874567	2	8	0,3333333333	5
284	9	9	5	0,3333333333	0,3668027211	200,0212872	0,0065306676	0,07425632644	0,0004849433852	9	7	0,02777777778	1
286	1	1	5	0,3097345133	0,3273469388	0	0	33	0	2	8	0	0
287	1	1	6	0,2777777778	0,2934693878	0	0	15	0	1	2	0	0
288	8	8	4	0,3480113636	0,381292517	503,3543315	0,0164344499	0,05336889285	0,0008770883957	1	2	0,25	7
289	1	1	5	0,2584388186	0,2717006803	0	0	8	0	1	2	0	0
291	1	1	5	0,2584388186	0,2717006803	0	0	8	0	1	2	0	0
292	9	9	4	0,3901273885	0,4207482993	19,6780756	0,00064248647	0,2491187144	0,0001600554034	1	8	0,5277777778	19
294	2	2	6	0,2825836217	0,3011564626	2,567099567	),0000838154488	1,578947368	0,0001323401824	8	2	0	0
298	11	11	4	0,3769230769	0,4119047619	357,4372505	0,01167027721	0,04591410259	0,0005358303052	8	2	0,2	11
299	1	1	5	0,274049217	0,2870068027	0	0	11	0	8	2	0	0
300	1	1	5	0,3093434343	0,3289115646	0	0	39	0	1	9	0	0
301	2	2	5	0,2722222222	0,2906122449	1,893611889	),0000618261685	2,475	0,0001530197671	9	7	0	0
302	12	13	4	0,3913738019	0,4268707483	1026,030124	0,03349974286	0,01865300077	0,0006248707293	9	9	0,1818181818	12
309	1	1	5	0,2816091954	0,2944217687	0	0	12	0	9	9	0	0
313	1	1	5	0,2816091954	0,2944217687	0	0	12	0	9	9	0	0
314	1	1	5	0,2816091954	0,2944217687	0	0	12	0	9	9	0	0
315	1	1	5	0,2816091954	0,2944217687	0	0	12	0	9	9	0	0
316	5	5	4	0,3475177305	0,374829932	279,8738626	0,009137843235	0,1638446849	0,001497187046	2	7	0	0
317	1	1	5	0,258166491	0,2696598639	0	0	5	0	2	7	0	0
318	12	13	4	0,3938906752	0,4302721088	495,3787458	0,01617404812	0,04123929364	0,0006670063199	4	3	0,2424242424	16
319	4	4	5	0,3597650514	0,3824489796	15,92503642	),0005199502552	0,7248370746	0,0003768792219	2	7	0,3333333333	2
336	1	1	5	0,2991452991	0,3133333333	0	0	19	0	9	7	0	0
337	1	1	5	0,2991452991	0,3133333333	0	0	19	0	9	7	0	0

Appendix 17. Specific Network Analysis Statistics: Mexican Whole Network

ID	Degree	Weight	Eccentricity	Closeness Centrality	Harmonic Closeness Centrality	Betweness Centrality	Bridging Coefficient	Clustering Coefficient	Modularity Class	Clustering	Triangles	Statistical Inference Class	Eigen Centrality
118	51	73	3	0,7272727273	0,84027777	441,1093832	0,1633133592	0,007378399905	0,001204991274	0,4015686214	0	0,4015686275	512
130	10	12	3	0,5255474453	0,5625	83,73846154	0,03100276251	0,06642459044	0,002059345802	0,4222222269	1	0,4222222222	19
331	3	3	4	0,385026738	0,42129629	0	0	0,7159353349	0	1	0	1	3
1001	10	13	3	0,5070422535	0,55092592	57,20139291	0,02117785743	0,07055248148	0,001494150394	0,5333333611	0	0,5333333333	24
1002	57	85	2	0,808988764	0,88194444	881,9199893	0,3265161012	0,003597210549	0,001174547163	0,3488215506	0	0,3363636364	518
1003	5	5	3	0,4137931034	0,45370370	0	0	0,3461538462	0	1	1	1	10
1004	20	29	3	0,5454545455	0,62037037	59,90952381	0,02218049752	0,03394576017	0,0007529338493	0,6315789223	0	0,6315789474	120
1005	36	65	3	0,6315789474	0,73611111	246,0815153	0,09110755842	0,008674327312	0,0007902967823	0,4444444478	0	0,4444444444	280
1006	5	6	3	0,4137931034	0,45370370	0	0	0,3461538462	0	1	1	1	10
1007	5	6	3	0,4137931034	0,45370370	0	0	0,3461538462	0	1	1	1	10
1009	29	41	2	0,6260869565	0,70138888	102,2862288	0,0378697626	0,02034189325	0,0007703426682	0,6182265878	0	0,618226601	251
1010	23	25	2	0,5950413223	0,65972222	153,3684261	0,05678209037	0,01867611609	0,001060468911	0,6996047497	0	0,6996047431	177
1011	10	12	3	0,5217391304	0,56018518	411,2	0,1522399111	0,01614073461	0,002457264002	0,1111111119	1	0,1111111111	5
1012	1	1	3	0,45	0,46759259	0	0	57	0	0	0	0	0
1018	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1023	20	23	3	0,5538461538	0,625	21,10269183	,00781291811	0,04458345278	0,0003483268658	0,9052631855	0	0,9052631579	172
1024	7	8	3	0,4965517241	0,53009259	0	0	0,3814330409	0	1	0	1	21
1025	7	7	3	0,4965517241	0,53009259	0	0	0,3814330409	0	1	0	1	21
1026	11	11	3	0,5034965035	0,55324074	0	0	0,2092178288	0	1	0	1	55
1027	16	25	3	0,5294117647	0,59259259	1,476190476	,000546534793	0,0821894753	0,00004491940788	0,9083333611	0	0,9083333333	109
1028	23	30	3	0,5669291339	0,64583333	5,323679741	,00197100323	0,04099441658	0,00008080012775	0,8339921236	0	0,8339920949	211
1029	27	50	3	0,5853658537	0,67361111	18,69402606	,00692114996	0,0257084277	0,0001779318835	0,7122507095	0	0,7122507123	250
1030	27	50	3	0,5853658537	0,67361111	18,69402606	,00692114996	0,0257084277	0,0001779318835	0,7122507095	0	0,7122507123	250
1031	27	50	3	0,5853658537	0,67361111	18,69402606	,00692114996	0,0257084277	0,0001779318835	0,7122507095	0	0,7122507123	250
1032	16	24	3	0,5294117647	0,59259259	1,476190476	,000546534793	0,0821894753	0,00004491940788	0,9083333611	0	0,9083333333	109
1033	25	38	3	0,576	0,65972222	83,53179662	0,03092624829	0,01812476453	0,000560530968	0,7233333588	0	0,7233333333	217
1034	1	1	4	0,3673469388	0,39120370	0	0	25	0	0	0	0	0
1035	3	3	3	0,4090909091	0,43981481	0	0	0,7228915663	0	1	1	1	3
1036	3	3	3	0,4090909091	0,43981481	0	0	0,7228915663	0	1	1	1	3
1038	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1039	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1040	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1041	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1042	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1043	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1044	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1045	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1046	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1047	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1048	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1049	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1050	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1051	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1052	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1053	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1054	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1055	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1056	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1057	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1058	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1059	23	23	3	0,5217391304	0,62037037	0	0	0,0457571894	0	1	3	1	253
1060	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1061	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1062	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1063	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1064	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1065	20	26	3	0,5538461538	0,625	6,508116883	,00240952124	0,05370476223	0,0001294027655	0,9315789342	0	0,9315789474	177
1066	7	7	4	0,4090909091	0,46527777	0	0	0,5470373711	0	1	0	1	21
1067	13	13	3	0,5142857143	0,56944444	0	0	0,1345685218	0	1	0	1	78
1068	13	13	3	0,5142857143	0,56944444	0	0	0,1345685218	0	1	0	1	78
1069	13	13	3	0,5142857143	0,56944444	0	0	0,1345685218	0	1	0	1	78
1070	1	1	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1071	1	1	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1072	1	1	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1073	1	2	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1075	1	2	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1076	1	1	4	0,3444976077	0,35879629	0	0	10	0	0	1	0	0
1077	19	19	3	0,5496183206	0,61805555	0	0	0,06700158169	0	1	0	1	171
1079	1	1	1	1	1	0	0	1	0	0	2	0	0
1080	1	1	1	1	1	0	0	1	0	0	2	0	0
1081	1	1	3	0,45	0,46759259	0	0	57	0	0	0	0	0
1082	3	3	3	0,3891891892	0,41898148	0,5	,000185116623	1,722846442	0,0003189275161	0,3333333433	0	0,3333333333	1
1083	1	1	3	0,375	0,39351851	0	0	23	0	0	0	0	0
1084	3	3	4	0,385026738	0,42129629	0	0	0,7159353349	0	1	0	1	3

Appendix 18. Specific Network Analysis Statistics: Canadian Key Actors Network

ID	Degree	Weight	Eccentricity	Closeness Centrality	Harmonic Closeness Centrality	Betweness Centrality	Bridging Coefficient	Clustering Coefficient	Modularity Class	Clustering	Triangles	Statistical Inference Class	Eigen Centrality
109	15	19	3	0,4316546763	0,5305555556	441,812818	0,007894736842	0	0	0	0	0	0,73463714
5	12	13	2	0,5555555556	0,6	491,556234	0,04034022184	0	4	0	0	0	1
51	2	4	4	0,3125	0,3555555556	2,023809524	3	0	0	0	0	0	0,20583624
192	1	1	4	0,303030303	0,3361111111	0	15	0	0	0	0	0	0,11509057
57	1	2	4	0,303030303	0,3361111111	0	15	0	0	0	0	0	0,11509057
25	2	4	4	0,3125	0,3555555556	2,023809524	3	0	0	0	0	0	0,20583624
7	3	5	4	0,350877193	0,4055555556	37,00238555	1,333333333	0	0	0	0	0	0,29997630
64	4	4	4	0,3488372093	0,4111111111	29,78018238	0,3169014085	0	4	0	0	0	0,33936819
69	6	6	4	0,4580152672	0,5097222222	157,4570619	0,3231459053	0	1	0	0	0	0,65896004
60	1	1	4	0,303030303	0,3361111111	0	15	0	0	0	0	0	0,11509057
162	2	2	4	0,3125	0,3555555556	2,023809524	3	0	0	0	0	0	0,20583624
68	9	9	4	0,48	0,5430555556	255,1880845	0,08444615043	0	5	0	0	0	0,81738715
110	5	5	3	0,3773584906	0,4194444444	122,7684772	0,08181818182	0	5	0	0	0	0,35707946
260	4	4	4	0,3726708075	0,4333333333	49,67640096	0,5591890124	0	5	0	0	0	0,39826307
126	1	1	4	0,2752293578	0,2944444444	0	5	0	5	0	0	0	0,05508679
169	1	1	4	0,2752293578	0,2944444444	0	5	0	5	0	0	0	0,05508679
111	12	13	3	0,4166666667	0,5	320,4115422	0,01308900524	0	1	0	0	0	0,59892796
78	1	2	4	0,2955665025	0,325	0	12	0	1	0	0	0	0,09414005
83	2	2	4	0,3468208092	0,3944444444	14,28260496	3,677419355	0	1	0	0	0	0,24577930
88	2	2	4	0,3141361257	0,3569444444	4,267412207	2,571428571	0	5	0	0	0	0,19153702
26	5	6	4	0,3726708075	0,4402777778	82,29331427	0,2257425743	)100000001!	4	0	0,1	1	0,37821135
1	3	3	4	0,3428571429	0,3972222222	22,4112613	1,168141593	0	3	0	0	0	0,29483323
8	1	1	4	0,2955665025	0,325	0	12	0	1	0	0	0	0,09414005
10	1	1	4	0,2955665025	0,325	0	12	0	1	0	0	0	0,09414005
112	4	4	3	0,375	0,4111111111	66,67365139	0,1792828685	0	4	0	0	0	0,34506339
99	1	1	4	0,2739726027	0,2916666667	0	4	0	4	0	0	0	0,05284833
113	10	14	3	0,4026845638	0,475	193,1973041	0,0238410596	0	0	0	0	0	0,58636198
90	1	2	4	0,2884615385	0,3152777778	0	10	0	0	0	0	0	0,09074567
47	6	9	4	0,4109589041	0,4791666667	96,66105202	0,1950111968	0	3	0	0	0	0,55382009
114	19	19	3	0,4615384615	0,5777777778	595,8203898	0,004653086547	0	2	0	0	0	0,98321071
108	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
189	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
61	3	3	4	0,350877193	0,4055555556	15,40451646	1,308977035	0	3	0	0	0	0,35446593
24	2	2	4	0,3389830508	0,3861111111	8,508917514	3,483333333	0	3	0	0	0	0,25706895
27	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
63	2	2	4	0,3351955307	0,3819444444	8,383147607	3,053571429	0	2	0	0	0	0,24690273
45	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
48	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
168	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
50	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
336	1	1	4	0,3174603175	0,3541666667	0	19	0	2	0	0	0	0,15163925
115	9	10	3	0,3973509934	0,4638888889	171,2303015	0,03076923077	0	3	0	0	0	0,62751919
116	11	12	3	0,4081632653	0,4861111111	232,5254641	0,01936525013	0	3	0	0	0	0,69130827
2	1	1	4	0,2912621359	0,3194444444	0	11	0	3	0	0	0	0,10542970
143	2	2	4	0,303030303	0,3430555556	5,11277786	1,941176471	0	3	0	0	0	0,16228532
92	2	2	4	0,306122449	0,3472222222	2,437072293	2,475	0	3	0	0	0	0,20282667
117	6	9	3	0,3821656051	0,4305555556	104,9887964	0,09345794393	),133333340:	4	0	0,133333333	2	0,35957490
142	2	2	4	0,2790697674	0,3069444444	0	1	1	4	0	1	1	0,07958371
337	3	3	4	0,320855615	0,3569444444	7,015580618	0,3846153846	),666666686!	4	0	0,666666666	2	0,13121581
118	2	2	3	0,3636363636	0,3861111111	3,403817507	1,5	0	4	0	0	0	0,20452110
119	9	9	3	0,3973509934	0,4638888889	113,1500244	0,0412371134	0	5	0	0	0	0,64369611
339	3	3	3	0,3680981595	0,3972222222	3,001832683	0,9230769231	0	5	0	0	0	0,36010796
82	2	2	4	0,3314917127	0,3777777778	4,458526648	3,053571429	0	2	0	0	0	0,24903622
16	2	2	4	0,3125	0,3555555556	2,023809524	3	0	0	0	0	0	0,20583624
29	1	1	4	0,303030303	0,3361111111	0	15	0	0	0	0	0	0,11509057
35	2	2	4	0,3125	0,3555555556	2,023809524	3	0	0	0	0	0	0,20583624
37	1	1	4	0,303030303	0,3361111111	0	15	0	0	0	0	0	0,11509057
154	1	1	4	0,2955665025	0,325	0	12	0	1	0	0	0	0,09414005
84	1	1	4	0,2857142857	0,3111111111	0	9	0	3	0	0	0	0,09526347
93	1	1	4	0,2857142857	0,3111111111	0	9	0	3	0	0	0	0,09526347
103	1	1	4	0,2912621359	0,3194444444	0	11	0	3	0	0	0	0,10542970

Appendix 19. Specific Network Analysis Statistics: Mexican Key Actors Network

ID	Degree	Weight	Eccentricit y	Closeness Centrality	Harmonic Closeness Centrality	Betweness Centrality	Bridging Coefficient	Clustering Coefficient	Modularity Class	Clustering
1002	5	6	2	0,5490196078	0,5892857143	24,43333333	0,06463844797	0,2244897959	0,01451067199	0,400000006
1001	11	12	3	0,4827586207	0,619047619	114,3666667	0,3025573192	0,01391465677	0,004209981251	0
1009	3	3	3	0,5	0,5357142857	8,666666667	0,02292768959	0,9777777778	0,02241818538	0,3333333433
1005	2	2	3	0,5090909091	0,5297619048	8	0,02116402116	3,548387097	0,07509813961	0
1024	1	1	4	0,3294117647	0,3779761905	0	0	11	0	0
111	3	4	2	0,5283018868	0,5535714286	15	0,03968253968	1,746031746	0,06928697405	0,3333333433
118	3	3	2	0,5283018868	0,5535714286	15	0,03968253968	1,746031746	0,06928697405	0,3333333433
1025	1	1	4	0,3294117647	0,3779761905	0	0	11	0	0
331	1	1	4	0,3294117647	0,3779761905	0	0	11	0	0
1084	1	1	4	0,3294117647	0,3779761905	0	0	11	0	0
1082	2	2	3	0,4117647059	0,4523809524	1,666666667	0,004409171076	1,71875	0,007578262787	0
130	2	2	3	0,4590163934	0,494047619	0	0	2	0	1
1083	1	1	4	0,4179104478	0,4583333333	0	0	20	0	0
1010	20	23	3	0,7	0,8333333333	165,2333333	0,4371252205	0,005291005291	0,002312831854	0,08947368711
1060	3	3	2	0,5283018868	0,5535714286	15	0,03968253968	1,746031746	0,06928697405	0,3333333433
1062	20	22	3	0,6666666667	0,7976190476	121,7333333	0,3220458554	0,006382978723	0,002055611843	0,1111111119
1061	1	1	4	0,4057971014	0,4464285714	0	0	20	0	0
1023	5	6	3	0,5090909091	0,5654761905	18,9	0,05	0,1764705882	0,008823529412	0,400000006
1018	2	3	4	0,4375	0,4880952381	0	0	5	0	1
1077	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1063	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1064	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1065	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1031	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1033	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1029	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1028	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1030	2	2	4	0,4375	0,4880952381	0	0	5	0	1
1011	1	1	4	0,4179104478	0,4583333333	0	0	20	0	0

Appendix 20. Canada Node List

Unique_ID	Node		Acronym	HELIX	Link
1	Government of Canada	1	GC	Government	https://www.canada.ca/en.html
2	Atomic Energy of Canada Limited	2	AECL	Government	https://www.aecl.ca/
3	Business Development Bank of Canada	3	BDC	Government	https://www.bdc.ca/en
4	Canadian Commercial Corporation	4	CCC	Government	https://www.ccc.ca/en/
5	Canadian Nuclear Safety Commission	5	CNSC	Government	https://www.cnsc-ccsn.gc.ca/eng/
6	Government of Alberta	6	AB	Government	https://www.alberta.ca/index.aspx
7	Goverment of New Brunswick	7	NB	Government	https://www2.gnb.ca/
8	Government of Ontario	8	ON	Government	https://www.ontario.ca/page/government-ontario
9	Government of Prince Edward Island	9	PE	Government	https://www.princeedwardisland.ca/en
10	Government of Saskatchewan	10	SK	Government	https://www.saskatchewan.ca/
11	Government of Yukon	11	YT	Government	https://yukon.ca/
12	Creative Fire Agency	12	CF	Industry	https://www.creative-fire.com/
13	First Nations Power Authority	13	FNPA	Civil Society	https://fnpa.ca/
14	Integrated Project Management Inc	14	IPM	Industry	https://ca.linkedin.com/company/ipm-integrated-project-ma
15	Lions Global	15		Industry	https://lions-global.com/
16	North Shore Micmac Distric Council	16	NSMDC	Civil Society	https://nsmdc.ca/
17	Workface Warriors	17		Civil Society	https://www.workforcewarriors.ca/
18	Canadian Association of Nuclear Host Communities	18	CANHC	Civil Society	https://www.canhc.ca/
19	Durham Region	19	DR	Government	http://durham.ca/
20	Clarington	20		Government	https://www.clarington.net/en/index.aspx
21	Pinawa	21		Government	http://pinawa.com/
22	Town of Deep River	22		Government	http://www.deepriver.ca/
23	CEO´s SMR Forum	23		Civil Society	https://smractionplan.ca/content/ceo-smr-forum
24	Bruce Power	24	BP	Industry	https://www.brucepower.com/
25	Énergie NB Power	25	NBP	Government	https://www.nbpower.com/Welcome.aspx?lang=en

26	Ontario Power Generation	26	OPG	Government	https://www.opg.com/
27	SaskPower	27	SP	Government	https://www.saskpower.com/
28	Qulliq Energy Corporation	28	QEC	Government	https://www.qec.nu.ca/
29	Canada´s Building Trades Union	29	CBTU	Civil Society	https://buildingtrades.ca/
30	Atlantica Centre for Energy	30	ACE	Civil Society	http://atlanticaenergy.org/
31	ClearPath	31		Civil Society	http://clearpath.org/
32	Council for Clean & Reliable Energy	32	CCRE	Civil Society	https://thinkingenergy.ca/
33	Energy minute Education Foundation	33	EM	Civil Society	https://energyminute.ca/
34	International Brotherhood of Electrical Workers	34	IBEW Canada	Civil Society	https://www.ibewcanada.ca/
35	International Brotherhood of Electrical Workers FIOE	35	IBEW	Civil Society	https://www.ibew37.com/
36	Institute of Global Energy Education	36	IGGE	Civil Society	https://globalenergyed.org/
37	International Union of Operating Engineers	37	IUOE	Civil Society	https://www.iuoe.org/about-iuoe/iuoe-canada
38	Let´s Talk Nuclear	38	LTN	Civil Society	https://www.letstalknuclear.org/
39	Mad Science	39	MS	Industry	https://www.madscience.org/
40	National Electrical Trade Council	40	NETCO	Civil Society	http://www.netco.org/
41	North American Young Generation in Nuclear	41	NAYGN	Civil Society	https://naygn.org/
42	Power Worker´s Union	42	PWU	Civil Society	https://www.pwu.ca/
43	Saint John Citizens Coalition for Clear Air	43	SJCCCA	Civil Society	NA
44	New Diplomacy of Natural Resources	44	NewDip	Civil Society	http://www.unac.org/newdips
45	Women in Nuclear Canada	45	WIN Canada	Civil Society	https://canada.womeninnuclear.org/
46	Ontario Society of Professional Engineers	46	OSPE	Civil Society	https://ospe.on.ca/
47	Canadian Nuclear Laboratories	47	CNL	Government	https://www.cnl.ca/
48	Ontario Tech University	48	UOIT	Academia	https://ontariotechu.ca/
49	Sylvia Feedoruk Canadian Center for Nuclear Innovation	49	SFCCNI	Civil Society	https://fedorukcentre.ca/
50	McMaster University	50	MAC	Academia	https://www.mcmaster.ca/
51	University of New Brunswick	51	UNB	Academia	https://www.unb.ca/research/cner/

52	Saskatchewan Research Council	52	SRC	Industry	https://www.src.sk.ca/
53	University of Toronto	53	U of T	Academia	https://www.utoronto.ca/
54	University Network of Excellence in Nuclear Engineering	54	UNENE	Academia	https://unene.ca/
55	Queen´s University	55	QU	Academia	https://me.queensu.ca/Research/Nuclear/
56	University of Regina	56	UofR	Academia	https://www.uregina.ca/
57	Atlantic Clean Energy Alliance	57	ACEA	Civil Society	http://www.atlanticaenergy.org/index.php?mact=News,cntr http://www.atlanticaenergy.org/index.php?mact=News,cntr
58	Canadian Electricity Association	58	CEA	Civil Society	https://electricity.ca/
59	Canadian Hydrogen and Fuel Cell Association	59	CHFCA	Civil Society	https://www.electricity.ca/search/?term=nuclear
60	Canadian Manufacturers & Exporters	60	CME	Civil Society	https://cme-mec.ca/
61	Canadian Nuclear Association	61	CNA	Civil Society	https://cna.ca/
62	Canadian Nuclear Society	62	CNS	Civil Society	https://www.cns-snc.ca/
63	Canadian Standards Association Group	63	CSA	Civil Society	https://www.csagroup.org/
64	CANDU Owners Group	64	COG	Civil Society	http://www.candu.org/
65	Electricity Human Resources Canada	65	EHRC	Civil Society	https://electricityhr.ca/
66	Energy Council of Canada	66	ECC	Civil Society	https://energy.ca/
67	Nuclear Insurance Association of Canada	67	NIAC	Civil Society	http://www.niac.biz/
68	Nuclear Waste Management Organization	68	NWMO	Civil Society	https://www.nwmo.ca/
69	Organization of Canadian Nuclear Industries	69	OCNI	Civil Society	https://www.ocni.ca/
70	Canada's Oil Sands Innovation Alliance	70	COSIA	Civil Society	https://cosia.ca/
71	The Mining Association of Canada	71	MAC	Civil Society	https://mining.ca/
72	Mining Innovation Rehabilitation and Applied Research Corporation	72	MIRARCO	Civil Society	https://mirarco.org/
73	Ontario Mining Association	73	OMA	Civil Society	https://oma.on.ca/en/index.aspx
74	Prospectors & Developers Association of Canada	74	PDAC	Civil Society	https://www.pdac.ca/
75	Saskatchewan Mining Association	75	SMA	Civil Society	http://saskmining.ca/
76	SUNCOR Energy	76	SUNCOR	Industry	https://www.suncor.com/
77	AECOM	77	AECOM	Industry	https://aecom.com/
78	AECON	78	AECON	Industry	https://www.aecon.com/

79	Bird Construction	79		Industry	https://www.bird.ca/
80	Black&McDonald	80		Industry	https://blackandmcdonald.com/
81	Bucephalus Consulting	81		Industry	https://www.bucephalusconsulting.org/
82	Burns McDonnell	82		Industry	https://www.burnsmcd.com/
83	BWXT Canada Ltd	83	BWXT	Industry	https://www.bwxt.com/
84	Canadian Power Utility Services Ltd	84	CPUS	Industry	http://www.cpusl.com/
85	CALIAN	85	CALIAN	Industry	https://www.calian.com/en/industries/nuclear
86	Cavendish Nuclear	86		Industry	https://www.cavendishnuclear.com/
87	Deep Trekker	87		Industry	https://www.deeptrekker.com/
88	Hatch	88		Industry	https://www.hatch.com/
89	Henderson Robb Marketing	89		Industry	http://www.hendersonrobbmarketing.com/
90	IDOM Consulting, Engineering, Architecture SAU	90	IDOM	Industry	https://www.idom.com/
91	Imagine 4D	91		Industry	https://imagine-4d.com/
92	Kinectrics	92		Industry	https://www.kinectrics.com/
93	L3HARRIS	93		Industry	https://www2.l3t.com/mapps/
94	McCallum Enviromental Ltd	94		Industry	https://www.mccallumenvironmental.com/
95	PCL	95	PCL	Industry	https://www.pcl.com/Meet-the-PCL-Family/Locations/Canad
96	Prodigy Clean Energy	96		Industry	https://www.prodigy.energy/
97	Querencia Partners	97	QP	Industry	https://querenciapartners.com/
98	Rander Canadian Innovative Solutions Inc	98	RCIS	Industry	http://rcisolutions.ca/
99	SNC-LAVALIN	99	SNC-LAVALIN	Industry	https://www.snclavalin.com/en
100	Stantec	100		Industry	https://www.stantec.com/en
101	Thomas Thor Associates	101		Industry	https://www.thomas-thor.com/us/
102	United	102		Industry	https://ueci.com/
103	Urenco	103		Industry	https://www.urenco.com/
104	Wild Matriarch	104		Industry	https://www.wildmatriarch.com/
105	Fox Construction Nuclear Services	105	ES Fox	Industry	https://esfox.com/
106	North American Helium	106	NAH	Industry	https://nahelium.com/

107	Alithya Digital Technology Corporation	107		Industry	https://www.alithya.com/en
108	Fluor	108		Industry	https://www.fluor.com/
109	ARC Nuclear Canada Inc	109		Industry	https://www.arcenergy.co/
110	Candu- An SNC-Lavalin Technology	110		Industry	https://www.snclavalin.com/en/markets-and-services/mark
111	GE Hitachi	111		Industry	https://nuclear.gepower.com/
112	Holtec International	112		Industry	https://holtecinternational.com/
113	Moltex Clean Energy	113		Industry	https://www.moltexenergy.com/
114	NUSCALE	114		Industry	https://www.nuscalepower.com/
115	Terrestrial Energy	115		Industry	https://www.terrestrialenergy.com/
116	UBattery Local Modular Energy	116		Industry	https://www.u-battery.com/
117	USNC Ultra Safe Nuclear	117	USNC	Industry	https://usnc.com/
118	Westinghouse	118		Industry	https://westinghouse.com/
119	X-Energy	119		Industry	https://x-energy.com/
120	Canada’s Regional Development Agencies	120	CRDA	Government	https://www.ic.gc.ca/eic/site/icgc.nsf/eng/h_07662.html
121	Canadian Space Agency	121	CSA	Government	https://www.asc-csa.gc.ca/eng/Default.asp
122	Environment and Climate Change Canada	122	ECCC	Government	https://www.canada.ca/en/environment-climate-change.htr
123	Global Affairs Canada	123	GAC	Government	https://www.international.gc.ca/global-affairs-affaires-monc
124	Health Canada	124	HC	Government	https://www.canada.ca/en/health-canada.html
125	Innovation, Science and Economic Development Canada	125	ISED	Government	http://www.ic.gc.ca/home
126	Natural Resources Canada	126	NRC	Government	https://www.nrcan.gc.ca/home
127	Trade Commissioner Service	127	TCS	Government	https://www.tradecommissioner.gc.ca/index.aspx?lang=eng
128	European Atomic Energy Community	128	Euratom		https://en.wikipedia.org/wiki/European_Atomic_Energy_Co
129	OECD Nuclear Energy Agency	129	OECD NEA		https://www.oecd-nea.org/
130	International Atomic Energy Agency	130	IAEA		https://en.wikipedia.org/wiki/European_Atomic_Energy_Co
131	Generation IV International Forum	131	GIF		https://www.gen-4.org/
132	International Framework for Nuclear Energy Cooperation	132	IFNEC		https://www.ifnec.org/ifnec/jcms/j_6/home
133	Clean Energy Ministerial	133	CEM		https://www.cleanenergyministerial.org/

134	Export Development Canada	134	EDC	Government	https://www.edc.ca/
135	United Nations Association in Canada	135	UNAC		https://www.unac.org/
136	NICE Future Initiative	136			https://www.nice-future.org/
137	McKinsey & Company´s	137			https://www.nice-future.org/
138	Nuclear Suppliers Group	138	NSG		
139	Atlantic Canada Opportunities Agency	139	ACOA	Government	
140	SMR Nuclear Energy Research Cluster	140		Industry	
141	Candu Energy Inc.	141		Industry	
142	Global First Power	142		Industry	Nuclear Suppliers Group
143	CNL – Chalk River Laboratories (main)	143		Government	
144	CNL – Ottawa office	144		Government	
145	CNL – Whiteshell Laboratories	145		Government	
146	CNL – Historic Waste Program (in The Port Hope Area Initiative Management Office (PHAI)-added)	146		Government	
147	CNL – Fredericton	147		Government	
148	United States Nuclear Regulatory Commission	148			
149	Alberta Innovates	149		Government	https://albertainnovates.ca/
150	Ministry of Energy of Alberta	150		Government	https://www.alberta.ca/energy.aspx
151	Pacific Northwest National Laboratory	151			
152	Advanced Nuclear Research Centre	152			
153	Department of Natural Resources and Energy Development (DNRED)	153	DNRED	Government	
154	Opportunities New Brunswick	154	ONB	Government	
155	Centre for Nuclear Energy Research	155	CNER	Academia	https://www.unb.ca/research/cner/html-nosidenav.html
156	Department of Aboriginal Affairs	156		Government	
157	Women's Equality Branch of the Executive Council Office	157		Government	
158	Brillian Labs	158		Civil Society	https://www.brilliantlabs.ca/
159	Future NB	159		Government	https://futurenewbrunswick.ca/

160	Future Wabanaki	160		Government	https://futurenewbrunswick.ca/future-wabanaki/
161	Darlington Nuclear Site	161		Government	https://www.opg.com/powering-ontario/our-generation/nu
162	Point Lepreau Nuclear Generating Station	162		Government	https://www.nbpower.com/en/about-us/in-the-community/
163	CAMECO	163	CAMECO	Industry	https://www.cameco.com/
164	Centre for Next Generation Nuclear	164		Industry	
165	Centre for Canadian Nuclear Sustainability	165		Government	https://theccns.com/
166	Canadian Light Source national synchrotron facility	166		Academia	https://www.lightsource.ca/
167	SMR Unit (Ministry of Environment's Climate Change Branch)	167		Government	-
168	University of Saskatchewan	168	USask	Academia	https://www.usask.ca/
169	Des Nedhe Group	169		Industry	https://desnedhe.com/
170	English River First Nation	170	EFRN	Government	
171	SMR Division (NRCan)	171		Government	
172	McGill University	172		Academia	https://www.mcgill.ca/
173	Assembly of First Nations	173		Civil Society	https://www.afn.ca/
174	KINAP Solutions	174		Industry	https://www.linkedin.com/company/kinap-solutions/about/
175	Kincardine	175		Government	
176	Port Hope	176		Government	
177	Pickering	177		Government	
178	County of Bruce	178		Government	
179	The Port Hope Area Initiative	179	PHAI	Government	https://www.phai.ca/
180	Weesoe Community Communications Technology	180		Civil Society	https://wcc-tech.ca/home/about/
181	Laurentian University	181		Academia	https://laurentian.ca/
182	Laborers' International Union of North America	182	LIUNA	Civil Society	https://www.liuna.org/
183	Society of Energy Professionals	183		Civil Society	https://www.thesociety.ca/
184	Canadian Council for Aboriginal Business	184	CCAB	Civil Society	https://www.ccab.com/
185	Saugeen Ojibway Nation	185	SON	Government	https://saugeenfirstnation.ca/
186	Historic Saugeen Métis	186	HSM	Government	https://saugeenmetis.com/

187	Métis Nation of Ontario	187		Government	https://www.metisnation.org/
188	World Association of Nuclear Operators	188	WANO	International	https://www.wano.info/
189	Nuclear Energy Institute	189	NEI		https://www.nei.org/home
190	Pickering Nuclear Site	190		Government	https://www.opg.com/powering-ontario/our-generation/nu
191	Government of Nunavut	191		Government	
192	University of Moncton	192		Academia	https://www.umoncton.ca/
193	New Brunswick Community College	193		Academia	https://nbcc.ca/
194	U.S. Nuclear Regulatory Commission (NRC)	194			
195	Nuclear Energy Advisory Council	195	NEAC		
196	Red Seal electrical	196			
197	Canadian Electrical Contractors Association	197	CECA	Civil Society	https://ceca.org/
198	Global Power Trade Unions	198		Civil Society	https://es-la.facebook.com/GlobalPowerTradeUnions/
199	Canadian Nuclear Workers Council	199	CNWC	Civil Society	https://cnwc-cctn.ca/
200	PlugNDrive	200		Industry	https://www.plugndrive.ca/
201	Skills Ontario	201		Civil Society	https://www.skillsontario.com/
202	Skills Canada	202		Civil Society	http://skillscompetencescanada.com/
205	National Nuclear Laboratories (UK)	205			https://www.nnl.co.uk/
206	US DOE Laboratories	206	DOE		
207	Clean Energy Research Lab	207		Academia	https://cerl.ontariotechu.ca/
208	ACE facility for climatic and seismic testing	208		Academia	https://ace.ontariotechu.ca/about_ace/ace-facts.php
209	International Organization for Standardization	209	ISO	International	
210	Innovation Saskatchewan	210		Government	https://innovationsask.ca/
211	Saskatchewan Centre for Cyclotron Sciences	211	SCCS	Academia	https://fedorukcentre.ca/facilities/saskatchewan-centre-for-
212	Saskatchewan Polytechnic	212		Academia	https://saskpolytech.ca/
213	Saskatchewan Nuclear Secretariat	213		Government	https://www.saskatchewan.ca/government/news-and-medi
214	Saskatchewan Research Council	214		Government	https://www.src.sk.ca/who-we-are/about-us
215	Western Economic Diversification	215		Government	https://www.wd-deo.gc.ca/eng/home.asp
216	Canada Foundation for Innovation	216	CFI	Government	https://www.innovation.ca/

217	Natural Sciences and Engineering Research Council of Canada	217	NSERC	Government	https://www.nserc-crsng.gc.ca/index_eng.asp
218	National Research Council Canada	218	NRCC	Government	https://nrc.canada.ca/en
219	Saskatchewan Department of Advanced Education	219		Government	https://www.saskatchewan.ca/government/government-str
220	Saskatchewan Department of Energy and Resources, and Environment	220		Government	https://www.saskatchewan.ca/government/government-str
221	CIFAR	221		Civil Society	https://cifar.ca/
222	Jhonson Shoyama School of Public Policy	222	JSGS	Academia	https://www.schoolofpublicpolicy.sk.ca/
223	Centre for the Study of Science and Innovation Policy	223	CSIP	Academia	https://www.schoolofpublicpolicy.sk.ca/csip/
224	McMaster Innovation Park	224	MIP	Academia	https://mcmasterinnovationpark.ca/
225	McMaster Manufacturing Research Institute	225	MMRI	Academia	https://www.eng.mcmaster.ca/mcmaster-manufacturing-res
226	McMaster Institute for Transportation & Logistics	226		Academia	https://mitl.mcmaster.ca/
227	SAMOSAFER	227		-	-
228	McMaster Nuclear Reactor	228		Academia	https://nuclear.mcmaster.ca/facility/nuclear-reactor/
229	Royal Military College	229		Academia	https://www.rmc-cmr.ca/en
230	University of Waterloo	230		Academia	https://uwaterloo.ca/
231	CaNRisk CREATE	231		Academia	http://canriskcreate.ca/
232	Western University	232		Academia	https://www.uwo.ca/
233	Canadian Nuclear Isotope Council	233	CNIC	Civil Society	https://www.canadianisotopes.ca/
234	Reactor Materials Testing Laboratory	234	RMTL	Academia	https://rmtl.engineering.queensu.ca/
235	Marine Additive Manufacturing Centre	235		Academia	https://www.unb.ca/mamce/
236	FactSage	236		Industry	https://www.factsage.com/
237	COMSOL Multiphysics	237		-	-
240	New Brunswick Foundation for Innovation	240		Civil Society	https://nbif.ca/
241	SLOWPOKE-2	241		Academia	https://www.rmc-cmr.ca/en/chemistry-and-chemical-engine
242	SRC Environmental Analytical Laboratories	242		Government	https://www.src.sk.ca/labs/environmental-analytical-laborat
243	Greenhouse Gas Technology Centre	243		Academia	https://www.uregina.ca/fm/find-us.html

244	Computational Materials Engineering Laboratory	244	MSE	Academia	http://www.ecf.utoronto.ca/~singhc17/
245	Fusion Materials Laboratory	245	UTIAS	Academia	https://www.utias.utoronto.ca/research-and-centres/fusion
246	Institute for Multidisciplinary Design & Innovation	246		Academia	https://www.mie.utoronto.ca/ut-imdi/
247	Ontario Center of Innovation	247	OCI	Civil Society	https://www.oc-innovation.ca/
248	Nu-Tech Precision Metals Inc	248		Industry	https://nutechpm.com/
249	Ontario Research Fund	249	ORF	Government	https://www.ontario.ca/page/ontario-research-fund
250	Economic Development Greater Saint John	250	EDGSJ	Civil Society	https://www.discoversaintjohn.com/place/economic-develo
251	C2 Solar	251		Industry	http://www.c2solar.ca/
252	Laurentis Energy Partners	252		Industry	https://laurentisenergy.com/
253	Canadian Manufacturing Coalition	253		Civil Society	https://www.manufacturingourfuture.ca/
254	World Nuclear Association	254	WNA		
255	Nuclear Industry Association United Kingdom	255			
256	Foratom	256		-	
258	Prospectors' and Developers' Association of Canada	258	PDAC	Civil Society	https://www.pdac.ca/
259	Clean Energy, Education and Empowerment Initiative (C3E)	259	C3E		https://www.cleanenergyministerial.org/initiatives-campaig
260	Canadian Council of Aboriginal Businesses	260		Civil Society	https://www.ccab.com/
261	Canadian Mining Innovation Council	261		Civil Society	https://www.cim.org/library/canada-mining-innovation-cou
262	Saskatchewan Industrial Manufacturing Suppliers Association	262	SIMSA	Civil Society	https://simsa.ca/about/#:~:text=SIMSA%20(the%20Saskatch
263	Sask. Trade and Export Development	263	Sask TED	Government	https://www.saskatchewan.ca/government/government-str
264	Sask Chamber	264		Civil Society	https://saskchamber.com/
265	Saskatchewan Industrial Energy Consumer Association	265	SIECA	Civil Society	http://sieca.ca/#:~:text=The%20Saskatchewan%20Industrial
266	MZ Consulting Inc	266	MZC		https://mzconsultinginc.com/
267	Chipewyan Prairie-Aecon Joint Venture	267	CPAJV	Industry	https://www.aecon.com/our-projects/indigenous-affairs/ae
268	Enoch-Aecon Joint Venture	268	EAJV	Industry	https://www.aecon.com/our-projects/indigenous-affairs/en

269	Aecon Six Nations	269	A6N	Industry	https://www.aecon.com/press-room/news/2015/04/13/135
270	Wachs Technical Services	270			
271	Chandos-Bird joint venture	271		Industry	http://www.cbsjv.ca/about/
272	Toronto Construction Association	272	TCA	Civil Society	https://www.tcaconnect.com/About-Us.html
273	Mechanical Contractors Association of Canada	273	MCAC	Civil Society	https://mcac.ca/
274	Hydro One	274		Industry	https://www.hydroone.com/
275	BC Hydro	275		Industry	https://www.bchydro.com/
276	Utah Associated Municipal Power Systems	276	UAMPS		
277	New Gold	277		Industry	https://www.newgold.com/
278	Kineticor	278		Industry	https://kineticor.ca/
279	EnNMAX	279		Industry	https://www.enmax.com/
280	Alberta Electric System Operation	280		Civil Society	https://www.aeso.ca/aeso/about-the-aeso/#:~:text=The%20
281	Altalink	281		Industry	https://www.altalink.ca/
282	Exxon Mobil	282			
283	TransAlta-Sunday 7 Energy Centre	283		Industry	https://www.transalta.com/
284	TransCanada	284		Industry	https://www.tcenergy.com/
285	Chevron	285		-	-
286	Capital Power	286		Industry	https://www.capitalpower.com/
287	ATCO Power	287		Industry	https://electric.atco.com/en-ca.html
288	City of Medicine HAT - 17 Power Plant	288		Government	https://www.medicinehat.ca/en/government-and-city-hall/u
289	Canadian Solar	289		Industry	https://www.canadiansolar.com/
290	Nextera	290			
291	ArcelorMittal Dofasco	291		Industry	https://dofasco.arcelormittal.com/
292	City of Hamilton	292		Government	https://www.hamilton.ca/
293	Sithe Global	293			
294	Independent Electricity System Operator	294	IESO	Industry	http://www.ieso.ca
295	Unilever	295			
296	Procter & Gamble	296			
297	Kruger	297			

298	Hydro-Québec	298		Industry	https://www.hydroquebec.com/residential/
299	Coleson Cove Generating Station	299		Government	https://www.power-technology.com/marketdata/coleson-c
300	Tron Construction	300		Industry	https://www.troncm.com/
301	Des Nehde Development	301		Industry	https://www.troncm.com/
302	George Gordon Developments Ltd	302		Industry	http://www.ggdevelopments.com/
303	Embalse	303			
304	Department of National Defence	304	DND		
305	Women in Nuclear UK	305			
306	UK Young Generation Networks	306	YGN		
307	International Thermonuclear Experimental Reactor	307	ITER		
308	European Nuclear Society	308			
309	Nuclear Innovation Institute	309	NII	Civil Society	https://www.nuclearinnovationinstitute.ca/
310	Centre for Canadian Nuclear Sustainability	310	CCNS	Government	https://theccns.com/
311	Energy Solutions	311			
312	Project Management Institute	312	PMI		
313	Allied Canada Nuclear Operations	313	ACNO	Industry	https://opencorporates.com/companies/ca/10201880
314	Canadian Infrastructure Bank	314	CIB	Industry	https://cib-bic.ca/
315	Electrical Power System Construction Association	315	EPSCA	Civil Society	https://www.epsca.org/
316	Canadian National Energy Alliance	316	CNEA	Civil Society	http://www.cnea.co/
317	Northeastern Alberta Aboriginal Business Association	317	NAABA	Civil Society	https://naaba.ca/
318	Spirit Omega Staffing	318		Industry	https://www.spiritomega.com/
319	Pride at Work Canada	319		Industry	https://prideatwork.ca/
320	Catalyst	320			
321	Black & Veatch	321			
322	Global Nuclear Fuel	322	GNF		
323	ENUSA	323			
324	Synthos Green Energy	324			

325	Fermi Energia	325			
326	Overland Contracting Canada Inc	326			
327	International Electrotechnical Commission	327	IEC		
328	Institute of Electrical and Electronics Engineers	328	IEEE		
329	Energoatom	329			
330	Kiewit Power Constructors	330			
331	Mitsubishi Electric Co.	331	MELCO		
332	Exelon	332			
333	Oregon State University	333			
334	Electric Power Research Institute	334	EPRI		
335	University of Idaho	335		Academia	
336	Ontario Institute of Technology	336	OIT	Academia	https://ontariotechu.ca/
337	Global First Power Limited Partnership	337		Industry	
338	Des Nedhe Institute	338		Civil Society	https://www.desnedheinstitute.com/
339	Dual Fluid Energy	339		Industry	https://dual-fluid.com/

Appendix 21. Canada Edge List

Source	Target	Type	Weight
1	2	undirected	1
1	120	undirected	1
1	121	undirected	1
1	122	undirected	1
1	123	undirected	1
1	124	undirected	1
1	125	undirected	1
1	126	undirected	1
1	127	undirected	1
1	45	undirected	1
1	41	undirected	1
1	115	undirected	1
1	5	undirected	1
1	26	undirected	1
1	24	undirected	1
1	27	undirected	1
1	25	undirected	1
1	4	undirected	1
1	134	undirected	1
1	3	undirected	1
1	13	undirected	1
1	39	undirected	1
1	139	undirected	1
1	140	undirected	1
140	25	undirected	1
2	141	undirected	1
2	142	undirected	1
2	5	undirected	1
6	8	undirected	1
6	10	undirected	1
6	7	undirected	1
7	25	undirected	1
7	109	undirected	1
7	113	undirected	1
7	5	undirected	1
7	155	undirected	1
155	51	undirected	1
7	47	undirected	1
7	6	undirected	1
7	8	undirected	1

7	10	undirected	1
7	57	undirected	1
7	158	undirected	1
7	38	undirected	1
38	51	undirected	1
7	159	undirected	1
7	160	undirected	1
8	161	undirected	1
8	143	undirected	1
8	26	undirected	1
8	6	undirected	1
8	7	undirected	1
8	10	undirected	1
8	162	undirected	1
8	24	undirected	1
8	25	undirected	1
8	27	undirected	1
8	163	undirected	1
163	164	undirected	1
8	165	undirected	1
9	25	undirected	1
10	27	undirected	1
10	166	undirected	1
10	6	undirected	1
10	7	undirected	1
10	8	undirected	1
10	167	undirected	1
10	49	undirected	1
49	168	undirected	1
13	126	undirected	1
13	27	undirected	1
13	5	undirected	1
171	126	undirected	1
14	27	undirected	1
14	26	undirected	1
14	126	undirected	1
15	172	undirected	1
16	25	undirected	1
16	126	undirected	1
16	113	undirected	1
16	109	undirected	1
16	139	undirected	1
16	69	undirected	1

17	173	undirected	1
17	174	undirected	1
18	68	undirected	1
18	5	undirected	1
20	26	undirected	1
20	161	undirected	1
20	179	undirected	1
21	145	undirected	1
47	5	undirected	1
22	143	undirected	1
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23	162	undirected	1
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25	142	undirected	1
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30	162	undirected	1
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232	231	undirected	1
50	233	undirected	1

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79	47	undirected	1
47	271	undirected	1
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84	99	undirected	1
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85	69	undirected	1
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93	91	undirected	1
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98	24	undirected	1
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102	68	undirected	1
102	314	undirected	1
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108	319	undirected	1
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113	90	undirected	1
113	47	undirected	1
113	51	undirected	1
113	5	undirected	1
113	68	undirected	1
113	162	undirected	1

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114	189	undirected	1
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114	27	undirected	1
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117	143	undirected	1
117	337	undirected	1
142	337	undirected	1
26	337	undirected	1
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118	5	undirected	1

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119	61	undirected	1
119	69	undirected	1
119	64	undirected	1
119	68	undirected	1
119	88	undirected	1
119	260	undirected	1
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233	24	undirected	1
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339	68	undirected	1
339	47	undirected	1
1	25	undirected	1
1	51	undirected	1

Appendix 22. Mexico´s Node List

UniqueID	Node		Acronym	Helix	Link
111	GE Hitachi	111		Industry	https://nuclear.gepower.com/
118	Westinghouse	118		Industry	https://westinghouse.com/
130	Organismo Internacional de Energía Atómica	130	OIEA	International	https://www.iaea.org/es
331	Mitsubishi Electric Co.	331		Industry	http://www.mitsubishielectric.com/
1001	Central Nucleoeléctrica Laguna Verde	1001	CNLV	Government	https://es.wikipedia.org/wiki/Central_Nuclear_Lag
1002	Instituto Nacional de Investigaciones Nucleares	1002	ININ	Government	https://www.gob.mx/inin
1003	International Radiation Protection Association	1003	IRPA	International	https://www.irpa.net/
1004	Sociedad Mexicana de Seguridad Radiologica A.C.	1004	SMSR	Civil Society	https://smsr.org.mx/
1005	Sociedad Nuclear Mexicana AC	1005	SNM	Civil Society	http://sociedadnuclear.mx/aboutUs.html
1006	Federación de Radio protección de América Latina y el Caribe	1006	FRACL	International	https://es-la.facebook.com/fralc.radioproteccion/
1007	Organización Panamericana de la Salud	1007	OPS	International	https://www.paho.org/es
1008	Universidad Nacional de San Martin	1008	UNSM	International	https://www.unsam.edu.ar/
1009	Comisión Federal de Electricidad	1009	CFE	Government	https://www.cfe.mx/
1010	Universidad Nacional Autónoma de México	1010	UNAM	Academia	https://www.unam.mx/
1011	Women in Nuclear Mexico	1011	WIN MEX	International	http://winmexico.org/
1012	Secretaría de Energía	1012	SENER	Government	https://www.gob.mx/sener
1013	Instituto Nacional de Electricidad y Energías Limpias	1013	INEEL	Government	https://www.gob.mx/ineel
1014	Triga Mark III Research Reactor	1014		Government	https://www.gob.mx/inin/acciones-y-programas/r
1015	Subcritical Chicago M900 Research Reactor	1015		Academia	http://ntrzacatecas.com/2015/07/05/reactor-nucl
1016	Chicago M200 Research Reactor	1016		Academia	https://www.ipn.mx/assets/files/sepi-esfm/docs/c
1017	Siemens SUR-100 Research Reactor	1017		Academia	http://www.acervo.gaceta.unam.mx/index.php/gu
1018	Academia de Ingenieria de Mexico	1018	AIM	Academia	https://es.ai.org.mx/
1019	Laboratorio de Instrumentación Espacial	1019	LINX	Academia	https://epistemia.nucleares.unam.mx/web?name=
1020	Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean	1020	ARCAL	International	https://www.iaea.org/about/partnerships/regiona arcal#:~:text=The%20Regional%20Cooperation%2

1021	Universidad Autónoma del Estado de México	1021	UAEM	Academia	https://www.uaemex.mx/
1022	Fundación Rafael Preciado A.C.	1022		Civil Society	http://frph.org.mx/fundacion/
1023	Instituto Politécnico Nacional	1023		Academia	https://www.ipn.mx/
1024	Universidad Autónoma de Nuevo León	1024	UANL	Academia	https://www.uanl.mx/
1025	Nvidia	1025		Industry	https://www.nvidia.com/es-la/
1026	Instituto Tecnológico de Estudios Superiores de Monterrey	1026	ITESM	Academia	https://tec.mx/es
1027	Toshiba	1027		Industry	https://www.toshiba.com/tai/
1028	Tenex	1028		Industry	https://rosatom-latinamerica.com/press-centre/ne
1029	Nukem	1029		Industry	https://www.nukemtechnologies.de/en
1030	Vertek Industrial Supply	1030		Industry	https://vertekindustrial.com/
1031	Grupo IAI	1031		Industry	https://www.grupo-iai.com.mx/
1032	Tecnatom	1032		Industry	https://www.tecnatom.es/
1033	Iberdrola, Ingeniería y Construcción	1033		Industry	https://www.iberdrola.com/
1034	Iberdrola MX	1034		Industry	https://www.iberdrolamexico.com/
1035	Massachusets Institute of Technology	1035		Academia	https://www.mit.edu/
1036	Comisión Chilena de Energía Nuclear	1036	CCHEN	Government	https://www.cchen.cl/
1037	British Nuclear Fuels Limited	1037	BNFL	Industry	
1038	Ansaldo Energía	1038		Industry	https://www.ansaldoenergia.com/
1039	Ansaldo Camozzi	1039		Industry	
1040	Equipos Nucleares ENSA	1040	ENSA	Industry	https://www.ensa.es/
1041	Nuclep	1041		Industry	https://www.nuclep.gov.br/pt-br/
1042	OKBM Afrikantov	1042		Industry	https://www.oecd-nea.org/jcms/pl_30620/okbm-a
1043	Oak Ridge National Laboratory	1043	ORNL	Government	https://www.ornl.gov/
1044	Comissao Nacional de Energia Nuclear	1044	CNEN	Government	https://www.gov.br/cnen/pt-br
1045	Lithuanian Energy Institute	1045	LEI	Government	https://latlit.eu/lithuanian-energy-institute-lei/
1046	National Agency for New Technologies, Energy and Sustainable Economic Development	1046	ENEA	Government	https://www.enea.it/en/enea/about-us
1047	Politico di Milano	1047		Academia	https://www.polimi.it/

1048	University of California Berkeley	1048	UC Barkeley	Academia	https://www.universityofcalifornia.edu/
1049	Tokyo Institute of Technology	1049	TIT	Academia	https://www.titech.ac.jp/english
1050	University of Zagreb	1050	UNIZG	Academia	http://www.unizg.hr/homepage/
1051	University of Pisa	1051	UNIPI	Academia	https://www.unipi.it/index.php/english
1052	Polytechnic University of Turin	1052	POLITO	Academia	https://www.polito.it/?lang=en
1053	University of Rome	1053		Academia	https://www.uniroma1.it/en/pagina-strutturale/h
1054	Georgia Institute of Technology	1054	Georgia Tech	Academia	https://www.gatech.edu/
1055	Elletrobas Electronuclear	1055		Government	https://www.eletronuclear.gov.br/
1056	University of Tenesse	1056	UTK	Academia	https://www.utk.edu/
1057	Ohio State University	1057	OSU	Academia	https://www.osu.edu/
1058	Ames Lab- Iowa State University	1058		Government	https://www.ameslab.gov/
1059	Sandia Lab- University of Michigan	1059		Government	https://ece.engin.umich.edu/event/advanced-mic
1060	Comision Nacional de Seguridad Nuclear y Salvaguardias	1060	CNSNS	Government	https://www.gob.mx/cnsns
1061	Instituto de Investigaciones Electricas	1061	IIE	Government	https://www.gob.mx/ineel
1062	Universidad Autonoma de Zacatecas	1062		Academia	https://www.uaz.edu.mx/
1063	Gobierno del Estado de Yucatan	1063		Government	https://www.yucatan.gob.mx/
1064	Areva	1064		Industry	https://www.sa.areva.com/EN/home-57/areva-s-a
1065	Bartlett de Mexico	1065		Industry	http://www.bartlettdemexico.com/
1066	GD Energy Services	1066		Industry	https://gdes.com/corporate/es/
1067	EERMS S.A. de C.V.	1067		Industry	https://www.quienesquien.wiki/es/empresas/eer
1068	PetroServicios	1068		Industry	https://www.petroservicios.com.mx/
1069	Control de Radiaciones e Ingenieria	1069	CRISAMEX	Civil Society	https://crisamex.com/
1070	Astra Navis	1070		Civil Society	https://www.facebook.com/pages/category/Scien
1071	RadioNuclear Team	1071		Civil Society	https://www.facebook.com/radionuclearteam
1072	Omniciencia	1072		Civil Society	https://www.facebook.com/OmnisciencíaDC/
1073	Ciencia Juvenil Mexicana	1073	CJM	Civil Society	https://juventud.com.mx/listing/ciencia-juvenil-m
1075	Standup for Nuclear	1075		International	https://standupfornuclear.org/

1076	Asociación Estudiantil de Ingeniería Física	1076	AEIF_MX	Civil Society	https://aeifmx.com/
1077	Asociación de Jóvenes por la Energía Nuclear en México	1077	AJENM	Civil Society	http://www.inin.gob.mx/plantillas/investigacion.ct
1078	Sindicato único de Trabajadores de la Industria Nuclear	1078		Civil Society	https://sites.google.com/site/sutinuclear/home/ac
1079	Uranio Mexicano	1079	URAMEX	Government	
1080	Consejo de Recursos Minerales	1080		Government	https://www.gob.mx/sgm/acciones-y-programas/p
1081	Instituto Tecnico de Toluca	1081	IIT	Academia	https://www.tolucatecnm.mx/
1082	Universidad Autonoma Metropolitana de Iztapalapa	1082	UAMITZ	Academia	http://www.iztapalapa.uam.mx/
1083	Gemany Government	1083		Government	https://www.bundesregierung.de/breg-en
1084	Ingenieros Civiles Asociados	1084	ICA	Industry	https://www.ica.com.mx/

Appendix 23. Mexico´s Edge List

Source	Target	Type	Weight
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1003	1004	undirected	1
1003	130	undirected	1
1003	1006	undirected	1
1003	1007	undirected	1
1005	1004	undirected	1
1005	130	undirected	1
1005	1006	undirected	1
1005	1007	undirected	1
1004	130	undirected	1
1004	1006	undirected	1
1004	1007	undirected	1
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1011	1073	undirected	1
1011	1075	undirected	1
1011	1076	undirected	1
1002	1009	undirected	1
1002	1001	undirected	1
1002	1005	undirected	1
1002	1024	undirected	1
1002	118	undirected	1
1002	1025	undirected	1
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1009	1005	undirected	1
1009	1024	undirected	1
1009	118	undirected	1
1009	1025	undirected	1
1001	1005	undirected	1
1001	1024	undirected	1
1001	118	undirected	1
1001	1025	undirected	1

1005	1024	undirected	1
1005	118	undirected	1
1005	1025	undirected	1
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1024	1025	undirected	1
1027	118	undirected	1
118	1025	undirected	1
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