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Para Public Entities as Anchor Organizations in Industrial Clusters

Evidence from Quebec's Cleantech Cluster

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Résumé

Le domaine de la géographie économique a pris un tournant relationnel au cours des dernières décennies. Alors que les études traditionnelles ont principalement porté sur la présence d'entreprises et de ressources pour expliquer la géographie des performances économiques, un nombre croissant d'études se sont intéressées aux interactions entre les agents économiques pour façonner l'économie d'un lieu.

Les études sur les grappes industrielles ont connu un «tournant relationnel» au cours des dernières décennies. Il y a maintenant un consensus croissant parmi les chercheurs sur le fait que la structure des réseaux interorganisationnels locaux contribue à la performance économique d'un cluster industriel. Les recherches existantes identifient les réseaux interorganisationnels comme un canal clé pour le transfert de connaissances entre entreprises co-implantées, générant des externalités de connaissances localisées qui stimulent la croissance économique. De plus, des études récentes montrent que les réseaux interorganisationnels sont des canaux clés par lesquels les connaissances externes sont diffusées aux entreprises locales, ce qui contribue à intégrer un cluster au système mondial de connaissances. La question de recherche de ce travail est donc devenue celle de savoir comment identifier les entreprises «d'ancrage» du réseau interorganisationnel qui sont particulièrement capables de mobiliser d'autres organisations et de favoriser la croissance collective.

Dans cette littérature, les acteurs parapublics sont souvent des organisations parapubliques qui constituent une source importante de soutien et de financement pour les associations industrielles, les centres de R & D, les universités, les start-ups et les PME. Ce mémoire construit un cadre théorique pour déterminer dans quelle mesure les organisations parapubliques jouent un rôle central dans les grappes industrielles.

Les propositions théoriques seront démontrées de manière empirique en construisant une base de données collectée à la main pour la grappe des technologies propres du Canada: Écotech Québec. En utilisant l'analyse des réseaux sociaux, ce travail constate que les entités parapubliques jouent un rôle d'ancrage dans la grappe puisqu'elles occupent une place centrale dans le cluster local et qu'elles peuvent tirer parti de leur position pour diffuser des connaissances importantes au reste de la grappe. En outre, ils jouent un rôle similaire sur la plate-forme mondiale, car ils permettent aux entreprises locales d'accéder aux ressources et aux connaissances d'autres grappes industrielles qui, eux, se situent au premier plan.

Mots clés : Analyse de réseau, Technologies propres, Para public, Gouvernement

Abstract

The field of economic geography has made a changed its focus towards relational turn in the past few decades. Whereas traditional studies have primarily focused on the presence of firms and resources to explain the geography of economic performance, a growing number of studies have become concerned with the ways in which economic agents interact to shape a location's economy.

Studies on industrial clusters have made a "relational turn" in recent decades. There is now a growing consensus among scholars that the structure of local inter-organizational networks helps drive an industrial cluster's economic performance. Extant research identifies inter-organizational networks as a key channel for the transfer of knowledge among co-located firms, generating localized knowledge spillovers that spur economic growth. Furthermore, recent studies show that inter-organizational networks are key conduits through which external knowledge is diffused to local cluster firms, helping to embed a cluster in the global knowledge system. A key research question has therefore become how to identify those "anchor" firms in the inter-organizational network that are particularly capable at mobilizing other organizations and fostering collective growth.

In this literature, an often-overlooked network actor is the public sector which provide an important source of support and funding to para-public organizations such as industry associations, R&D centers, universities, startups and SMEs. This thesis builds a theoretical framework to investigate the extent to which para-public organizations play the role as anchor tenants in industrial clusters**.**

Theoretical propositions are analyzed empirically by building a hand-collected network dataset for Canada's premium cleantech cluster: Écotech Québec. Using social network analysis, it is found that para-public entities play an anchor role in Écotech in the sense that they have a central position in the local cluster as well as the ability to leverage their position to spread important knowledge to the rest of the cluster. In addition, they play a similar role on the global platform as they provide local firms with access to resources and knowledge from other premium industrial clusters.

Keywords : Clusters, Networks, Cleantech, Para Public, Economic Geography

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List of Abbreviations and Acronyms

Écotech Québec : ÉQ

Canada Cleantech Alliance : CCA

International Cleantech Network : ICN

Venture Capital: VC

Cleantech: CT

Small & Medium Enterprise: SME

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Introduction

The field of economic geography has made a clear “relational turn” in the past few decades (Boggs and Rantisi 2003). Whereas traditional studies have primarily focused on the presence of firms and resources to explain the geography of economic performance, a growing number of studies have become concerned with the ways in which economic agents interact to shape a location’s economy.

This relational turn has become particularly evident in research of industrial clusters. There is a growing consensus among scholars that the structure of local inter-organizational networks helps drive an industrial cluster’s economic performance (Ter Wal and Boschma, 2009). Extant research identifies inter-organizational networks as a key channel for the transfer of knowledge among co-located firms, generating localized knowledge spillovers that spur economic growth (Owen-Smith and Powell, 2004). Furthermore, recent studies show that inter-organizational networks are key conduits through which external knowledge is diffused to local cluster firms, helping to embed a cluster in the global knowledge system (Bathelt et al., 2004; Wolfe and Gertler, 2004). A key research question has therefore become how to identify those “anchor” firms in the inter-organizational network that are particularly capable at mobilizing other organizations and fostering collective growth (Giuliani 2005).

In this literature, an often-overlooked network actor is para-public organizations such as liaison centers and business development services centers which provide an important source of support and funding to industry associations, R&D centers, universities, startups and SMEs. **This thesis leverages Network Analysis to better understand the position of the para public (i.e. government-backed) organizations in a cluster’s inter-organizational network and to analyze whether these actors can play an Anchor role for the rest of the network.**

To answer this question, an analysis of Canada’s Cleantech Cluster was conducted. This cluster was chosen for several reasons. First, cleantech is a knowledge-intensive industry that is characterized by high rates of innovation and R&D, therefore ensuring the

importance of knowledge flows. Second, cleantech companies tend to agglomerate in a limited number of industrial clusters. Third, there is evidence in the literature that cleantech companies benefit from local externalities by being tied to Urban centers. Fourth, cleantech companies heavily rely on formal inter-firm collaboration both locally and globally, thus making a network analysis particularly relevant. Finally, governments play an important role in the development of cleantech clusters.

This thesis is divided into five sections. Section 1 offers a comprehensive coverage of the literature review to obtain a better understanding what clusters are, why inter-organizational networks matter for the aggregate performance of industrial clusters, and which role anchor tenants play in industrial clusters. Section 2 then develops the research proposition by highlighting the importance of researching the role of para-public organizations as anchor tenants. Section 3 provides an overview of the unique network dataset that has been collected for Écotech and which methodology is used to study the research propositions. Section 4 describes the findings. Section 5 provides concluding remarks.

1. Literature Review

It is widely recognized that industrial agglomerations, or otherwise known as *clusters*, are a key driver to national economic growth (Marshall 1919, Porter 1990, Gordon 1999, Delgado et al. 2010). As regions grow and become increasingly specialized, there is no shortage of examples to explain the impact of a strong environment on the growth and success of its firms. Amongst others, clusters such as Silicon Valley, Boston Technology Cluster and Bengaluru ICT cluster have been studied by scholars. What these clusters have in common is signs of positive externalities from which firms can benefit from by participating in these clusters (Porter 1998, Bathelt 2001, Turkina et al. 2016).

But what about these geographic locations, and more importantly these clusters, make for a positive environment for firms to strive? Clusters have been defined as “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions [...] in a particular field that compete but also cooperate” (Porter 2000, 16).

The following sections will provide findings from the fields of Economic Geography and Network Analysis to better understand the above definition as well as how it relates to some of the questions shared above.

1.1 Foundations on Industrial Clusters

1.1.1 Marshallian Externalities

Throughout economic geography, Alfred Marshall is known as the founder of the theory of localization, also known as *industry-specific agglomeration, industrial clusters* or even, *Marshallian clusters*. In his book *The Principles of Economics*, he suggests that there are two types of firms: those which “depend on the general development of the industry” and those which are “dependent on the resources of the individual houses of business engaged in it and the efficiency of their management” (Book I, Chapter XII, 1919). Hence,

he divides firms into external and internal economies (Book I, Chapter XII, 1919) (Figueiredo et al. 2009, 1).

Based on these two types of firms, Marshall proposes three reasons why firms from the same industry can benefit from geographically clustering together.

First, there is the benefit of the *presence of input providers*. These can be explained as the presence of strong suppliers to support the firm's activities and make them more efficient. In Marshall's world, this could have meant a firm producing shoes would need to have access to leather suppliers.

Second, Marshall explains the benefit of the *presence of a strong labor pool*. As people drive the productivity of a firm, a specialized and pre-trained labor force has a large impact on the firm's resources and productivity. Using the above example of a shoe factory, a company would benefit from accessibility of experienced employees who could have come from other shoe factories hence bringing their knowledge and expertise with them. Therefore, this factory would gain in productivity and save on precious resources as the employees don't need as extensive training to learn and complete their respective tasks.

Third, he explains the need for industry-specific *knowledge spillovers* between firms. Here, knowledge spillovers come from the environment. They can be obtained through interaction with other firms from the same industry, but also from the passage of employees from one firm to the next as mentioned above. Therefore, if there are many shoe manufacturers in the same region, they will benefit from the presence of each other through a rise in specialized knowledge available in their direct environment.

Additionally, being in close proximity to competitors means that firms can also be more quickly made aware when their competitors make moves. Thus, this theory states that close proximity is also a source of competition, which can further fuel productivity increases.

All in all, according to Marshall, these three externalities of industrial clusters represent the basic environmental needs for a firm to optimize its productivity and ability to specialize (*Industry and Trade*, 1919) (Figueiredo et al. 2009, 2).

1.1.2 Porter's adaptations

While Marshall's observations were based on post-industrial revolution England, many points remain valid in today's complex industrial landscape. Thus, fueled by Marshallian Externalities and Ricardo's theory of comparative advantage where countries will naturally invest in areas for which they are more naturally endowed (1817), Porter developed a new theory for national competitiveness called the Competitive Advantage of Nations (Porter 1990), which could be seen as a contributor to today's industrial cluster theory.

Porter introduced a theory where countries and industries are able to alter, what would have been, their natural progression which would have been implied by Ricardo, and instead, create their own wealth. This can be done by creating an environment where companies can "benefit from having strong domestic rivals, aggressive home-based suppliers, and demanding local customers" (Porter 1990, 1), but this cannot happen in all industries and therefore a country will be brought to further specialize in a particular industry.

But what makes a country competitive? Porter defines competitiveness of nations as a level of productivity where the nation aims to increase the standard of living for its citizens (Porter 1990, 5). Reaching productivity will imply that a nation will constantly work to *upgrade itself* (ibid, 5). This also means that a nation will ideally have all labor and capital used in a productive way, but also, in the aspect of foreign trade, how this productivity measures against other countries' industries which may also be striving for productivity.

Porter's Diamond of National Competitiveness aims to reconcile the various single factors to growth of a nation into one analytical framework or, as referred to by the author, a *self-reinforcing system*. Therefore, the Competitive Advantage of Nations describes the environment necessary for a country to yield a competitive advantage in a specific industry in comparison with other countries. These advantages arise from the attributes

of favorable factor conditions, demand conditions, related and supporting industries, firm strategy, structure and rivalry as well as government involvement contribute to a country's ability to become a leader in a certain industry (Porter 1990).

In more detail, the four elements of competitiveness are based on Marshall's three sets of externalities where input providers and a strong labor pool are elements of Porter's Related and Supporting Industries, and the presence of knowledge spillovers could be seen as a piece of Factor Conditions.

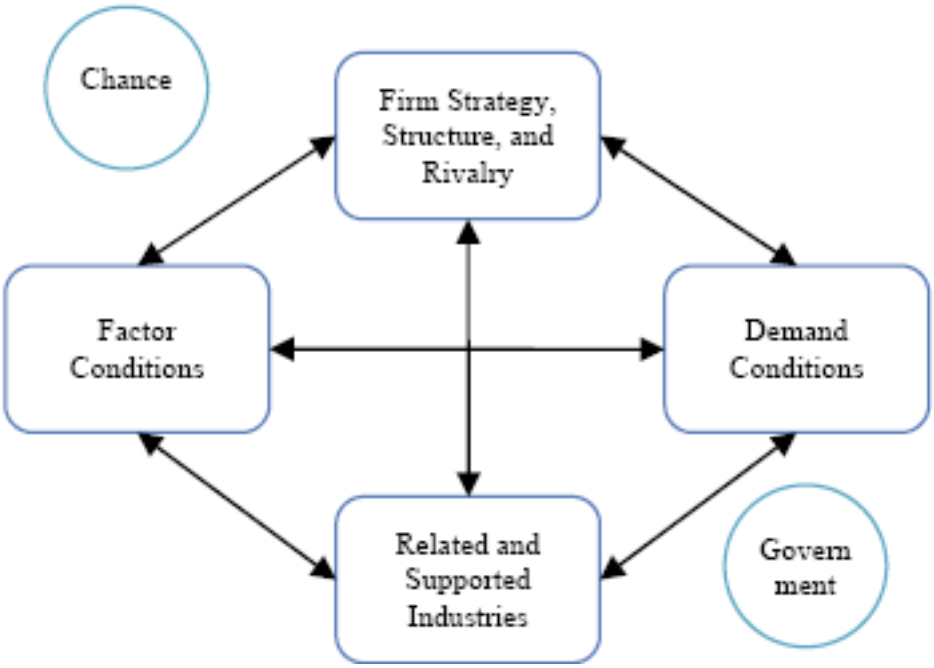

Figure 1 - Porter's Diamond of National Competitiveness (Porter 1990)

It is the combination of these factors which will create a positive environment for a firm to grow. The above diamond can be used to analyze and compare industries in different countries in order to determine whether or not the industry has a competitive advantage, or, in Porter's words, is adequately productive.

In the same text, Porter also discusses the concept of industrial agglomeration. A country will rarely have only one industry. It will most often have many clusters of competitive industries which will contribute to yielding a competitive advantage for the nation (Porter

1990, 28). This being said, for firms from many industries to benefit from their environment, they will need a similar set of externalities. Therefore, industries within a country or region are not usually totally unrelated. Their necessity to pull from the same labor pool will mean that companies will settle in regions where other companies are similar or complementary to them, and so, a favorable ecosystem made up of both competitive and complementary firms will be created.

1.2 Industrial Clusters today

In 2000, Porter leveraged Marshallian externalities once more into a new paper on industrial clusters. This time, he defined clusters as “geographic concentrations of interconnected companies, specialized suppliers, service providers, firms in related industries, and associated institutions [...] in a particular field that compete but also cooperate” (2000, 16).

This time, he adds to Marshall’s three externalities the importance of the general environment and the quality of the microeconomic business environment of the cluster’s location in order to ensure its success and, most importantly, its ability to reach productivity (2000, 5). To him, the necessary elements to increase productivity are access to specialized inputs and employees, information, presence of complementarities between products and services, and a strong institution which serves the public good (Porter 2000, 9).

Since, some authors have enlarged Porter’s list of factors to encompass many more success factors, which could otherwise be seen as a more detailed version of Porter’s diamond. For instance, a framework outlining critical success factors (CSF) has been socialized by authors such as Adams (2005), Sainsbury (1999), Saxenian (1994) and Weil (2009) (Tavassoli and Tsagdis 2013). While these authors have long debated the relevance of said CSFs, Tavassoli and Tsagdis used all 15 outlined by a collection of authors to describe the Swedish ICT cluster Linköping (2013).

The fifteen CSFs are the following:

1. *Right vision* for the cluster expressed by both groups of leaders and members of the cluster
2. *Trust* in regard to the cluster association
3. *Proximity* between firms and important actors
4. *Preexisting knowledge* in the cluster's region and for the technology
5. *Brand name*
6. *Presence of at least one strong actor*
7. *Networking and collaboration*
8. *Physical infrastructure*
9. *Finance*
10. *Innovation and R&D*
11. *Entrepreneurship*
12. *Growing company base* in terms of cluster members
13. *Staff attraction* – often tied with #6
14. *External links*
15. *Support organizations* in the form of Chambers of commerce and cluster associations

When comparing this framework with Porter's diamond and Marshall's set of externalities, one can notice some common themes such as presence of elements included in Factor Conditions, presence of supporting industries as well as, to some extent, a vision or strategy. With that said, the CSFs above take a deeper dive in the intricacies of the success of a group of firms in a specific region.

While some elements are repetitive, the above lists include other, more human, elements such as the need for trust amongst actors (2), networking and collaboration (7), a growing company base (12) and the presence of external linkages (14). These four items have a clear thread which ties them together and this is the human network dimension of industrial clusters which may not have been covered in earlier economic geography theory. This leads the discussion towards the study of the role of networks in clusters and, this, over time.

1.3 Moving towards a network view of clusters

While above contributions detail the needs of a nation to reach global competitiveness, it fails to properly detail the *how* behind these externalities, hence leaving a gap in the literature. More specifically, how does a firm benefit from Marshallian externalities? Can they tap into these benefits by simply being present in an industrial cluster? Or do they need to engage and link with other firms and organizations from the ecosystem? Gordon takes the position that the inter-organizational network structure in an urban center is a strong contributor to the industrial cluster's growth (Gordon 1999).

In 1999, Gordon detailed three types of industrial agglomeration explaining the dynamics around Marshallian externalities as seen in today's urban centers. These were divided into three models: Pure Agglomeration, Industrial-Complex Model and the Social-Network Model (Gordon 1999).

First, he describes the pure agglomeration where firms are in the same location and benefit from the same externalities. He discusses an environment where firms are close to each other without interacting or cooperating but still manage benefit from the opportunities available in the local environment and, this, *by law of large numbers* (Gordon 1999, 517). What is referred to here is that given the sheer size of the city, positive externalities are bound to be present. For example, by sheer size of population, there must be strong labor available for hire. This type of environment is comparable to any large city where companies agglomerate in no particular order or fashion and benefit from each other more by luck than by strategy.

Second, the Industrial-complex Model is where there are "identifiable and stable relations among firms [and] which are in part manifested in their spatial behavior" (Gordon 1999, 518). These stable relations could also be described as formal ties between firms such as buyer-supplier relationships, but Gordon specifies that they must be within the same geographic location. This type resembles more the industrial cluster mentioned by Porter earlier on where companies agglomerate with a specific goal in mind. They benefit from each other more strategically in this type than the prior.

Third, and last, the Social-network Model is where firms interacting within a geographic environment not only benefit from a common talent pool and access to local resources, but also, from each other's complementarities. Therefore, social integration would become more and more pertinent to the growth of the firms operating within a specific industry (Gordon 1999, 520).

Indeed, this form of social agglomeration heavily bases itself on Granovetter's sociological literature stream. A particularly influential paper from this stream is Granovetter's study called The Strength of Weak Ties where a significant contribution regarding the importance of strong connections for the growth of large networks is made (1973). This study ties together micro and macro levels of the study of networks. A main contribution of the paper is the finding that cold ties with strangers will have a stronger impact than warm ties with family and friends (Granovetter 1973). Therefore, Gordon uses this finding to describe an environment where firms' employees can benefit from connecting amongst each other, and this leads to growth of the firm and, by result, of that industry as well.

Additionally, this last typology of industrial agglomeration suggests that the benefit of clustered firms is, not only in the environment, but in the shared knowledge the environment provides to the firm through the firm's network.

What Gordon adds to this previous literature is a city-level analysis where, locally, firms and employees interact amongst each other to share and receive knowledge to and from their network. And, these interactions become drivers for important knowledge spillovers.

Along a similar vein, Wolfe and Gertler share some knowledge on the importance of interaction between firms through which they emphasize the importance of, not only the presence of certain key factors in a cluster, but also the *flows* and *dynamics* which these factors create (Wolfe & Gertler 2004, 1084). Thus, in their opinion, what was missing from Porter's cluster explanation is a dynamic, as opposed to static, description of clusters.

i. Local network implications for industrial cluster growth

Amongst *flows*, Gertler and Wolfe describe inflows of talented workforce and capital as well as outflows of knowledge (ibid., 1084-1085). About *dynamics*, the authors describe local social dynamics such as network creating behavior between actors and historical path dependency as determinants of the cluster's current state (ibid., 1085).

Moreover, many authors have detailed the benefits to collocating. Beyond what has already been discussed, the main points of interest are the reduction of transaction costs, the gain and codification of knowledge, and, lastly, the development of strong partnerships leading to an increase in innovation.

For one, Maskell and Lorenzen have called collocation a strategy for transaction cost reduction (Maskell & Lorenzen 2004, 1002). They argue that the cluster is a market organization which allows for important actors to more efficiently create pipelines and interact with customers. (Maskell & Lorenzen 2004, 1002). Furthermore, they conclude by saying that the evolution of a cluster is never premeditated, but instead, a result of actions taken by individual firms pursuing different strategies (ibid., 1002). As far as networks go, this proximity is directly tied to the building of a trusting network between the firm and its customers to better serve their needs.

A second benefit from participating in the local network comes from the local buzz that is created in the shared local knowledge (Bathelt 2004). This buzz consists of "a continuous flow of updated information of specific interest for the local industry, together with a multitude of interpretations and informed suggestions on how to transform any new turn of events into something commercially viable" (Bathelt 2006, 1003).

A third benefit to building a strong local network is tied to one of Marshall's main externalities, that of the sharing of knowledge where the codification of knowledge within the firm should be somewhat congruent with the network's codification of knowledge. Nevertheless, companies must protect and conceal the knowledge they accumulate in order to gain or maintain their competitive advantage. Therefore, much of the knowledge

of the cluster lies in the firms which collaborate with the core firms (i.e. suppliers, customers and other supporting industries), but more importantly, in the people who work for the firms.

Malmberg and Maskell further this thought by exploring the diffusion of tacit, or uncodified, knowledge (1999, 17). While unworthy knowledge may be shared widely, precious tacit knowledge could be the source of the actors' next competitive advantage. Therefore, it will only be shared with other agents when relationships are high in trust (ibid., 17). Trust, a qualitative metric, is difficult to measure. To overcome this issue, these authors studied cooperation between firms in various sizes of industrial networks. Networks with less cooperation would thus exhibit a lower level of trust, and networks with more cooperation the opposite (Malmberg and Maskell 1999., 18).

In network theory, this would be explained by different measures of closeness and centrality measuring at which speed can information travel through the network. Moreover, the amount of partnerships present in the network will have an impact on the speed of information transmission.

Alternatively, other authors also added the idea that, within smaller high trust network, newcomers may have to go through a rite of passage to prove their trustworthiness (Jackson 2008). Alongside this, while smaller networks can exhibit higher degrees of trust or elements of *insidership*, larger networks may show all the contrary being plagued by elements of *liability of outsidership* where foreign firms may have a hard time entering a local network as they lack social capital to leverage trust with their peers (Johanson and Vahlne 2009).

A fourth benefit for strong local embeddedness is the building of local relationships through partnerships. Indeed, a paper emphasized a preference for geographic proximity for partnerships to be successful (Hansen 2014, 380). Additionally, Maskell and Lorenzen suggest investing time in relationships which are upstream or downstream from the firm's

respective position in the network to yield as much return as possible as dependent on the firm's strategy (2004).

On the other hand, other authors have found that there is more value in harnessing ties with firms in other clusters to benefit from other knowledge pools. This will be expanded in the following section.

ii. Global integration of industrial clusters

While local *buzz* helps drive internal information flows resulting in increases in innovativeness, this also occurs on the global platform where the most successful clusters have been found to maintain and nurture ties with other successful clusters from around the globe (Bathelt 2004, 33).

In fact, a study of the Bangalore IT cluster showed that the cluster's life cycle stage has an impact on the different types of networks the cluster is seeking for growth. In theory, cluster life cycle ranges from Growth to Maturity to Decline where different agglomeration levels and needs can be observed at each distinct phase (Menzel and Fornahl 2007). The early stage IT cluster in Bangalore depended more on non-local and diaspora linkages. Moreover, a paper on Montreal's Aerospace cluster showed that some clusters can specialize in one area of the supply chain and, therefore, a local cluster will have to look elsewhere to find its inputs (Turkina et al. 2017). On the other hand, local linkages were found to gain importance in the later stages (Sonderegger & Täube 2010, 394) as they may be more important for maintenance of ties with customers (Lucas et al. 2009, 201).

This being said, building internal knowledge requires a completely different set of skills as building external knowledge – as discussed above through the concept of codified learning. This idea ties with the following theme of knowledge pipelines.

Indeed, Bathelt discussed necessity for knowledge flows between successful clusters (2004). He furthers this finding through the study of the acquisition of knowledge and growth of global networks through temporary clusters such as international trade fairs and conventions (2006, 1005). He even found that the participation in trade shows could

explain the unlikely success of solitary firms that are not located in industry agglomerations. Hence, this supports the claim that integration into global networks is key to gain access to the right knowledge for growth. Additionally, this paper suggests that, despite unique successes of small solitary firms, presence at temporary clusters is complementary rather than a substitute to being present in a local cluster and yielding those externalities.

Bathelt's contribution on knowledge pipelines stated that, not only does a cluster have to have a strong internal base of knowledge to be successful, it must also build relationships with other clusters from other regions to fetch additional knowledge. This being said, linkages must be strategic for them to be fruitful.

To this point, Bathelt suggests a systematic selection of linkages which aim to maintain the knowledge flows into the cluster (Bathelt et al. 2004). This is important for information on market trends and new technologies to enter the cluster (Bathelt et al. 2004) keeping the firms within the cluster aware of what their competitors are up to, not only locally, but around the world. His proposition on local buzz, discussed above, must therefore be supplemented by the information flowing in from foreign clusters. This can only happen through the creation of "a well-developed system of pipelines connecting the local cluster to the rest of the world" (Bathelt 2004, 45-46). Connecting to propositions from Uzzi and Jackson, a firm will be better off if, first, it is central in the network, and, second, it is connected to other central firms (Jackson 2008, Uzzi 2005). Given the limited number of pipelines a firm can be a part of simultaneously (Bathelt et al. 2004, 47), strategic choices in the formation of alliances are a must to stay relevant within the cluster.

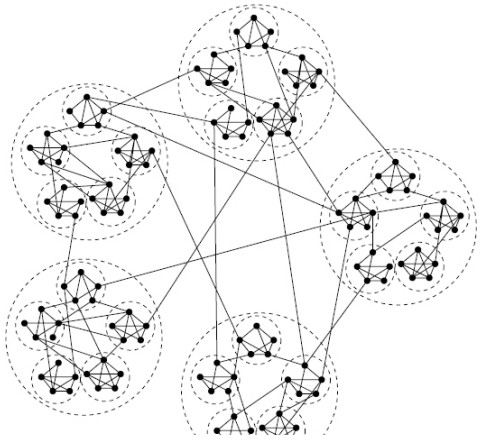

Figure 2 Network visualization

Figure 2 sums up nicely the "relational turn" this literature review is highlighting which has been discussed in the above two sections. A good way to think about industrial clusters is a group of co-located firms which form a local

network (within circles) among each other that influences the flow of local knowledge externalities. Some of these firms also develop global linkages to other clusters (ties across circles) which allow them to tap into external knowledge pockets. As a consequence, a cluster needs to be seen as embedded in a global cluster network (Turkina et al. 2016). This idea brings the discussion over to study of Anchor Firms as one could think the nodes with external links could be.

iii. Anchor Firms in the Local Network

Building strategic alliances was discussed by several authors over the years. One important contribution was made by Lucas where knowledge pipelines are built through ties with anchor organizations. In this case, anchor organizations could be large private firms, a publicly regulated utility, a joint venture formed by public utilities or research institutions (Lucas et al. 2009, 196). Authors explain one of these four types of organizations as detrimental to the growth of the sector going to the extent of saying that absence of an anchor firm could explain the weak growth of one of the clusters at study. Their idea is simple; presence of one of those four, more specifically large firms and research focused universities, attracts talented labor, and talented labor is a must to the growth of an innovative technology focused sector (ibid., 196-200).

Moreover, Giuliani et al. (2005) defined anchor firms as firms which hold both local and global ties. She detailed the anchor firm concept by studying the roles of firms in networks. She found that there are five types of roles which arise for firms:

1. Technological gatekeepers (TGs) are firms that are both highly connected locally and globally
2. Active Mutual Exchangers (AMEs) are also highly connected, but not as much as TGs.
3. Weak mutual exchangers (WMEs) are less connected to AMEs, but play a similar role.
4. External Stars are firms that have strong linkages with external networks, but very little locally.

5. Isolated Firms are highly disconnected at both local and global levels (Giuliani et al. 2005, 60).

These distinct roles have an impact on the cluster's ability to absorb learning from ties with outside knowledge centers, diffuse it to the local network and use it to their advantage. To this extent, the structural makeup of the network combined with the knowledge base of the firms will have an impact on the usage of this knowledge (Giuliani et al. 2005, 64). An interesting contribution by this paper is that, instead of leaving things to luck, Giuliani puts forward the idea that clusters will structure themselves in a much more deliberate way than the literature has suggested in the past (ibid. 64). Ties with any of TGs, AMEs and WMEs would provide the firm with an advantage over others.

1.4 Government Involvement in Industrial Clusters

Although authors keep their findings broad in regard to anchor organizations, there is reason to believe government entities, such as para public or public organizations, could play this strategic role. As passing information through the network is a large piece of the strength of a local network, a neutral player could become key in playing this position. With this reasoning in mind, the following section will review the brief literature around government -cluster dynamics, and this, with a network perspective where possible. The goal will be to shine light on a possible role the government can and has played in cluster development.

Generally speaking, the academic field of Economic Geography bares little mention of government involvement as a source of competitive advantage. Therefore, this section will review some key thoughts on public sector influence in industrial clusters.

1.4.1 Government involvement in economic development and industrial clusters

While many authors chose to leave aside the government in their analysis of industries, Porter included the government in cluster's ecosystem as was represented by the Diamond of National Competitiveness shared earlier on. He also put forward that there is no evidence of the government being a key player in the success of an industry. While

examples like Singapore and Japan support the idea that government can have a positive influence on the development of industry through strong and supportive policies, other examples like Germany, where government intervention has been minimal, leads to think that government has might be best off leaving the private sector to organize itself (1990, 3). Further on in this text, Porter adds that many subsidized industries and companies are rarely competitive (1990, 9). This debate leads to a very situational conclusion where each government is to adapt to its industries' ebbs and flows.

Therefore, Porter concludes by saying that the role of government is to encourage and support growing industries (1990, 29). He adds that, for the government to support National Competitiveness, the government is to follow these rules in their policy development:

1. *Focus on specialized factor creation* – the government is to choose key areas to develop and focus its energy on those.
2. *Avoid intervening in factor and currency markets*
3. *Enforce strict product, safety and environmental standards* – strict government regulations are to force companies to become increasingly competitive and innovative.
4. *Sharply limit direct cooperation among industry rivals* – this rule instructs governments to encourage competition by limiting opportunity for monopoly in industries.
5. *Promote goals that lead to sustained investment* – government is to direct capital investment
6. *Deregulate competition* –
7. *Enforce strong domestic antitrust policies* –
8. *Reject managed trade* – government trade policy is to support open markets and, therefore, work towards the creation of free trade agreements with its neighboring countries.

(Porter 1990, 29-34)

Along the same vein as above, Nishimuro and Okamuro studied the impact of government support programs on cluster development (2011). Their main finding is that indirect support programs are more helpful than direct support programs (2011, 724). They concluded this by seeing the positive impact of indirect support programs on knowledge-based industries such as technology. In contrast, they found direct R&D support programs to be ineffective as they bare the weight of the *crowding-out effect* where, in order to avoid public criticism, the government is forced to act in certain ways which may or may not be beneficial to the economy (ibid., 724). Examples of this could be wide funding to all companies or financing projects with a lower political risk. As the government's role is to fill gaps, support programs should be aimed towards supporting riskier projects, not low risk ones.

In addition, these authors found that many SMEs were not even aware of the programs and therefore were unable to leverage them to their advantage. In their opinion, government support programs should aim to enhance network and alliance formation, financial and sales transactions, and innovation activity. They describe a shift in support program structuring over time towards these goals (ibid., 724) - an important factor to cluster development.

More specific to the development of technology clusters in Canada, Wolfe and Gertler conducted several case studies of Canadian clusters and described them in their 2004 paper. They concluded that public institutions, although quiet and often overseen, play an important role in "shaping the regional-industrial evolution by making certain kinds of strategic choices by firms easier, and others more difficult" (Wolfe & Gertler 2004, 1088). These authors also acknowledge the government as a key player in building the knowledge infrastructure through financing to universities, research center, government labs and other similar knowledge-generating organizations (ibid., 1088). They add that the government involvement may and may not always be deliberate or strategic (ibid., 1088). It goes to wonder the effect the government's burden of fairness may have on the industrial cluster in question, but beyond that, whether the public sector is aware of the importance of the influence it may have on its environment.

Furthermore, an article by McDermott on the role of public private entities in the upgrade of emerging market industrial clusters proposes that government-supported entities can play a key role in the upgrade of these clusters and help them become more attractive to developed countries' industrial clusters (McDermott et al. 2009). The figure below shows the key positioning of public private entities in the network.

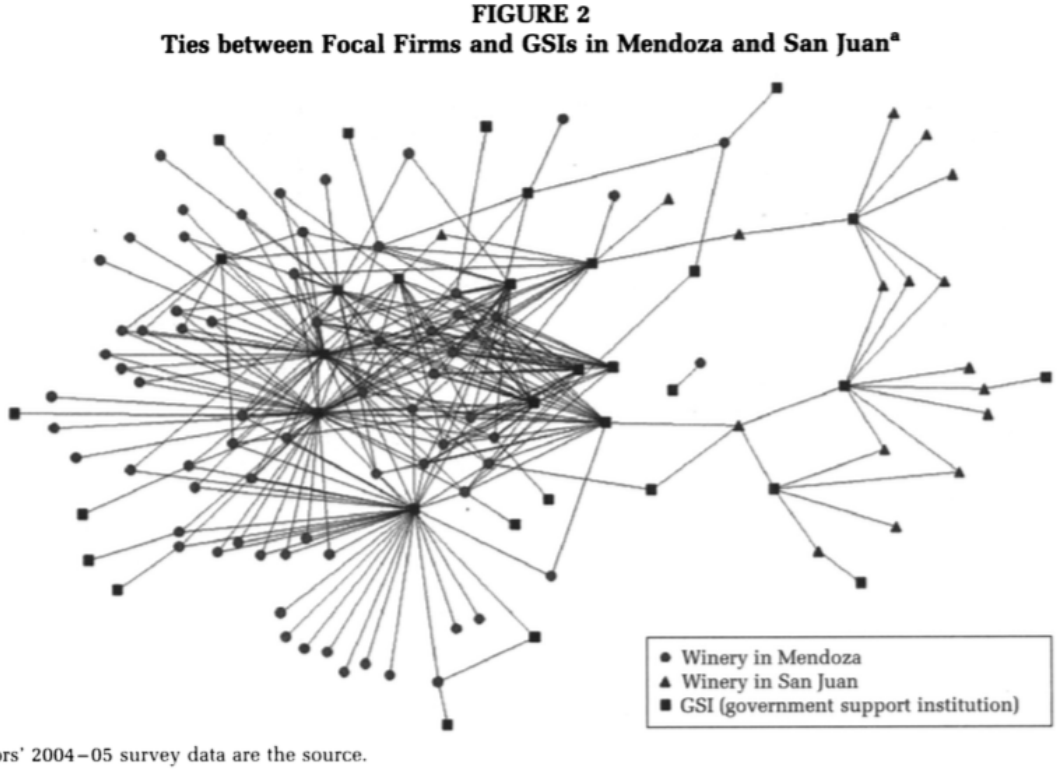

Figure 3 - 'Public-Private Institutions as Catalysts of Upgrading in Emerging Market Societies' (McDermott et al. 2009, 1292)

These examples therefore support the idea that government agencies and government-supported organizations, also known as para public organizations, could have a key role in the development of the industrial cluster by its position as a connector or network broker within the local and global network. They also support the claim that government backed entities can play a key role in connecting industrial clusters across the planet, hence, facilitating knowledge transfers between clusters.

2. Research Proposition

2.1 Gaps in the literature

The literature review above combined two major bodies of literature; economic geography (i.e. Industrial cluster theory) and network analysis. The goal of this paper will be to leverage concepts from these fields and apply them to the context of Cleantech in Quebec.

In regard to industrial clusters, two important gaps arose. First, there is insufficient study and understanding around the role and network position of the government in industrial clusters. While literature generally agrees on the importance of some government support, little enter into detail about what this support should look like. Second, some propositions offered by authors can be quite theoretical, thus this paper will use a practical example to support or infer the propositions below.

Next, many papers within the study of international clusters discuss the importance of interacting with other clusters from around the world. This paper will therefore attempt to fill the gap in the literature where no paper has yet used Network analysis to observe the position of the para public organizations in both local and global levels of networks. This approach will be key to understand how the position in one network applies to the other, and vice versa. This approach will be useful for both the field of Economic Geography and the field of Network Analysis.

2.2 Propositions

From a theoretical perspective, the goal will be to fill the above gaps in the literature. On the other hand, from a practical perspective, this paper aims to answer the three following propositions, as well as strengthen the field's understanding of the role of government-backed organizations in the local and global network.

This being said, this paper will address the three following propositions:

1. Para public organizations play the role of anchor organizations in the local cluster network.
2. Para public organizations are connectors between global resources and the local cluster.
3. Para public organizations act as anchor organizations creating space for knowledge to move from the global to the local network.

3. Data

3.1 Choice of Cleantech Sector for this Analysis

To investigate above propositions, and retain a practical implication to this study, it is crucial to use an existing industry. Evidence from the local and global context for Cleantech as well as Cleantech literature shows that this sector is knowledge intensive, there is evidence of geographical clustering, it leverages ties with local and global players, and the government plays an important role in the development of clusters. Furthermore, past literature on Cleantech has not yet taken a network view to analyze the structure and dependencies of the sector. Past literature mostly took a policy-view (Sinclair-Desgagne 2013, Chartier et al. 2017), a look at the implications on global value chains (Sinclair-Desgagne 2013), a look at productivity in the green economy (Jackson 2011) or an observation of tariffs (Mendon 2009). To this extent, these elements make Cleantech an interesting sector to explore in the context of this research.

i. A knowledge-intensive sector

Cleantech is defined by any technology which does not harm the environment, while maintaining or increasing efficiency and productivity. This encompasses all assets, technologies and businesses which cover clean energy, or sustainable products or services (Cleantech.org 2018). Cleantech's cross sectoral nature and embeddedness in technology therefore suggests it is a knowledge intensive sector, which is in line with above literature.

ii. Geographical clustering

The Cleantech industry worldwide has grown over the last few years. In fact, the Cleantech Group suggests evidence of 54 distinct Cleantech clusters around the world (The Cleantech Group 2018).

iii. Urban ties

Evidence of geographical clustering can sometimes be tied to ties with urban centers. Indeed, research on cleantech has shown a high density of SMEs and individual grassroot initiatives leading to a social network reliant business environment (Horwitch and Mulloth

2010; Vauterin and Virkki-Hatakka 2016). As opposed to other, more traditional sectors, a high density of SMEs could also mean absence of large anchor organizations which could potentially slow down the growth of a sector - but that is not the case. Research shows that networks and network building initiative have helped the cleantech sector grow in urban centers.

In addition, a research paper on New York City shows the significance of grassroot movements in the growth of the Cleantech industry, but also the degree to which these innovative initiatives are grounded in city-level activities, policies and investment projects allowing SMEs to grow their network. Some examples provided in the article are network building initiatives such as Green Drinks, vision42 and GREEN.US (Horwitch and Mulloth 2010, 29). These municipal initiatives tie with Gordon's findings on social-network agglomeration in urban centers where firms can benefit from the sheer size of the city they are in by *law of large numbers.* This contribution strengthens the argument for the importance of networks in Cleantech.

iv. Global ties

Along the same vein, cleantech SMEs' ties with local government such as municipal or provincial organizations seem to have given them access to other global clusters via municipal cleantech initiatives. Evidence from both academic and online research has shown that municipalities have come together to grow the Cleantech movement.

Online research in the cleantech sector yielded international, provincial and municipal initiatives such as the C40 project led by international cluster associations. This project offers opportunities to cleantech companies around the world to pitch on municipal projects in all participating cities. The goal is to lead the way to the creation of more sustainable cities through a growing network of climate change actors. The project was launched in 2005 (C40 Cities 2016). This type of project aims to increase the knowledge exchanges between cluster organization member firms as well as increase opportunity for firms to partner together on innovative solutions for municipal problems.

v. Government involvement

Much of the research executed on cleantech today is about Cleantech's difficulty in attracting investment. Cleantech's root in technology and innovation has been is most often explained as the cause for the mismatch on speed of return on investment in comparison to firms from other industries (Georgeson 2014). As 70% of Cleantech is energy-related, the size of capital needed is far larger and often requires investment from both private and public sources (Cumming et al. 2016). In addition, the size of these projects increases the risk and spreads out the return, hence, lowering interest for conventional venture capitalists.

To break down these barriers, ample research on the dualities between public and private investment sources has been done. First, Cumming found that increased media coverage and government support are positively correlated to the growth of cleantech (Cumming et al. 2016, 91-93). He also says that, given the size of the CT deals, VC cannot have an impact alone. His paper calls for flexible government policy and encouragement in CT VC (Cumming et al. 2016, 94). Second, Lange et al. concluded that a firm's legitimacy in seeking financial support will increase to one, private or public source, if financial support is won from the other side (Lange et al. 2014, 15-17). To this extent, government and VC partnerships with firms become increasingly important for Cleantech firms to gain legitimacy. Third, Bürer found that some government financial programs will have a larger impact on VCs than others. He also specified a need for a mix of policies to reach full efficiency in the sector. (Bürer 2009, 5005).

These studies therefore state that the legitimation brought to firms by financing from other areas of the ecosystem will reduce the perceived riskiness of the investment. Moreover, these studies show that government involvement will have an impact on private sector investment and, therefore, there is an inherited necessity for firms to seek grants and partners within the business environment to gain legitimacy.

This paper takes the position that, based on the five reasons above as well as past literature on the topic, a network-based study of the Cleantech sector will be fruitful to

better understand the structure of the industry, and the role of government, and government-backed entities, in the ecosystem. This will therefore allow us to verify the above propositions on whether government entities can assume the role of anchor organizations within the network and if these same organizations can assume the role of connectors between the local network and the international network.

3.2 Main Actors in examination in this study

To facilitate this study, industry clusters were chosen as a basis for the network. As Canada is a leader in Cleantech Innovation, as proven by its upwards movement from 7th to 4th place on the Global Cleantech Innovation index (shown below), the study of Canadian cluster integration worldwide became an easy choice.

Table 1 - Global Cleantech Innovation index displaying the top ten countries over time. (Cleantech Group 2018)

	2017	**2014**	**2012**
Denmark	1	5	1
Finland	2	2	4
Sweden	3	4	3
Canada	4	7	7
United States	5	3	5
Israel	6	1	2
United Kingdom	7	6	10
Germany	8	9	6
Norway	9	14	11
Switzerland	10	8	16

Furthermore, as Écotech Québec is the strongest regional cluster organization in Canada, it became the prime subject for this study. Industry clusters like Canada Cleantech Alliance and International Cleantech Network were then added to the study as they are

partners to Écotech Québec. To better equip the reader, the following sections will give further information on the three clusters.

3.2.1 Écotech Québec

Écotech Québec (ÉQ) is the organization representing the industrial agglomeration of clean technology companies in the province of Québec. It was created in 2008 by three entrepreneurs – two from the clean tech sector and one from private finance. They sought the support of the *Communauté métropolitaine de Montréal* (CMM), the *Ministère du Développement économique, de l'innovation et de l'exportation* (MDEIE), the *Ministère des Affaires municipales et des Régions de l'Occupation des territoires* (MAMROT) and the *Agence de l'Efficacité Énergétique* (AEE) to fill a gap identified in the sector and offer a voice to the sector companies of the region. The organization was officialized in 2009 under the Écotech Québec name. It now operates out of the Montreal World Trade Center since 2010 (Écotech Québec 2018).

Since, Écotech Québec has grown to a team of five working to support the growth of the sector in Québec. In response to identified needs for knowledge, networking, recognition, demand and support, EQ advocates for the sector on both the local and international platform exemplified by initiatives in public policy and global representation (Écotech Québec 2018).

This organization is kept alive through contributions from both the public and private sectors. While the public sector subsidizes the organization's activities significantly, the private sector matches this subsidy through significant contributions to the group. The membership fee assumed by the member companies is more of a *symbolic* contribution.

The organization's activities are divided in four areas: Knowledge, Networking, Positioning and Public Policy. In the area of Knowledge, they commit to growing "specialized knowledge and expertise about needs and trends in both the national and international realms" (Écotech Québec 2018). Regarding Networking, they create connections between industry players in the hopes to yield opportunity and partnerships

for the sector (Écotech Québec 2018). In the realm of Positioning, they work to increase the recognition of Quebec's cleantech sector both locally and internationally (Écotech Québec 2018). Lastly, regarding Public Policy, ÉQ encourages industry leaders to support the acceleration of the development of clean technologies in Québec's regions (Écotech Québec 2018).

As described earlier, there are many definitions to what is considered Clean technology. For the benefit of this paper, the definition used by Écotech Québec will be used to describe these companies.

The definition encompasses "all new products, services and processes that:

- significantly reduce negative impacts on the environment (environmentally effective)
- offer users superior performance at a lower cost (economically superior)
- help improve quality of life by optimizing resource use (socially responsible)" (Écotech Québec 2018).

This being said, the sector description encompasses several areas of specialization. Therefore, Écotech Québec is organized under a membership system where it represents and promotes companies from Québec's regions from ten different sub-sectors. These sectors are Air, Green Chemistry, Water, Eco-Mobility, Energy Efficiency, Renewable Energy, Waste, Soil & Groundwater, Agriculture and Enabling Technologies.

One of the services Écotech Québec offers is to support connections in the industry. Thus, the organization fosters relationships with industry leaders which also support the growth of the sector. ÉQ has both private sector and public-sector partners. These are Bell, Davies, Fondaction, énergir, Enerkem, Cycle Capital Management, Desjardins, FP Innovations, Investissement Québec and EY. From telecommunications to investment and consulting firms, these companies represent an array of prominent industries in the region. ÉQ also benefits from the support of all three levels of government through the

support of the *Communauté métropolitaine de Montréal (CMM), Ministère de l'Économie, de la Science et de l'Innovation (MESI)* and the Canada Economic Development (CED).

Écotech Québec also supports the international growth through strategic alliances with 12 Cleantech organizations, like Renewable Energy Hamburg or GreenCape from South Africa, and Chambers of commerce around the globe such as the Québec-Florida Chamber of Commerce and the Canada China Business Council (Écotech Québec 2018). These relationships permit the passing of important industry knowledge regarding upcoming industry trends and innovative technologies, but also the opening of possibilities for the Québec industry (Écotech Québec 2018).

Lastly, Écotech Québec fosters a relationship with the Canada Cleantech Alliance regarding national industry growth and the International Cleantech Network for international relations. These connections aim to unite the Canadian effort and open Canada for exports in this industry as well as open Quebec's industry to international partnerships and customers.

3.2.2 Canada Cleantech Alliance (CCN)

Canada Cleantech Alliance (CCN) is the national organization which aims to promote the Canadian cleantech sector both nationally and internationally. It was created in 2016 with the goal to unite the Alberta Clean Technology Industry, BC Cleantech CEO Alliance, MaRS Discovery and Écotech Québec. Canada Cleantech Alliance is also housed in Montreal's World Trade Center. Écotech Québec and Canada Cleantech Alliance share staff (Canada Cleantech Alliance 2018).

Its activities are similar to those of Écotech Québec in that it aims to spread knowledge and provide advice to decision makers regarding the growth of the sector. This organization unites provincial organizations and provides them with a platform for communication and collaboration (Canada Cleantech Alliance 2018).

3.2.3 International Cleantech Network (ICN)

International Cleantech Network (ICN) is a network of 13 clusters from Europe, North America and South Africa. Its role is to unite companies, universities and research entities, and the public sector. This organization has three goals: (1) providing its members and their SMEs with a platform for finding relevant partners for cleantech projects (2) offering internationalization opportunities, and (3) sharing knowledge regarding the organization of networking events for firms involved in the member clusters (ICN 2017).

Some important collaborations ICN has participated in are the International Green Growth Study of OECD (2012), European Cluster Collaboration Platform (E.C.C.P.) and a research project called ICLEI with the University of Amsterdam (ICN 2017). Current projects ICN collaborate on are C40 cities, a union of 91 cities for climate leadership, scale-up, coolsweep, and Interreg North Sea Region Northern Connections (ICN 2017).

Clusters included in ICN are Tenerrdis (France), Clean Tech Delta (Netherlands), GreenCape (South Africa), Cleantech ALPS (Switzerland), Greentech South (UK), CLEAN (Denmark), Research Triangle Cleantech Cluster (USA), GreenTech Cluster (Austria), Renewable Energy Hamburg (Germany), TWeeD (Belgium) and Sustainable Business Hub (Sweden) (ICN 2017). Most are located in Europe.

3.3 Methodology

In order to verify the research propositions, quantitative data was used to complete this analysis of the Cleantech cluster of Quebec: Écotech Québec. The purpose of this method is to gain a global perspective from the data analysis.

The data collection procedure was based on similar procedures used by Turkina et al. (2017) and Turkina and Van Assche (2018) in their empirical papers on Montreal's Aerospace cluster and the Bengaluru IT cluster.

3.3.1 Data Collection

3.3.1.1 Building the Database

The quantitative portion of this research took the form of a network analysis by leveraging secondary data found on the Internet. Therefore, to map the local network, data was hand-picked from, first, Écotech Québec's member list and, second, company's websites, more specifically, where they have chosen to display their partnerships (i.e. website landing page or *About Us* section). The partners were then listed in a spreadsheet so as to better understand who is connected to whom. When entering the data, the core firm was listed on the left, and then, all associated firms were listed in the row corresponding. This is called a network matrix and can then be treated by the software *UCI6*.

Given the size of ÉQ's inner network, this database was limited to the firms from the following sections of ÉQ's member page: Air, Water, Agriculture, Green Chemistry, Energy Efficiency, Eco-Mobility (Green Transport), Renewable Energy, Waste Management, Enabling Technologies and Soil & Groundwater[1]. The section called "Others" was ignored as it is unclear what specialization the firms within it have. A quick review of that section showed that it is mostly comprised of municipal actors, MNEs and supporters of the cleantech industry which do not contribute to the creation and invention of new Cleantech solutions. Therefore, these members have been put aside as their contribution to the cluster is unclear.

Regarding the database's organization, all companies are entered into the database in the same way (Appendix B for sample database). Firms mentioned on Écotech Québec's website, within the specific divisions (not including "Other") were entered in the Core Firm column. Their partners were then added one by one in the corresponding row.

As defined above, partnerships and strategic alliances between firms are a great way to develop a business network. Therefore, only formal linkages as demonstrated in horizontal ties by way of partnership were accounted for in this project. Although there is interest in understanding informal linkages, they would be practically impossible to map out given the diffused nature of the information as well as corporate secrecy tied to this

[1] Link for more information: http://ecotechquebec.com/en/members/directory/

information. Additionally, partnership type, time or weight were not accounted for as this would add a significant degree of complexity to the analysis, and time to complete the exercise was limited.

This exercise was repeated to map the international cleantech network where, using the International Cleantech Network (ICN)'s webpage, secondary data was extracted so as to understand which cluster organizations and partners are connected to ICN and which projects they and their members collaborate on. This information was listed in a spreadsheet in a similar fashion to the local network list.

3.3.1.2 Building the Attribute List

Simultaneously, a list of firm-level attributes was made in order to describe the firms in both databases. This list of attributes is based on elements from Porter's theories of the Competitive Advantage of Nations and Clusters, and from the literature on innovation ecosystems discussed in the literature review earlier on.

Attributes include primary and secondary sector, region, province, country and presence of an international partnership. For the core firms, the primary and secondary sector, region and province were taken from the Écotech Québec member list in regard to the core firms and, otherwise, deducted from the firm's website. The presence of an international partnership was documented as 1 or 0, where 1 meant the company had at least one partner from an international source and 0 meant the company had none. Using a coding key, firms were associated to the appropriate codes to signify all possible answers to each attribute.

For example, Écotech Québec, below, is assigned 0 and 0 to sectors as it does not have one identified sector. It received 1 for region and province as it is located in Montreal, Quebec. To International Partnership, it received a 1 as it is tied to many clusters from outside of Canada. On the other hand, GiGrow, an innovative firm in the agricultural sector of CT, was assigned 1, 8, 2 and 1 as it is part of, firstly, Agriculture and secondly, Energy

Efficiency as well as is located in Montérégie, Quebec. It does not have any international partnerships and therefore received a zero for that attribute.

Table 2 - Excerpt from Attribute List

core firms	**primary sector**	**secondary sector**	**region**	**province**	**intl partnership**
ecotech quebec	0	0	1	1	1
gigrow	1	8	2	1	0

In order to tell a full story, attributes were also collected for the partners of the core member firms. In this case, there was no website to pull this data from quickly and therefore methods of deduction were used to find these pieces of information. This includes reading About pages and looking for sectors served on the company's webpages. When two sectors were identified a combo of Primary and Secondary sector was documented. Following this process, if the sector was unclear, the primary sector was registered as "no data".

3.3.2 UCI Net

Once the data was collected, it was run through a program called UCI Net in order to create a powerful image of the network in question. The version of UCI Net used in this research is UCI6 (Borgatti et al. 2002). The attributes were then superimposed onto the network to help tell a full story. From this web, many measures can be calculated to help understand the structure of the network.

3.3.3 UCI Net and Specific Network Vocabulary

UCI Net is a software which uses pre-tested algorithms to crunch the data[2]. UCI Net reveals the measures described in the last section as well as displays the nodes and linkages in an appealing way to the reader.

Network theory uses a specific vocabulary to communicate network items as well as measurements. This section will review the specific terms used in this paper. First, in terms of descriptive vocabulary, network analysis uses the words *nodes* and *links.* Nodes refers to the companies or agents interacting with each other. Links are the ties which connects them. Second, measures of networks will be used to understand the dynamics of the local Cleantech industry. These will be used as tools to better understand the network. A simplified summary of the most important elements for this research is provided here:

Table 3 - Network Vocabulary

Term	**Definition**
Paths and Cycles	Terms used to refer to the passage of information between the nodes. The technical distinction between the two is whether the involvement of each node is distinct, as in a path, or not, as in a cycle (M. O. Jackson 2008, 23-24).
Trees, Stars and Complete Networks	A *tree* is a connected network with no cycles. A *star* is a particularly connected node as opposed to other nodes in the network. It can also be referred to as a *forest.* A *complete network* is a network in which all possible links are present (M. O. Jackson 2008, 27-28).
Neighborhood	Complete set of nodes which a specific node is connected to (M. O. Jackson 2008, 28-29).

[2] No new algorithms will be developed in this research.

Degree and Network Density	*Degree* is the amount of links to which one node is connected to or "the cardinality of a nodes neighborhood" (M. O. Jackson 2008, 29). Whereas the *density* of a network is equal to the total number of links within the network expressed as an average degree (M. O. Jackson 2008, 29).
Cliques	Measures of tightness of the nodes in the network. A *clique* is a group comprised of at least three nodes which are completely connected. Cliques are measured by using the *clustering* coefficient (M. O. Jackson 2008, 36-37).
Centrality	*Centrality* can be measured by *degree*, *closeness*, *betweenness* and *neighbor's characteristics*. *Degree* is the simplest measure where an algorithm evaluates the level of connectedness of a node (M. O. Jackson 2008,38). *Closeness* "tracks how close a given node is to any other node" (M. O. Jackson 2008, 39). *Betweenness* evaluates how well connected one node is in reference to all other nodes by looking at the number of *paths* it lies on between other nodes (M. O. Jackson 2008, 39). Lastly, *neighbor's characteristics,* or *Eigenvector centrality*, measures the importance of a node in terms of the importance and relative power of connectedness of its neighbors (M. O. Jackson 2008, 40).

In addition, there are other important concepts in the field of network analysis to be considered.

First, the *Small World* concept is one of measures which are the most often studied in network literature. This concept is used to large networks which exhibit small diameters and small average path length (M. O. Jackson 2008, 86-87). Goyal found that the

presence of several highly interlinked *stars* and an increase in average degree causes for an increasingly Small world. (Goyal 2006, 10).

Next, *homophily*, as explained by Granovetter (1983), is where individuals will have a natural preference to bond with those who are similar to themselves. In a growing and innovation reliant network, homophily could have a dangerous effect in the context of a small world network as explained by Goyal above.

Lastly, *liability of outsidership* is a well-known concept in the field of International Business. This happens when a firm from the outside has a hard time connecting with the center of the network due to its foreignness. It can be studied in network analysis by looking at firms on the periphery of the network more specifically – and what has put them in this position (Johanson and Vahlne 2009).

These terms and concepts will be used as tools in the analysis of the Cleantech sector in Quebec, Écotech Québec, and its relations to other cluster organizations. More specifically, the Stars, Network Completeness, Cliques, Centrality and Liability of Outsidership will be used in the following analysis.

3.4 Assumptions and Paper Structure

Several assumptions are made in this form of data collection. First, it is assumed that if a company has a significant partnership with another firm, it will be mentioned on their site. Second, partnership with Écotech Québec is implied by the presence of these firms in the member list. Third, given the limit in information, all partnerships are placed on one level. Therefore, these firms and their partners will be analyzed in a horizontal manner, thus ignoring specificities like buyer-supplier relationships. There will also be no mention of strength of ties as this data was not available. And fourth, the presence of a tie between two nodes assumes the passing of information between the two players. This being said, further research could be done to verify this piece of information.

This being said, the following section will review this paper's main findings in relation to the three propositions; the anchor role of public and para public entities in the local and global network.

As the network is made up of many types of organizations and firms, this paper took a layered approach to analyzing the roles of different actors to better understand the different dynamics of the ecosystem. To this extent, the findings will be shared in two sections: local and global network.

To answer the first proposition, the next section will first review local network analysis. This will include a general description of the network's structure, acknowledgement of highly connected firms (i.e. Stars) and their role in the network, a description of interfirm cooperation and findings about International firm ties. Throughout, network measures will be shared in support of the findings. More specifically, various measures of centrality will be used as support to the anchor role of Écotech Quebec in the local network.

Next, to support the second proposition, the global network will be analyzed to highlight the position of Écotech Québec amongst other industrial clusters around the world. This will be done by explaining ÉQ's closeness to the core of the network as well as to other strong players in the global network. Once again, network measures will be used to support the argument that ÉQ holds an anchor role in the global network.

4. Description of Findings

In order to verify this paper's propositions on the importance of government-backed entities as anchor firms in the network, research was done on the local and global networks of Écotech Québec. The goal of this section is to present the reader with a data-based view on Écotech Québec's internal structure and how they have been integrating internationally.

This section is structured the following way. First, the internal network of Écotech Québec, characterized by its member firms and their partners, will be presented. Findings of a general nature will be described first and followed by elements of a more specific nature. In this fashion, the position of government entities as exemplified by para public and public organizations will be reviewed last and used as a Segway into the international integration of the cluster.

This second section will be studied by displaying external ties Écotech Québec has with other cluster organizations around the world. This second web will help us understand Écotech Québec's internationalization pattern.

4.1 Local network

In analyzing the network of Écotech Québec (ÉQ), 111 firms (including ÉQ) were collected from the member page of the cluster organization's website. These 111 firms represent firms participating in the cleantech divisions of the following sectors: Agriculture, Water, Waste, Energy Efficiency, Enabling Technologies, Renewable Energy, Soil & Groundwater, Air, Eco-mobility and Green Chemistry. For the convenience of this analysis, all firms apart of the Other category were put aside as a sector was not specified.

This first sub section will give a high-level description of Écotech Québec's internal structure. Next, the sub sectors will be divided to give a more detailed view on the position and influence each sub sector has on the network. Then, network measures will be

provided to transit into the External network, where findings pertaining to the external network will be shared.

Before diving into the details of this research's results. Here are some descriptive statistics about the data collected. As mentioned earlier, the database included 111 companies which acted as core nodes. Following the methods highlighted in the Methodology section above, the network was expanded to a total of 436 nodes. Of this network, there were 111 links to Écotech Québec as each company represented a member of EQ's base. Furthermore, this was the representation per Cleantech primary subsector.

Descriptive Statistics	
Total amount of nodes in the network	436
Total amount of core nodes	117
Number of linkages	426
Links to Écotech Quebec	111

Cleantech by Primary Subsector	
Agriculture	2
Water	17
Waste	13
Renewable Energy	18
Eco Mobility	11
Green Chemistry	9
Energy Efficiency	23
Other	3

This distribution will be reviewed in more detail later on in this paper.

Moving into the network view of the sector, the following graph is a basic representation of Écotech Québec's internal network of firms. For ease of reading, the table below displays the associated sectors or groups of sectors to their respective colors.

Table 4 - Color Coding for Simple Network

Sector or groups of sectors	**Color**
All Cleantech sectors (described above)	Green
Government departments or agencies (i.e. Federal, Provincial, Municipal levels of government)	Red
Para government agencies (i.e. industry associations, international agencies & associations, and chambers of commerce)	Medium blue
Support firms (incubators or accelerator programs, universities and research centers)	Pink
Financial institutions (venture capital investment firms, investment funds and banks)	Orange
Other sectors	Dark blue
No data	Grey

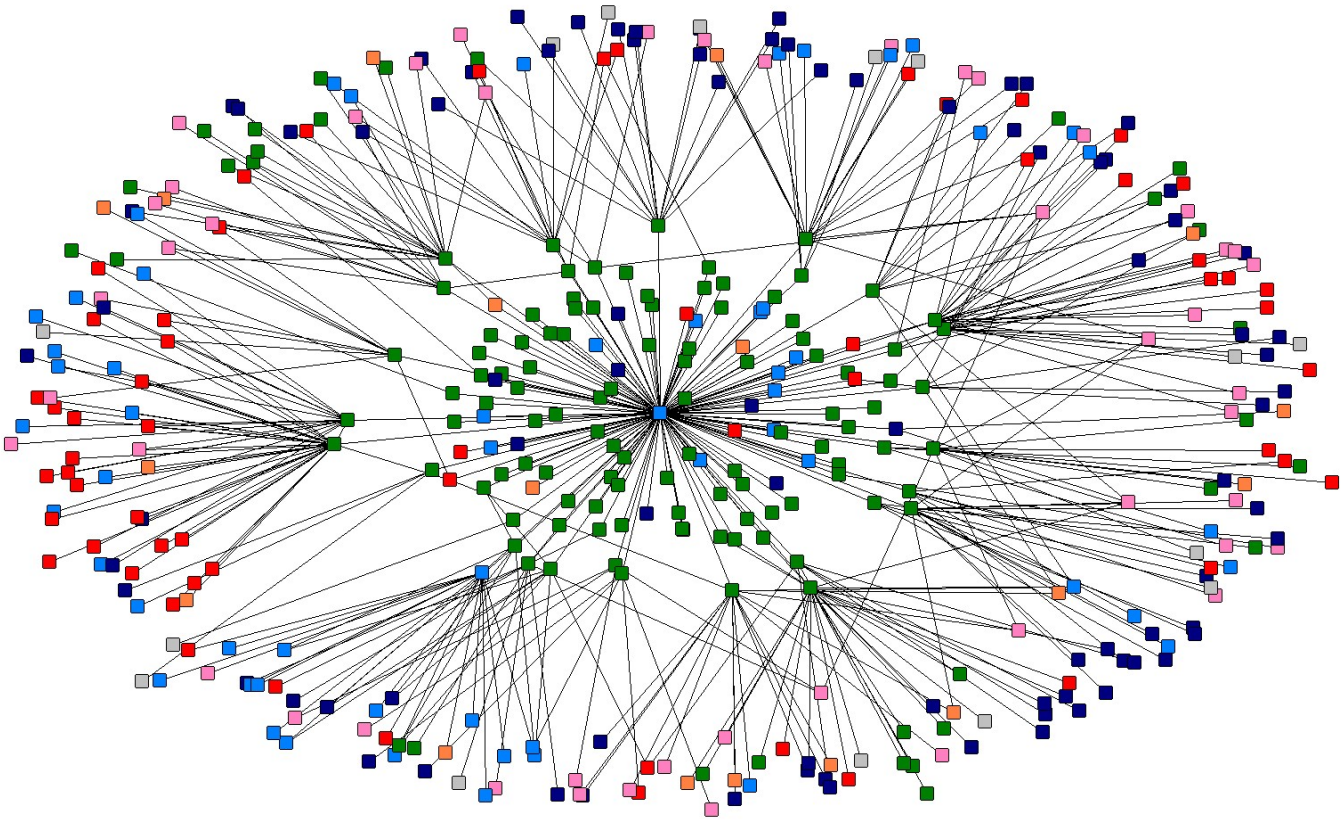

Figure 4 - Écotech Québec's inner network

With a first look at this network, some early observations are the following. First, the general network is organized by *Hub and Spoke* where a Hub, the central node, holds a special position in the network by which it diffuses all information out to the Spokes. Second, few Cleantech firms (green) carry many partnerships and few are connected to more than one other Cleantech firm. Third, as Cleantech is multisectoral, it would have been expected to see a much higher density of firms from other sectors like Forestry, Oil & Gas, or Mining, but instead this figure shows a high density of government agencies, para public organizations and support firms than of other types of firms. With these ideas in mind, the next sections will provide more detail on the way this sector is organized in order to later provide insight on this paper's propositions.

4.1.1 Écotech Québec' layered local network

A closer analysis shows that the graph can be divided into three layers of nodes.

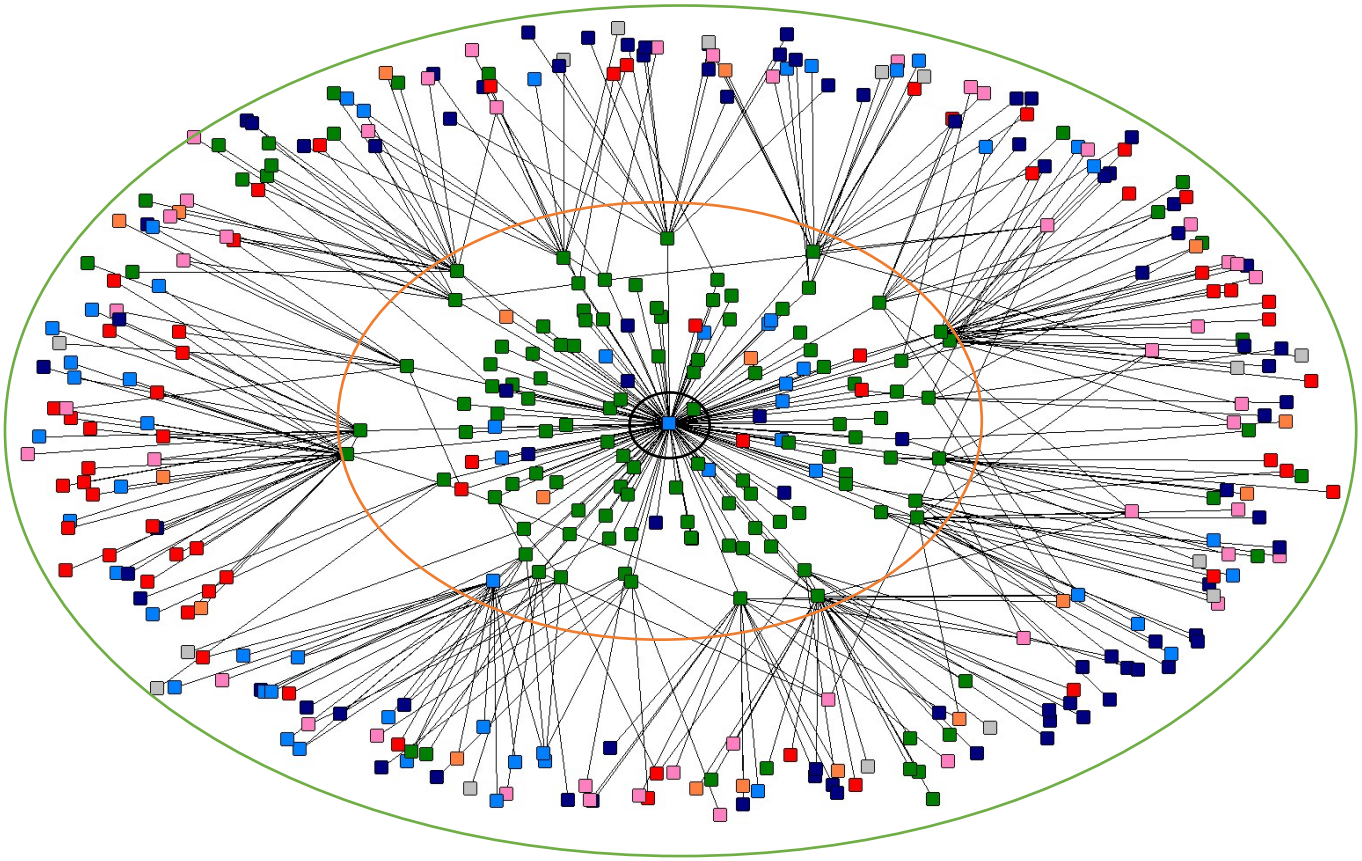

Figure 5 - Layered network

The first layer, in black, is the core of this network. In this case, the core is Écotech Québec as the network was built from the Écotech Québec's member list. The second layer, in orange, are ÉQ's members and Prestige members. They are ÉQ's direct network. This layer includes both the intensely connected nodes and the highly disconnected ones. The third layer, in green, are partners of Écotech Québec's members. These are a mix of government agencies, industry associations, financial institutions and firms from other sectors. Additionally, some second layer nodes happen to share third layer connections as visible on the far-left and far-right side of the graph.

Regarding the other colors of nodes in the second ring, the Prestige status is given to all firms contributing a large financial amount to Écotech Québec. Therefore, this explains the positioning of the other colors in the second layer and their connectedness between each other.

While the division of the above layers was done by eye, network centrality support, core periphery, geodesic distance and Eigenvector centrality measures support this finding.

i. Centrality

Regarding centrality, Freeman's degree centrality, as applied to an undirected network, counts the amount of links each node has (Hanneman and Riddle nd). This score reflects the speed at which information will spread in the network. This network has an average degree of **2.12** as visible in the table below. This means the network's nodes are, on average, highly disconnected as, on average, the nodes have connections to 2.12 other nodes.

This being said, ÉQ scored the highest (129), in comparison to the next highest scoring 29 and 17, from the second layer, and 0-2 in the third layer.

All in all, this measure shows the level of centrality each node has. Therefore, it is expected that Écotech Québec score much higher than all other firms. Additionally, this measure confirms the aforementioned suspicion of the presence of *Stars* in this network.

Table 5 Descriptive Statistics

Degree Centrality Descriptive Statistics	
Mean	2.21256039
Standard Error	0.34445847
Median	1
Standard Deviation	7.0086931
Sample Variance	49.1217789
Range	128
Minimum	1
Maximum	129
Sum	916
Count	414

ii. Core periphery

Furthermore, core periphery, an algorithm which estimates the degree of closeness a node has to the core, measures also support this division. As expected, the only node with a core degree of 1.0 is Écotech Québec. The average degree for core is 0.004. This means the majority of nodes are connected to few cores – supporting the assumption of several Stars and many disconnected nodes.

iii. Geodesic Distance

Geodesic distance refers to the shortest path between two nodes and, in other words, the speed at which information is transferred through the network. The average geodesic distance for the network is 2.2. This strengthens the previously mentioned assumption of three levels within this network as it takes, on average, two nodes to connect any two nodes in the network.

This is important as it supports this paper's first proposition where government-backed entities can play the role of anchor organizations and contribute to the growth of the cluster's network.

iv. Eigenvector Centrality

As mentioned earlier, the eigenvector score of a node measures its influence on other nodes. A higher score means the node's influence on the network is stronger and a lower score means it has little influence on its network. This being said, a node's connectedness to a node with a high score will raise its own score. This network has a relatively low average score of 0.025, with a high score of 0.68 belonging to Écotech Québec and a low score of 0.004 belonging to many companies in the network. The standard deviation, of 0.042, suggests that most of the data has a low Eigenvector degree.

This data leads us to say that Écotech Québec is the most central and influential node in this network and that a very small number of nodes are also very connected. This finding supports the paper's first proposition as a node's ability to exercise influence on other nodes is a key component to Anchor organizations.

Table 6 - Descriptive Statistics Eigenvector Centrality

Descriptive Statistics		
Eigenvector		
1	Minimum	0.004
2	Average	0.025
3	Maximum	0.689
4	Sum	10.655
5	Standard Deviation	0.042
6	Variance	0.002

4.1.2 Network completeness and Stars

To better understand whether the network is complete or not, this step looked at the graph's reorganization upon the removal of Écotech Québec (see below). Notice how all

nodes which were, at first, in the second layer of the previous graph now find themselves pushed to the side. What cannot be seen in the graph is that, in total, 77 out of 110 firms are pushed to the side equaling to 64.5% of the total set of nodes. This is because their only connection was with Écotech Québec. Therefore, what is left in the center of this graph is the nodes which were originally further away from the center.

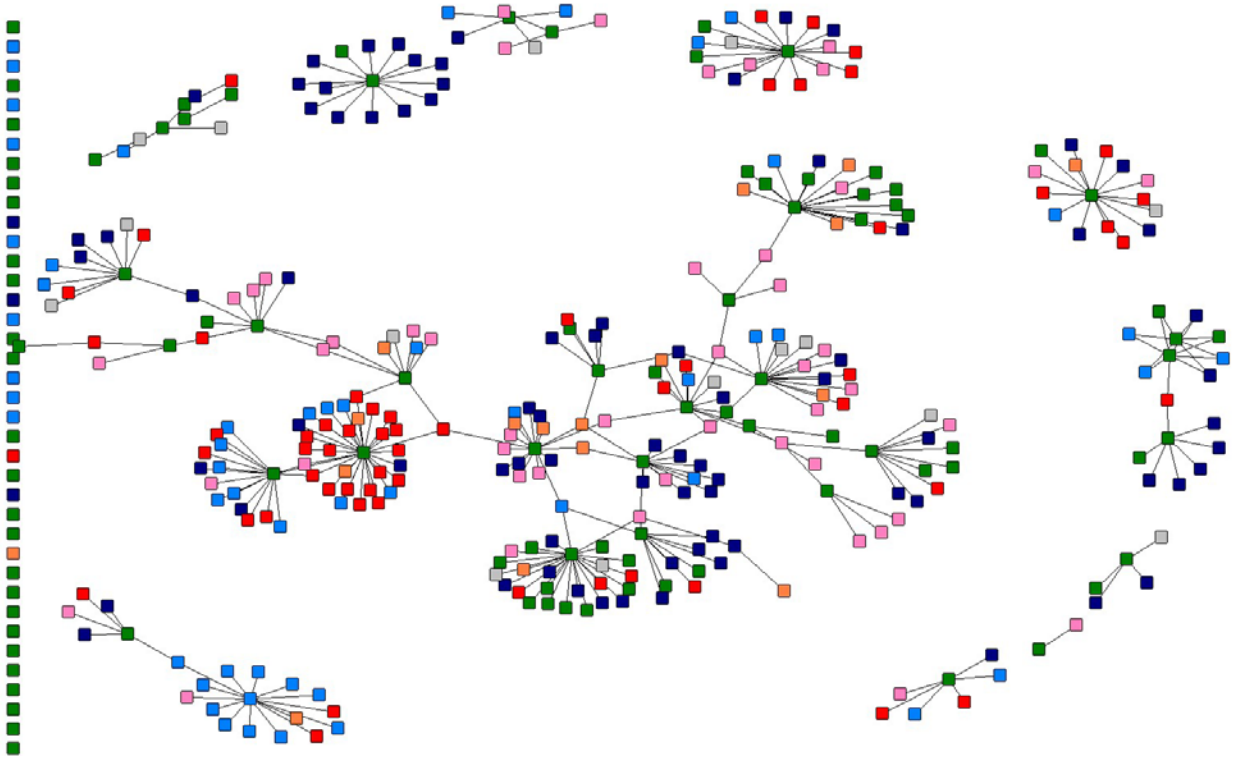

Figure 6 - Écotech Québec's internal network if ÉQ were removed

Therefore, this graph singles out the intensely connected firms in the network. In Network theory, these would be referred to as *Stars,* single intensely connected firms in a network of disconnected nodes. When ÉQ is removed, these stars become the new cores to the network. As shown in Figure 6, these cores are green and therefore, are firms from the Cleantech industry. This is expected as the network was first built based on Écotech Québec's member list and, second, on the member's displayed partnerships, What is interesting though, is that some firms are more connected than others giving them a clear advantage in terms of access to resources and knowledge.

The Stars in the network have much higher degree centrality scores hence pulling the overall score up. For instance, Écotech Québec, Réseau Environnement and Aquarehab have the highest scores as they are connected to the most nodes. Écotech Québec scored 129 whereas Réseau Envionnement scored 29 and Aquarehab 17. This also shows to what extent the network revolves around Écotech Québec.

Section 4.1.5 below will show the subsector origin of these Stars.

4.1.3 Regional Distribution within the Internal Network of Cleantech Firms

To properly determine the presence of a cluster in Quebec, this research divided the Cleantech firms by region. This showed an increased agglomeration of firms in Montreal (54 firms) followed by the region of Montérégie (18 firms) and Capitale-Nationale (9 firms).

For more detail, the following table provides the count of firms per geographic region within the province of Quebec.

Table 7 - Regional distribution

Region	**Count of Firms**
Montréal	54
Montérégie	18
Capitale-Nationale	9
Estrie	7
Bas-St-Laurent	3
Chaudières Appalaches	1
Mauricie	5
Centre du Québec	1
Nord du Québec	3
Lanaudières	1
Laurentides	2
Outaouais	1
Laval	4

Oakville	1

Given no past research has limited the geographic region of a cluster. One could argue a more intense Cleantech cluster is present in Montreal, and a diluted cluster can be observed throughout all of Quebec. This paper did not dig deeper to find out whether the geographic location had anything to do with the firm's success of choice of partners. Based on past literature by Gordon, one could assume some advantage to arise from being located in the large metropolitan areas. In this case, this would mean Montreal.

4.1.4 Cooperation between Firms

Given this paper chose to use partnerships as a base for the network, the following section will review the intensity of partnerships between ÉQ's member firms, with other industries and with international firms.

i. Cooperation within the Écotech Québec member network

Despite the extensive size of this network, this study found that little cooperation happens between the member firms of Écotech Québec. A count of mentions amongst the connection database showed that Kosmos Innovation, Réseau Environnement, Innofibre, Enviro Accès, Mabre Canada, Energère, Énergir, Enerkem and TM4 Electrodynamic Systems are the only firms which were listed in another member's list of partners.

What does this mean for the network? Most of Écotech Québec's firms either do not cooperate or cooperate with firms outside of the ÉQ bubble. This could be expected as it ties with above literature where firms try to find partners with others who may have complementary knowledge to their own.

And what do these firms have in common? In terms of network positioning, this analysis could not pull a connection between these firms. In terms of connectedness, only four of the above (Kosmos Innovation, Innofibre, Réseau Environnement and TM4 Electrodynamic Systems) reported partnerships with more than just Écotech Québec.

Beyond that, only Kosmos Innovation and Innofibre came from the same primary subsector (Waste Management), all others came from different subsectors.

Further research would have to be done to better understand this particular network dynamic.

ii. Cooperation of Cleantech firms with other industries

As Cleantech is multi sectoral, this research also attempted to map out the other sectors Cleantech is partnered with. Out of a total network composed of 418 firms, the following table displays the distribution and concentration of partner firms amongst other industries. The goal here was to see whether a particular industry is more so connected to Cleantech or not.

Table 8 - Network sector distribution

Industry	**Count of Firms**	**Percentage of Other Industries**	**Percentage of Total Network**
Telecommunications	2	2.90%	0.478%
Law	2	2.90%	0.478%
Construction and Infrastructure	18	26.09%	4.306%
Chemicals	1	1.45%	0.239%
Unspecified Technology	12	17.39%	2.871%
Consulting	5	7.25%	1.196%
Mining	2	2.9%	0.478%
Forestry	4	5.8%	0.957%
Safety	2	2.90%	0.478%
Agriculture	1	1.45%	0.239%
Automotive	1	1.45%	0.239%
Oil & Gas	1	1.45%	0.239%

Biogas	1	1.45%	0.239%
Electronics	5	7.25%	1.196%
Medical	1	1.45%	0.239%
Non-Profit	6	8.70%	1.435%

As can be seen on the above graph, there is a higher concentration of firms from the Construction or Infrastructure, Technology and Electronics industries than any other. This is congruent with expectations as, first, Cleantech is a technology focused sector and, second, it is often associated to municipal level of activities and the development of *Smart Cities* as discussed in the earlier on.

Although this is congruent with some of the Cleantech literature, it does not reflect the complementarity of cleantech solutions to more traditional, and notoriously *unclean* sectors, such as Forestry or Extractive sectors like Oil & Gas and Mining. These sectors are not as represented in the table above as they could be. This could demonstrate a weakness of the sector's commercialization strategy as seeking a more diverse set of customers could help grow the sector. Further research would need to be done to properly close this gap.

iii. International firm ties

Based on Bathelt's body of research on the importance of global ties for a firm to benefit from outside knowledge, this paper chose to integrate international ties to gain insight on the position of the firms in the global Cleantech network. Therefore, in regard to international ties, this project found that, while Écotech Québec may encourage the growth of local firms internationally, unfortunately only 22 out of the 118 firms actually had at least one tie with international organizations or firms abroad.

This finding therefore challenges the data point shared in Appendix A that 85% of firms from the Canadian Cleantech sector are exporting their products or services. Otherwise, if it does not challenge, it suggests that exporting cleantech firms may be located outside of Quebec as Quebec's cleantech firms have little international exposure. Furthermore,

this finding would require further research to properly understand which sectors have ties with international partners and why. This paper did not extend this part of the research beyond this point.

This being said, this finding will be useful when looking at the international embeddedness of Écotech Québec in 4.2

4.1.5 Cleantech subsectors within the ÉQ network

To further understand the internal structure of the network, this next section will detail the positioning of Cleantech subsectors as represented by the green nodes in the above graphs. First, a review of the distribution of the member companies within the network. Second, a study of the positioning of subsectors as well as their relative importance will be provided. Third, representations of the cleantech network with removal of certain subsectors will be shown and briefly described to depict the relative importance of sub sectors against others. This will give an overall review of the structure of Écotech Québec's industry structure.

Before diving into the details of the organization of the network by subsector, it is important to understand the distribution of companies amongst sub sectors. The chart below displays well the subsector distribution amongst Écotech Québec member pool by primary and secondary industries. It is to be kept in mind that firms could decide on two subsectors therefore making it look like there are many more firms than in reality.

Table 9 - Distribution of Cleantech Subsectors

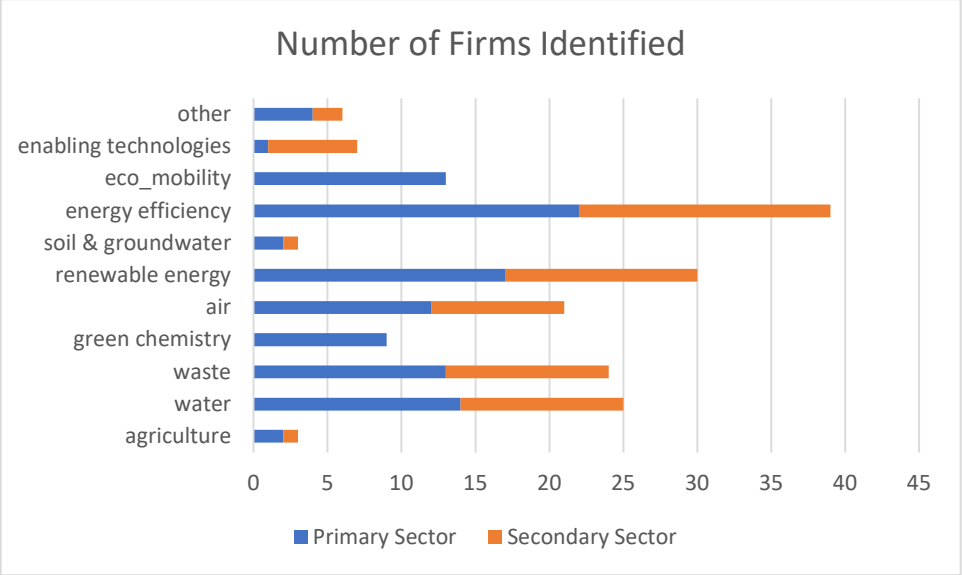

Table 9 shows a visible prominence of firms in the air, waste, water and energy sectors for both renewables and energy efficiency. With this in mind, the later analysis will demonstrate the position of these sectors in the overall network. These will be observed in more detail in the subsequent sections.

This being said, as mentioned earlier, the Cleantech firms actually take up a small piece of the entire network. More specifically, the table below shows the space occupied by each Cleantech primary subsector.

Table 10 - Space occupied by each subsector

Primary sector	**Percentage of entire network**
Agriculture	0%
Water	4%
Air	3%
Green chemistry	2%

Soil & Groundwater	0%
Renewable energy	5%
Waste	3%
Energy Efficiency	6%
Eco-mobility	3%
Enabling Technologies	0%

Next, for ease of reading, the following table displays the colors associated to the sectors in the network diagram. The same colors as above apply (p. 42) and to those are added the following color codes to detail the Cleantech subsectors.

Table 11 - Color coding for Cleantech Subsectors

Cleantech subsectors	**Color**
Water	Bright Blue
Agriculture	Light Purple
Air	Bright Green
Renewable Energy	Fuschia
Eco-mobility	Teal
Green chemistry	Yellow
Energy efficiency	Purple
Waste	Brown
Soil & Groundwater	Khaki
Enabling technologies	Maroon

This new graph, shown below, details the subsector origin of the stars. Notice how many of these *stars* come from the Water, Green Chemistry and Energy Efficiency cleantech subsectors.

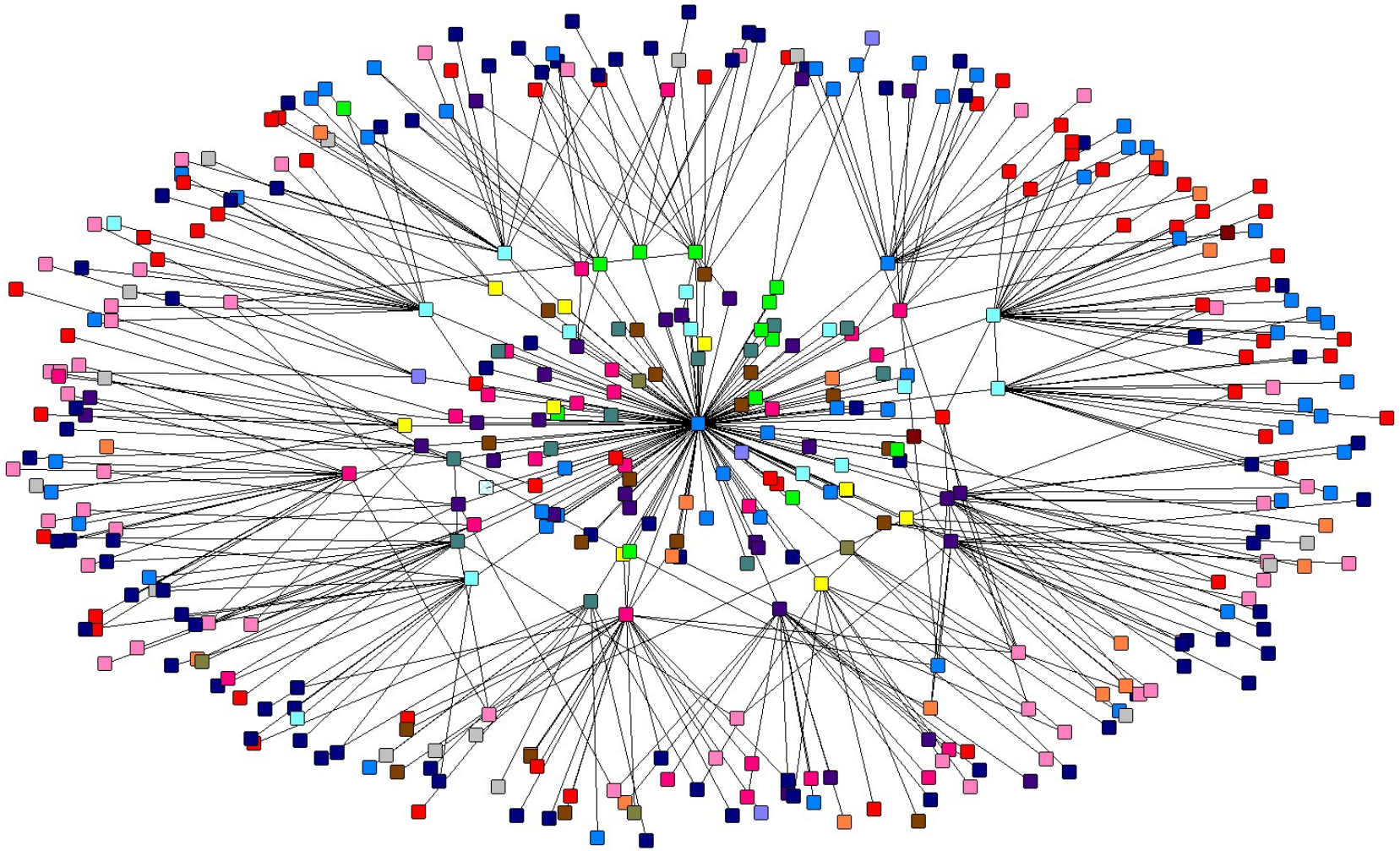

Figure 7 - Cleantech Sector Network with Subsectors

Another way of looking at this is to place all nodes in a circle, below, to observe the density of links coming from specific locations. As the Stars reposition themselves, the intensity of links coming from specific areas are more evident in this graph. Of course, Écotech Québec's presence in the para public category, represented by the medium blue, gives the impression of a centrality of this category. Beyond that, ties stemming from the Water, Green Chemistry, Renewable Energy, Eco-Mobility, Energy Efficiency and Soil & Groundwater appear to be denser than those coming from other subsectors.

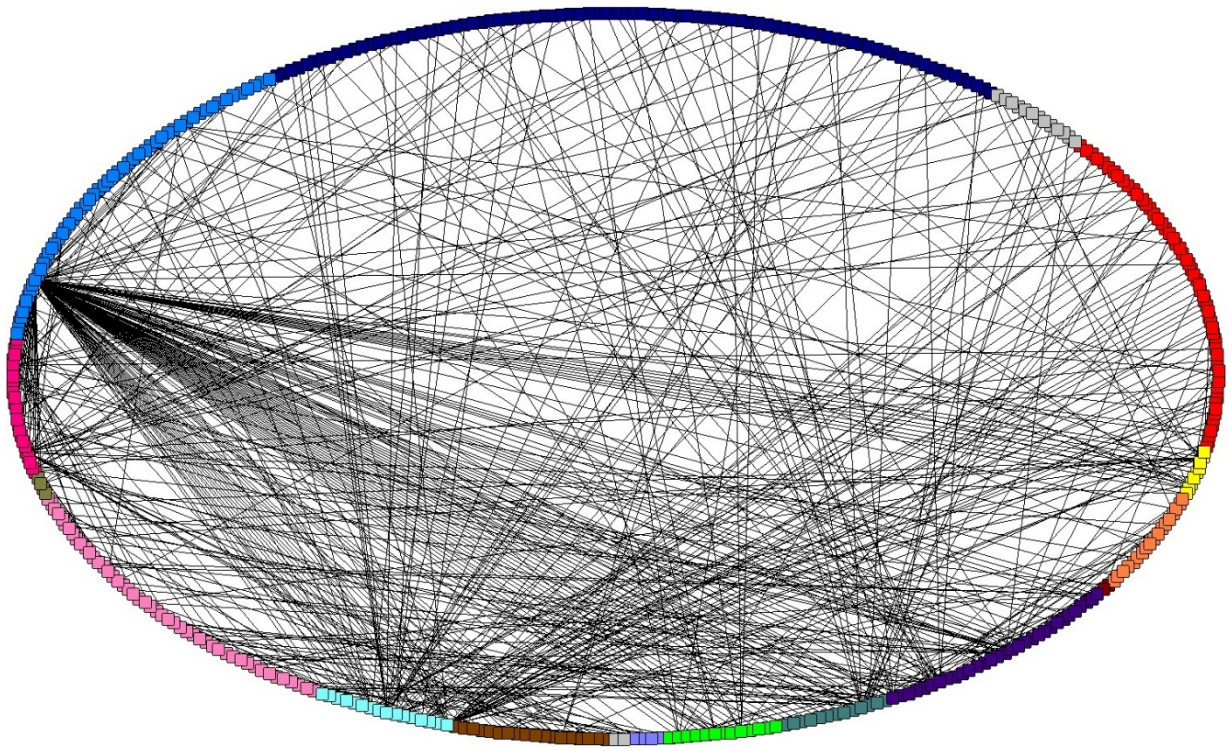

Figure 8 - Cleantech Sector in Circle

The density of links coming from these subsectors could lead one to believe that these subsectors are more important than others. This is not necessarily the case as will be demonstrated in the following tests.

4.1.5.2 Relative group importance

In conducting the analysis, subsectors were removed from the network subsequently to better understand their importance in the network. In most cases, the subsector removal

had little to no impact on the larger network. The most noticeable impact was where firms disappeared from the network, therefore, resulting in the shrinkage of the network. This being said, the network's organization, for the most part, remained stable. For example, the below network represents that of Écotech Québec following the removal of the Energy Efficiency segment of sector.

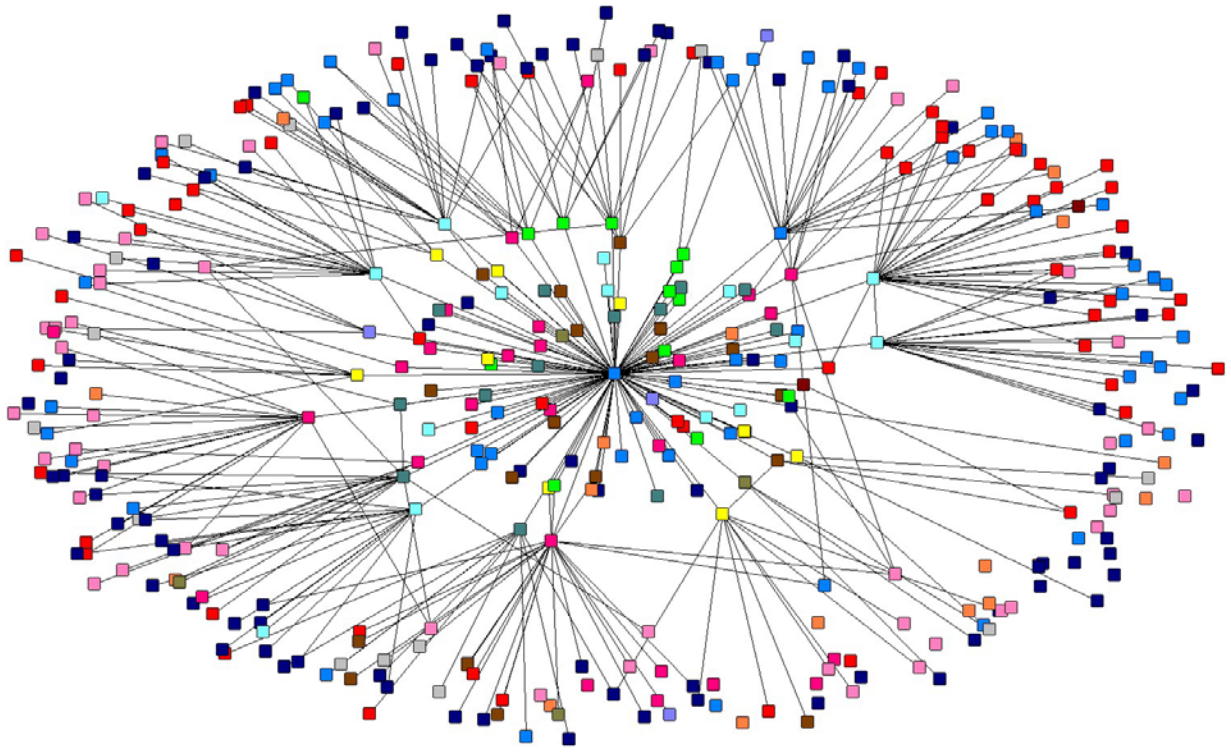

Figure 9 - Écotech Québec's network without the subsector of Energy Efficiency

Similar observations are found when conducting the same experiment on the other subsectors. Therefore, these tests not only demonstrate the relative importance of the sectors, but also, their relative insignificance. The point here being that no subsector is so central to the entire network that it would even partially fall apart if it were removed. Furthermore, the dispersion of Stars in the network could lead us to believe almost all subsectors has its own Star firm. This could be the subject for further research. Thus, this finding also points to the lack of specialization of the Cleantech sector in Quebec where no subsector is so strong that it would impact the entire network.

4.1.5.3 Relative importance of para public and government agencies

When the same test was conducted by removing the Para public agencies, a very different result was obtained (see below).

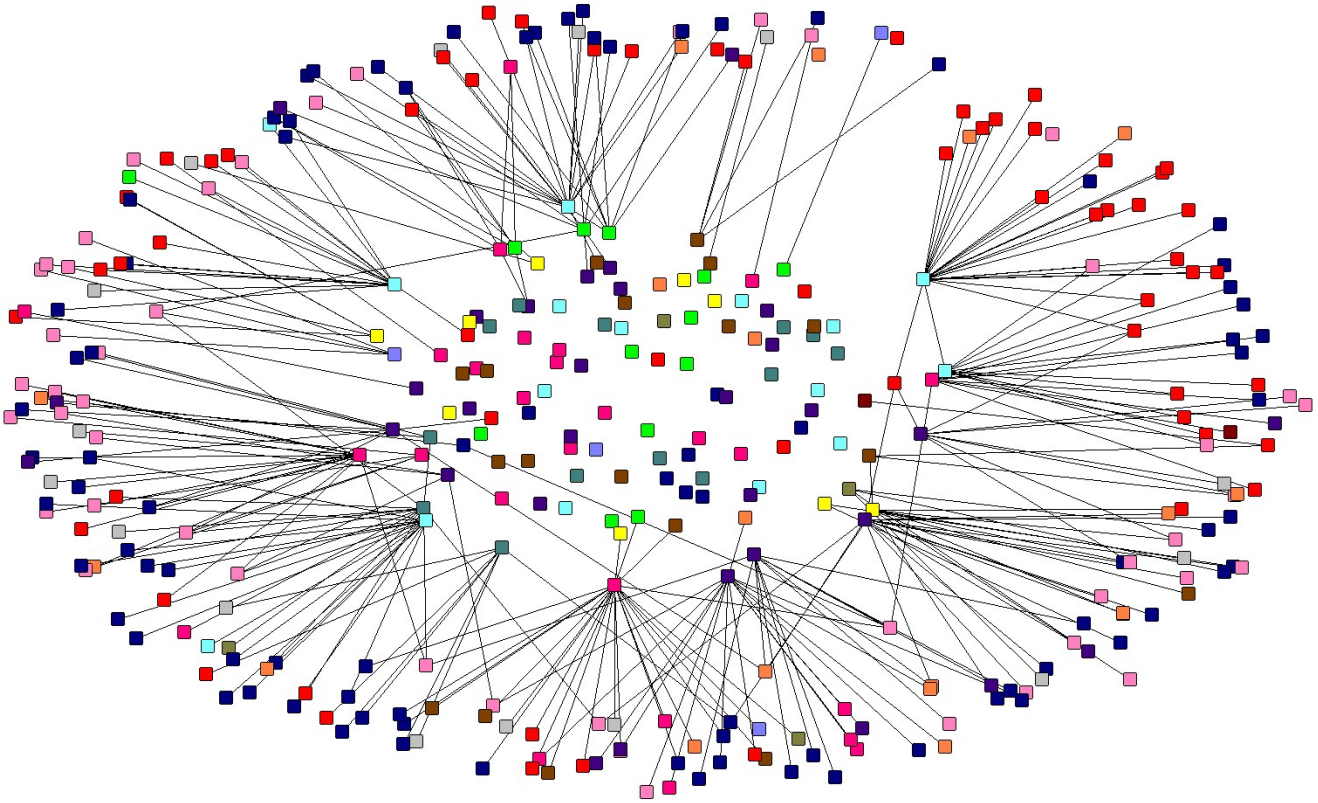

Figure 10 - Removal of Para public agencies and industry associations

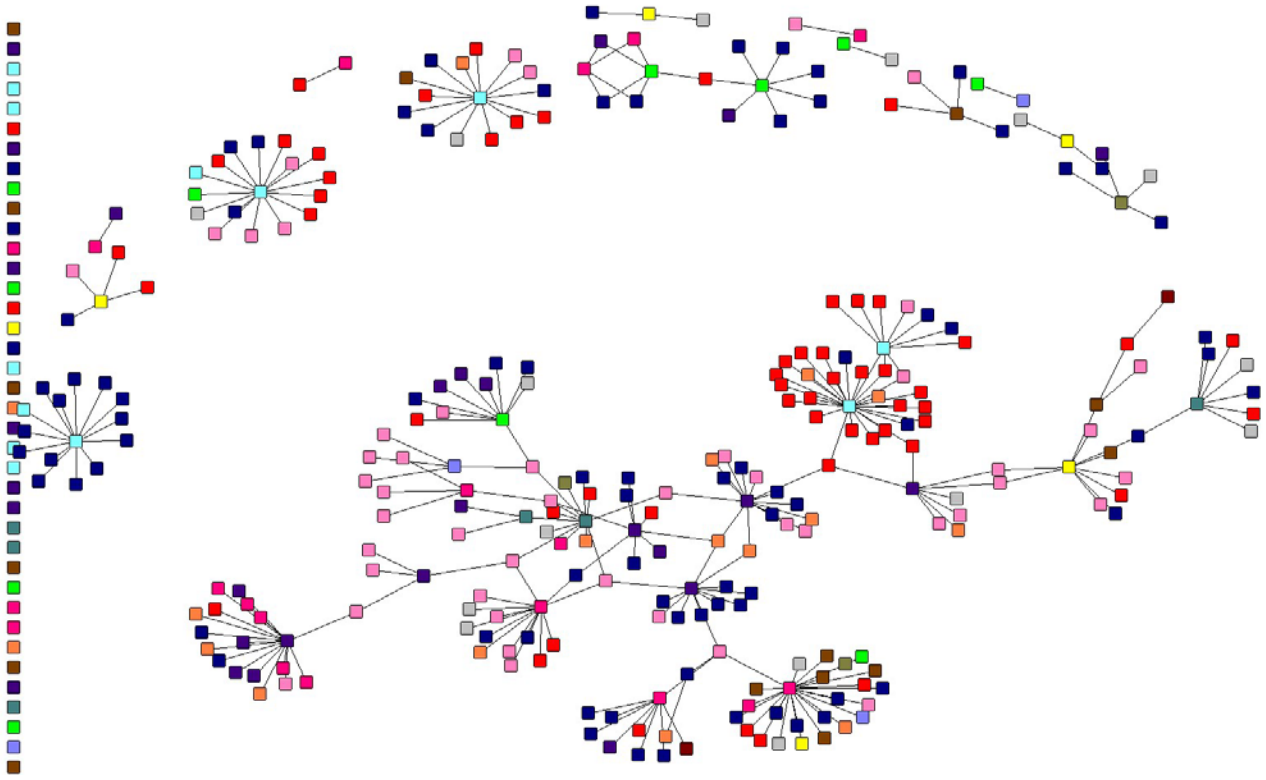

Figure 11 - Following Figure 10 above, this figure shows the reorganization of the sector following the removal of para public organizations

The removal of para public entities also has an impact on average degree centrality for the network as it drops to 1.55. This means that, on average, nodes are connected to 1.55 other nodes in this specific network. This is a significant change from the 2.2 average obtained with the full network.

Another view of this is by looking at the network's readjustment if both the governmental and para public organizations were removed. The network falls apart even more as visible on Figure 12 below.

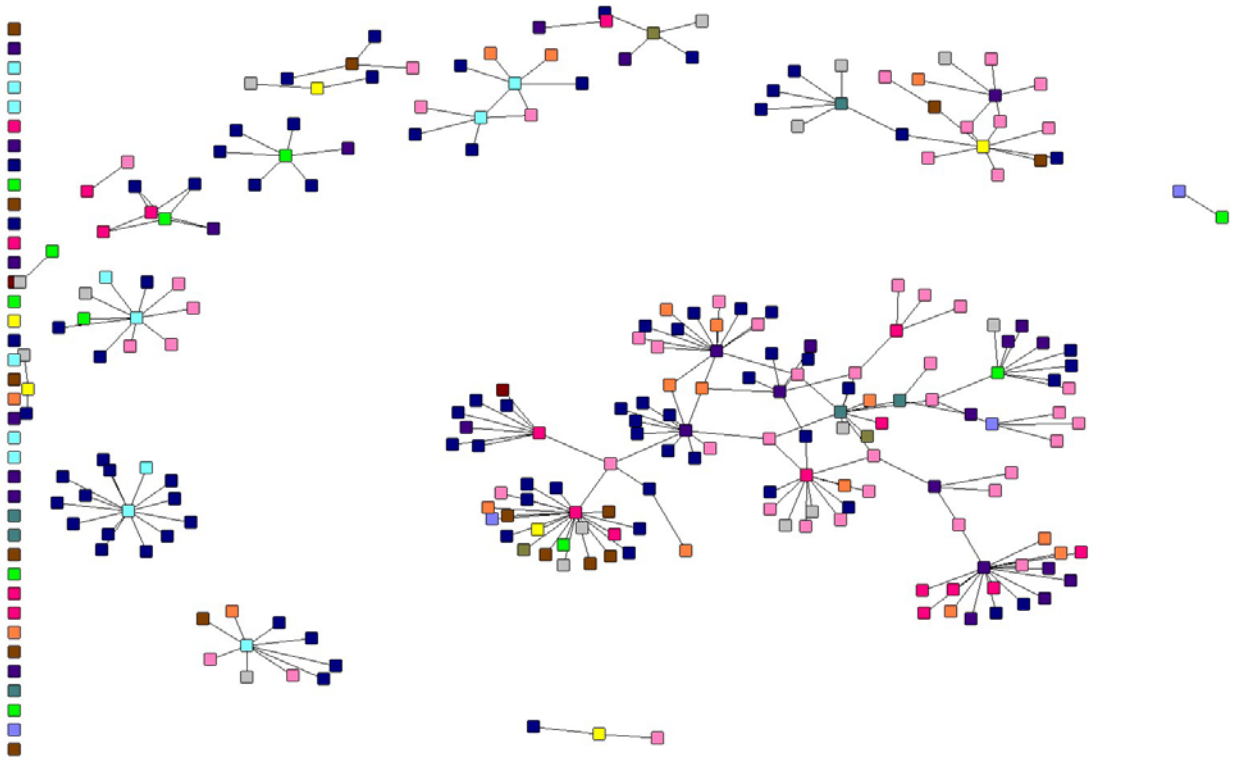

Figure 12 - Removal of both governmental and para public agencies

These graphs therefore show a complete disintegration of the network as a result of the removal of government and para public entities. The average degree centrality now drops to 1.43. This removal does not have as large an impact as did the para public firms but still show the disconnectedness of the network as a result of their removal.

To this extent, of the total network, 32% belong to supporting organizations (including support and government) and 11% from Para public agencies such as industry and cluster association as opposed to 26% from Cleantech and 20% from other producing sectors. This means the network is split down the middle between firms and supporting organizations, hence, explaining the important effect these organizations have on the total network.

This finding leads to the idea that there is an intense reliance of the sector and subsectors on supporting industries. It could also support the claim that there may be too many of these types of organizations for the sector to handle. As discussed earlier on in the Critical

Success Factor list, a clear strategy must be elaborated in order for the cluster to succeed. One could wonder what strategic impacts these para public agencies have on firm's individual strategies.

This disintegration therefore supports this paper's first proposition of the importance of governmental and para public entities for the creation of ties between entities of an industry's network. This paper also questioned the integration of clusters to the international industry network.

4.1.6 Key Takeaway

In summary, this section covered the position of para public entities, as exemplified by Écotech Québec, in respect to other firms from Cleantech subsectors as well as against firms from other sectors all together. The results showed that no subsector is stronger than another, but on the other hand, Para public organizations and government entities have a significant impact on the network's organization.

It therefore provides support to the first proposition where para public and government entities play an important role as an anchor firm to provide the network with knowledge by its central position in the network.

4.2 Écotech Québec's integration into the Global Network

So as to better understand the international network of cluster organizations and where Écotech Quebec positions itself within it, this study mapped out the network as can be seen in the graph below. To complete this task, the industrial clusters were mapped as per their published partners on their websites.

Once again, several items are at play when reading and understanding this graph. First, the size of the nodes varies based on their centrality measure. Second, as cluster organizations do not all identify with one industry more than another, colors represent the geographic regions where the organization is located. The following table helps show the

color codes used for the following graph. Third, some key actors have been identified and will be used in the next section.

Table 12 - Geographic color coding

Geographic Region	**Color**
International	Pink
Europe	Green
Canada	Blue
USA	Red
Africa	Yellow

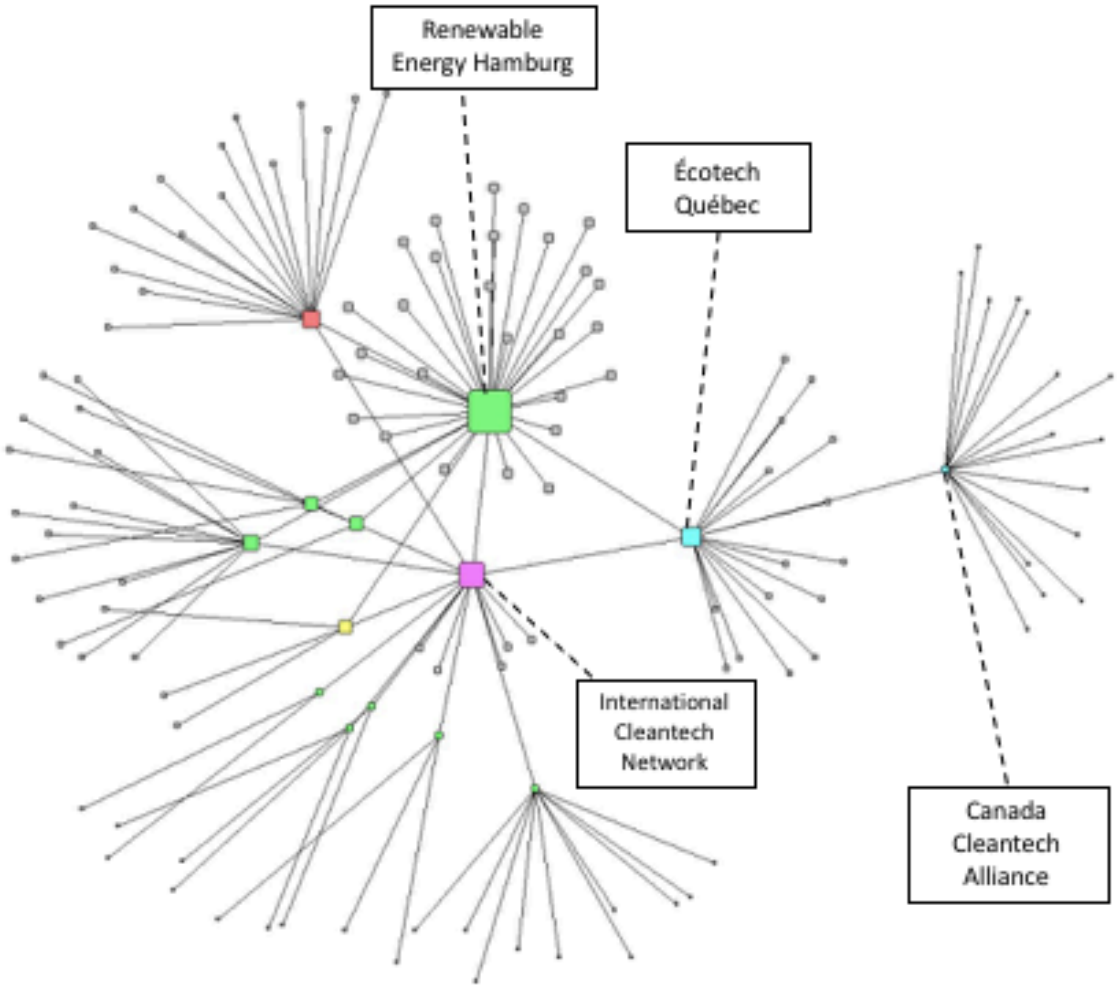

Figure 13 - International network of cleantech clusters of International Cleantech Network and Écotech Québec where nodes are sized by their centrality measure

This graph demonstrates Écotech Québec's position within the international network of cleantech industrial organizations. Some key findings arise here.

First, locally, this image shows that Écotech Québec is the doorway to the international platform for the Canada Cleantech Alliance. This is congruent with the description of important actors shared above where was showed that the staff between ICN, CCA and ÉQ are partially shared. This indicates that Écotech Québec is a stronger and more connected cluster organization than other Canadian ones.

Second, it displays the close ties between European clusters and Écotech Québec, but surprisingly the low number of ties with any other region. For instance, it would have been expected to see more ties with the USA as Canada is geographically close to that country. Instead, Écotech Québec can reach an American cluster through their connection to European clusters such as Renewable Energy Hamburg. This seems inefficient given the geographic proximity of Canada and the USA. The graph above suggests that geographic proximity may not be enough for associations to maintain relationships together. Additionally, this could reflect differences between the way the USA's Cleantech environment is structured versus Quebec's.

Similarly, there is a clear absence of links with Asia and Australia. This points to the idea that this network may not be as developed as one would think, and instead, may be quite regionally centered toward *Western* countries.

Lastly, as node size varies based on centrality measure, higher importance is brought to those nodes with the most amount of connections. Thus, in the above network, Renewable Energy Hamburg arises as the connection champion followed by the International Cleantech Network and Écotech Québec.

On the flip side, if nodes are resized based on the number of members in their cluster, a slightly different picture is shown. The following image is the same as the one above, except the size of the nodes are changed.

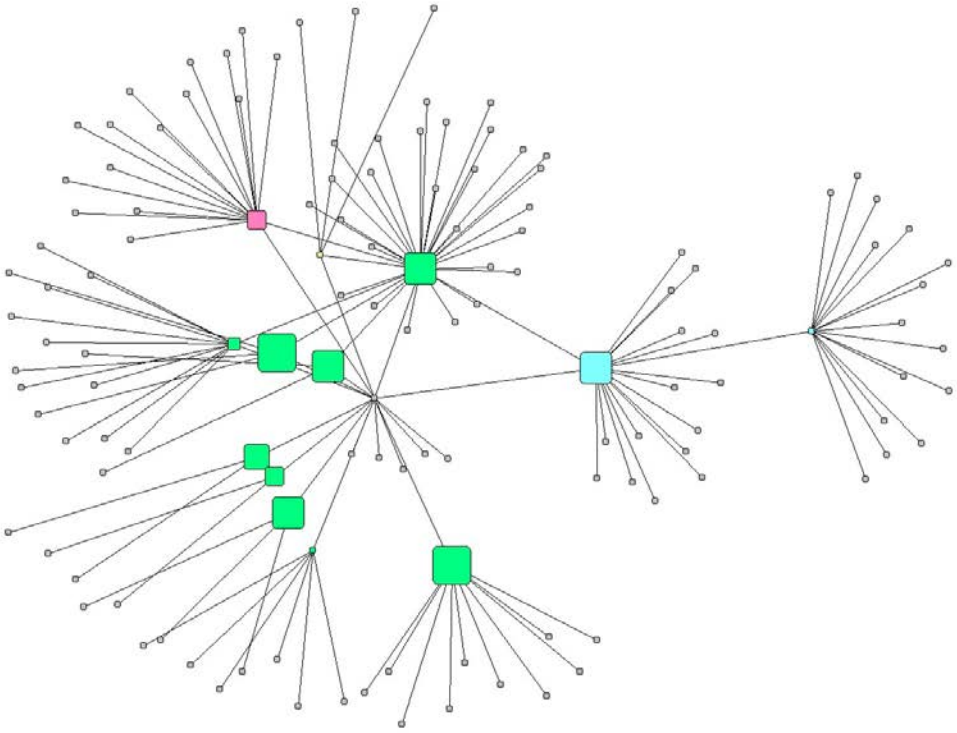

Figure 11 - International network of cleantech clusters of International Cleantech Network and Écotech Québec where nodes are sized by their member count.

For further detail regarding the above graph, the following table displays the number of member firms per organization.

Table 13 - Member density per cluster organization

Cluster Organization	**Number of member firms**
International Cleantech Network	None
Écotech Québec	180
Canada Cleantech Alliance	No data
Tenerrdis	216
Cleantech Delta	26
Green Cape	No data
Cleantech Alps	No data
Greentech South	250

Clean	164
Research Triangle Cleantech Cluster	50
Greentech Cluster	187
Tweed	116
Sustainable Business Hub	82
Renewable Energy Hamburg	190

If cluster size by member count is associated with cluster strength and maturity, Renewable Energy Hamburg maintains its position, but the graph also shows that Europe could be considered the strongest and most mature region regarding the growth and popularity of cleantech as the clusters of Tenerrdis, Greentech South, Greentech Cluster, Tweed and Renewable Energy Hamburg are the largest. This high concentration of cleantech firms in Europe may be an indicator of the strength of cleantech in Europe as opposed to that in another region. This study did not look further into what has made Europe a strong region for Cleantech.

As ICN does not have member firms, it loses its position as the most influential organization in the network. This being said, ICN's goal is not to support firms but to unite cluster organizations. To this extent, ICN's mandate is fulfilled by the connections it provides these cluster organizations with in order to grow their own sectors.

4.2.1 Measures of Global Network

The following measures support the role the International Cleantech Network plays in connecting other organizations to increase industry knowledge flows.

Table 14 - Measures of ÉQ's External Network

Measure	**Score**
Average Degree Centrality	0.2474
Cliques	6 (minimum 3 nodes)

Regarding the first measure, average degree centrality, is the average amount of links connected to a given node. In this case, the network is open. Thus, it is to be expected that this number not be very high as the network spans over several geographic areas meaning the interconnectedness of nodes would be quite low.

Next, the concept of cliques is used to support the role of ICN as a network connector. A clique is a fully complete subnetwork. To this point, UCI Net identified six cliques in the context of this network. These are the following.

1. ICN, Tenerrdis and Renewable Energy Hamburg
2. ICN, Cleantech Delta and Renewable Energy Hamburg
3. ICN, Green Cape and Renewable Energy Hamburg
4. ICN, Research Triangle Cleantech Cluster and Renewable Energy Hamburg
5. ICN, Renewable Energy Hamburg and Écotech Québec

These cliques demonstrate a few things. First, as mentioned earlier, ICN is a confirmed broker between other organizations by its participation in five cliques. Second, this strengthens the previously mentioned strength of the organization called Renewable Energy Hamburg in the overall network. One could conclude that the International Cleantech Network could be an anchor for the international network to build itself off of. Third, Écotech Québec is close to other strong actors in the international network. Thus, Écotech Québec's connection to the International Cleantech Network partially supports ÉQ's ties with international firms as well as their member firm's ties with international firms. The following investigation of ÉQ's participation in international projects will help validate or invalidate the second proposition.

4.2.2 Network and Projects

This study also took the opportunity to investigate projects put together by the International Cleantech Network. The goal of this step was to gain a better understanding of whether these partnerships have been profitable for Écotech Québec and its members.

The list of projects examined were the following: Coolsweep, Interreg North Sea Region Northern Connections and Scale Up, C40 Cities, Urban Future Lab, Global Opportunity Explorer and ESCP4i (ICN 2018). All these projects were found on the International Cleantech Network's website.

There are two main findings which arose from this exercise. First, in nearly all projects, the member organizations are European only. This leads to the conclusion that it may have been difficult for Écotech Québec to join those ones as they may be exclusive to Europe in their nature, and therefore, Écotech Québec may suffer from *Liability of Outsidership* in this particular case.

4.2.3 Key Takeaways

This finding leads to a partial conclusion that these partnerships with European para public entities may not be in Écotech Québec's best interest as they are not able to fully take advantage of them. Therefore, proposition 2a, where ÉQ's member firms can benefit from international resources, may be difficult to confirm based on this data as there is no evidence of members of ÉQ benefiting from these resources.

While this may be a disadvantage to Écotech Quebec's international ties, there are other advantages. For instance, ÉQ's maintenance of ties with important cluster organizations, such as Renewable Energy Hamburg, is a source of knowledge for the Écotech Québec's member firms. Hence, this supports proposition 2b where para public entities can play an anchor role in the passing of information from the global to the local network. To this extent, Écotech Québec's ties with international organizations creates space for knowledge transfers to happen.

5. Discussion and Concluding Remarks

As shown by the literature review, gaps were left around the implication of government entities in innovative industrial cluster growth regarding the role to take. To fill this gap, this paper leaned on literature from the fields of economic geography as well as network research to analyze the position of para public entities in the Cleantech cluster in the province of Quebec, Écotech Québec, and its positioning in the local industrial cluster as well as the global network of cluster organizations.

Based on insight from other authors, and with the hope to fill some gaps in the literature, this paper suggested three propositions for the dynamics around government-backed entities in industrial clusters.

1. Para public organizations play the role of anchor organizations in the local cluster network.
2. Para public organizations are connectors between global resources and the local cluster.
3. Para public organizations act as anchor organizations creating space for knowledge to move from the global to the local network.

5.1 Main Findings

In an effort to tie the findings on Écotech Québec's local network with the results from analysis done on its international network, these are the main findings from the above analysis which answer to the above three propositions.

First, the cleantech network in Québec is highly centered around its key node which is Écotech Québec. This was found by, first, taking a look at the network and, second, using network measures of centrality to qualify the importance of the centrality. In addition to this, the network is made up of a few highly connected Stars amongst many highly disconnected nodes. These stars are firms from the cleantech sectors and find themselves connected to, for the most part, their own networks. Therefore, a first finding could be that, although most of the network is highly disconnected, single firms from different subsectors grow the network by their vast web of partnerships. A second finding

is that, for the other disconnected nodes, Écotech Québec is often the only connecting node. This leads to the conclusion that little cooperation happens between Écotech Québec members.

This being said, these few stars can sometimes connect to each other via key players originating from the government, financial institutions, para public agencies (i.e. cluster associations or industry organizations) and supporting firms (accelerator programs, universities and research centers). While Écotech Québec is the main connector in the network, other governmental and para public organizations also have a strong impact on the network's structure as was demonstrated by the deterioration of the network following their removal. This embeddedness in support organizations leads to a third conclusion that the cleantech cluster in Quebec where it has not reached full maturity in terms of Cluster Life Cycle, and therefore, could use some help from a neutral actor.

In addition, as the sector may be young, it does not show signs of a clear advantage given to one subsector over another. To this extent, no subsector actually ends up taking precedence over others in the network and, therefore, no one subsector assumes the lead in the network. This lack of leadership also entails a lack of Anchor organizations. This provides space for Écotech Québec to assume this role by its business development goals, hence, providing support to Proposition 1.

Écotech Québec's position as the core for the network provides a platform for firms to come together and share knowledge between each other. Although this paper did not investigate the flows of knowledge per se, one could assume the neutrality of this organization as well as other governmental and para public organizations provided to the firms creates a trustworthy space to gain knowledge from. Therefore, Écotech Québec's central position is an important knowledge broker for the cluster.

The points shared above therefore supports our first proposition where para public organizations play an anchor role, by their centrality, in the network's local structure.

Second, regarding Écotech Québec's position in the international network, the organization seemed to show a strong position as demonstrated by its closeness to Renewable Energy Hamburg and International Cleantech Network. This being said, while Écotech Québec showed strong ties with other industrial cluster organizations and, by that link, access to global resources, the member firms do not seem to exhibit the same patterns as they do not have many ties with firms from an international origin. Therefore, Écotech Quebec's position in the international network supports the idea that they play an anchor role for the local network as they interact with other strong clusters providing the local network with knowledge and external resources as demonstrated by their implication in Cleantech projects.

Having previously mentioned that ties between nodes assumes the presence of knowledge flows, **these findings provide support to this paper's second and third propositions where para public entities play the role of Anchor organizations by their ability to access resources and knowledge from global clusters and relay them back to the local cluster.**

This being said, as this paper did not look past the network position of Écotech Quebec it cannot reach a conclusion as to why local firms did not show more partnerships with firms from outside Canada. Given Écotech Québec has many ties with European cluster, one could have expected firms to have more partners from Europe as well.

As this was not the case, this could mean many things. For one, local firms could not be interested in internationalizing. For two, they could be interested but not ready. For three, they may not have a need to be filled by international ties. Otherwise, Écotech Québec's ties with international organizations could also be in the wrong area. Écotech Québec's ties are mostly with Europe and this could be a mismatch with local firm interests. As Canadian firms are generally more comfortable with trading with the USA (as supported by data shared in Appendix A), it is surprising that Écotech Québec does not, at this time,

count ties with any organizations from the United States of America or from other parts of the Americas.

All in all, this paper supports the claim that para public organizations play the role of anchor organizations in both local and global networks. This paper also takes the position that these findings could also be generalized to other young and innovative sectors with a heavy reliance on networks due to the scope of their projects and a strong inherited government presence as attributed in Cleantech literature to the heightened riskiness of investments.

5.2 Theoretical and Practical Contributions

This paper makes several contributions. First, contributions are made to the fields of International Business and Economic Geography. This paper suggests a repositioning of the role of para public entities in industrial clusters. While this player has often put aside and, maybe even, taken for granted in past literature, this paper gives more importance to an often muted actor. Second, this repositioning also entails that the government's role as a source of funding and resources must be acknowledged as a player in the cluster's development as opposed to a simple bystander.

Second, by using network analysis, this paper supports and strengthens other paper's cases for a relational turn to the fields of International Business and Economic Geography. Furthermore, the importance of networks and network building activities are emphasized here.

Third, from a more practical angle, this paper found that ties to para public entities are key to receiving knowledge either from global or local actors and spreading knowledge to the rest of the local network. To this extent, these findings suggests to firms to strengthen their ties with their local industrial cluster organization as was also suggested by Granovetter whereby people were more likely to find their next job through acquaintances.

Fourth, from a practical point of view, this paper also stumbled upon some more findings regarding Écotech Québec and its member firms. Given these secondary findings are not tied to the research topic, they are not necessarily conclusive, but instead, to be treated as food for thought. They are covered in Appendix B.

5.3 Further Research

As in any research, this paper could not cover all facets of the story. There are many avenues left unexplored leaving space for further research.

First, this paper stayed rather high level in its analysis. The way the database was structured did not leave much space to look at sub sector specificities. For instance, no data was collected on the firm-level analysis so as to understand the inner workings of the *Stars.* An in-depth study of one particularly central sub sector and its behavior could help better understand the choices in partners as well as the opinion of firms on the support received by public and para public institutions. This could be completed by way of interviews leading to a qualitative research.

Second, certain aspects of this paper's database were not used to their full extent. For example, attributes were collected on region as shared in 4.1.4, but not observed from a network point of view. One could look at whether firms from certain areas in Quebec exhibit similar patterns or not. For instance, is a sub-cluster from a specific sub-sector present in a region of Quebec? Otherwise, do firms located geographically closer to the Écotech Québec reap more benefits than firms located further away? These are questions which could be answered with the current, or slightly improved version, of this database.

Third, patterns in cooperation were also skimmed through rather quickly. It could be interesting to take a qualitative look at the firms Cleantech firms cooperate with and why. Innovation focused network literature has suggested that firms cooperate with other firms which are complementary to them. Consequently, is that also the case in Cleantech? And,

if so, is there a preferred match between specific subsectors? These findings would have important practical implications.

Fourth, this paper stumbled across other findings which have been shared in Appendix B. These secondary findings provide a practical and strategic implication to Écotech Quebec and its commercialization tactics. Thus, practically speaking, this type of research could help find commercialization opportunities for Cleantech firms coming from Quebec, but also help Écotech Québec find an international commercialization strategy which would work with its member firm's interest. To this extent, many strategic implications exist when studying networks which this research did not get to in full detail.

Lastly, section 5.1 above suggests that there is a gap between the positioning of Écotech Québec in the global network and the local firms' interest to do business in those areas. This mismatch is important and could have a large impact on ÉQ's success with the local firms. This could also be studied in more detail upon further research.

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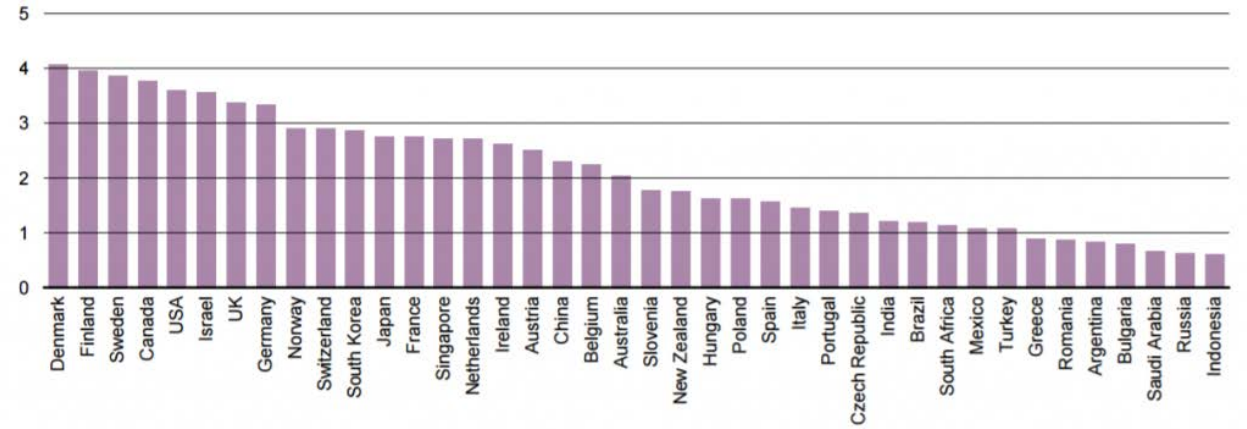
Appendix A: Context

With heightened concern for climate change, Cleantech has gained in popularity, and countries investment has also increased with the hopes to compete internationally on their abilities to innovate. Below is the ranking of all countries scores on innovation as ranked by The Cleantech Group in 2017. This scoring reflects the effort and investment put into the sector by each country. This image shows the importance of Cleantech in not only western countries, but emerging markets as well.

Table 1 - Global Innovation Index Country Scores (The Cleantech Group 2017)



Domestic Context for Cleantech

Closer to home, Canada has shown impressive leadership in this industry.

Putting aside a recorded decline in the industry in 2014, Cleantech in Canada has been growing steadily (Analytica Advisors 2016). This sector is young and, therefore, mostly made up of SMEs. Surprisingly, the Clean Technology sector is the sixth largest industry in Canada in terms of employment (Analytica Advisors 2016, 71).

A survey conducted by Analytica Advisors indicated that 87% of firms were exporting in 2014. This export participation represents 10 times that of all other Canadian companies

combined (2016, 5). This suggests that there is something in the nature of the industry to support exporting earlier on or exporting faster. Of export markets, the United States (US) came in first as a location to export to, followed by areas in Europe, China, other parts of Asia and the UK (2016, 5).

Geographic clustering in Canadian Cleantech

In regard to regional strength, according to Statistics Canada, Canadian 2015 sales of 'environmental and clean technology goods'[3] totaled $3.4 billion of which those manufactured in Ontario equated to 2 Billion dollars and, in Quebec, $750 million (2015). 61.1% of Ontario's sales originated from the renewable energy sector ($1.2 billion). 36.8% of Quebec's sales belonged to smart grid development and energy storage solutions ($121 million) (Statistics Canada 2015). British Columbia and Alberta were next in terms of amount of sales ranking at $161 million, of which 42.5% came from smart grid and energy storage technologies, and $135 million each (Statistics Canada 2015).

Furthermore, in 2015, exports from Ontario and Quebec totaled $850 million and resulted in 71.7% of total sales in 'environmental and clean technology goods and services', of which $670 million (78.8%) went to the US (Statistics Canada 2015).

This data shows a regional strength in Ontario and Quebec potentially providing a competitive advantage to Canada. One could speculate that this regional strength could have something to do with the presence of strong Cleantech clusters in those provinces.

[3] The definition of 'environmental and clean technology goods and services' used by Statistics Canada is the following: "Clean technologies are defined as any process, good, or service that reduces environmental impacts through:

- environmental protection activities that prevent, reduce, or eliminate pollution or any other degradation of the environment;
- resource management activities that result in the more efficient use of natural resources, thus safeguarding against their depletion; or
- the use of goods that have been adapted to be significantly less energy or resource intensive than the industry standard" (Statistics Canada 2015).

Toronto's MaRS District and Quebec's Écotech Québec are two large cluster organizations.

This portrait of Canada's Cleantech Industry leads to the conclusion that the government's involvement may have triggered the creation of a positive environment for this sector to grow. To this extent, some questions have arisen from this analysis. The International success of Ontario and Quebec push the conclusion that these regions are higher performers than the rest of Canada.

Appendix B: Secondary Findings

This paper also stumbled upon a series of secondary findings in completing the network analysis. These secondary findings are important from a strategic standpoint as well as from a theoretical perspective.

Sector Strategy

In respect to the Critical Success Factor (CSF) model developed by Menzel and Fornahl (2010), the following table displays a quick summary of the data retrieved during this research on Écotech Québec's achievement of Cluster CSFs.

#	**Critical Success Factor**	
1	"a focused, clear, ***right vision*** in the policy makers, firms, cluster support organizations, to be able, for example, to communicate effectively with investors, firms and other actors.	
2	***trust*** between the cluster firms, between the firms and LIU, and/or support organizations.	(Ins. Inf.)
3	***geographical proximity*** between the firms and between the firms and other actors	
4	***preexisting knowledge*** in the region prior to the formation of the cluster.	(Ins. Inf.)
5	***strong actor(s)*** in the cluster in providing, for example, technical expertise, incubation space, diffusion of best practice, innovation, attracting and retaining skilled labor.	(Ins. Inf.)
6	the cluster's ***brand-name*** […]	✓
7	local and extra local ***networking*** (collaboration) between: firms, firms and other actors to increase knowledge integration and value added.	
8	***physical infrastructure*** […] within the region	✓
9	***finance*** […] to firms.	✓
10	***innovation***/R&D within firms […]	
11	***entrepreneurship*** at individual, organizational, and collective levels […]	✓

12	***growing company base*** […]	✓
13	***staff attraction*** […] from outside the cluster	(Ins. Inf.)
14	***external links*** from the cluster and its firms to outside markets […]	
15	cluster ***support organizations*** […] in training, coordinating R&D projects, interfirm and fostering spin-offs."	✓

(Tavassoli Tsagdis 2014)

Recommendations to Écotech Québec

This paper's research showed that Écotech Québec may be missing some key elements to make it competitive.

(1) ***Lack of vision***: In order to grow, a cluster must maintain a minimum of coherence in its focus (Bathelt 2005, 205). Écotech Québec's wide range of subsectors gives the impression that they have not quite narrowed in on one or few specific areas to focus their energy. Additionally, although Écotech Québec is central to the organization, many other support organizations like accelerator programs, industry associations and other government entities are also present in the network. These agents could be contributing to the confusion around the vision established and therefore the large diversity within the sector.

(2) ***Large territory:*** Most successful clusters generally limit themselves to an urban center. Écotech Québec's coverage of the entire province may be too large. It could be worth it to limit coverage to Montreal only.

(3) Lack of cooperation between firms: This research showed that Écotech Québec may try to support firms in their cooperation activities, very little of them actually do cooperate together. This could be an indicator of the absence of complementarities between firms in the same region, but also the distance between the activities that firms actually do. Coverage of less subsectors could help spring more cooperation.

(4) ***Local and extra local networking:*** While Écotech Québec has external links, most firms do not. This limits their access to outside knowledge within their own industries, but also their access to outside industries which could benefit from their

services. Given the cross sectoral nature of Cleantech, both pieces here end up reducing firms' commercialization opportunities.

(5) ***External Links***: Similarly, while Écotech Québec has links with outside organizations, they do not seem to be transferred to the local cluster. Écotech Québec could consider questioning these ties and redirecting based on what the local firms need instead of the opposite.

Lastly, while research is often built around ties between municipalities and Cleantech firms, there is reason to believe this might not be the best strategy for Cleantech firms to pursue. Municipalities as actors of government are embedded in bureaucratic frameworks which may limit the speed at which they can assess and adopt a new technology. This paper found that ties to other industries were quite few and far between as shown in Table 4 (p. 46). Therefore, there could be more potential for these firms to rethink their clientele and investigate opportunities with other more traditional sectors which have suffered from a *dirty* reputation. Here, reference is made to sectors like Mining, Oil & Gas and Forestry. These sectors only took a tiny piece of the industry network. All in all, there is reason to believe faster commercialization can happen if Cleantech firms review their value proposition and get closer to those who may be more willing to pay for it.

Appendix C: Snapshot of Database

Core Firms	**Partners**									
ecotech quebec	energir	desjardins	bell	davies	fondaction csn	communaute metropolitaine de montreal	investissement quebec	mamot	meie	developpement economique canada pour les regions du quebec
canada cleantech alliance	ecotech quebec	bc cleantech ceo alliance	actia	mars cleantech	innovacorp	the maritimes energy association	bionb	pei bioalliance	the newfoundland and labrador environmental industry association	the arctic energy alliance
eau	impact 8	fondation montreal inc	institut d_entrepreneuriat banque nationale	connexite montreal	ecotech quebec					
gigrow	ecotech quebec									
aquarehab	acrgtq	acsiq	admq	aimq	agmq	atpa	awwa	catt	comaq	combeq
aquartis	ecotech quebec									
aquatech	ecotech quebec									
dbo expert	ecotech quebec									
e2metrix	ecotech quebec									

Appendix D: Snapshot of Attributes

core firms	primary sector	secondary sector	region	province	country	international partnership
ecotech quebec	0	0	1	1	1	1
canada cleantech alliance	0	0	1	1	1	0
eau	1	7	1	1	1	0
gigrow	1	8	2	1	1	0
aquarehab	2		3	1	1	1
aquartis	2	8	2	1	1	0
aquatech	2	8	2	1	1	0
dbo expert	2	2	4	1	1	0
e2metrix	2		4	1	1	0
econeau	2		1	1	1	0
emo3	3	2	3	1	1	0
groupe brio	2	8	1	1	1	0
innoveox canada	2	2	1	1	1	1
ino	11	2	3	1	1	0
kosmos innovation	7	2	2	1	1	0
nb_biomatrix	7	7	1	1	1	0
oco technologies	3	2	1	1	1	0
pompaction	2		5	1	1	1
probiosphere	2	2	1	1	1	0
reseau environnement	2	5	5	1	1	1
technologies clinnup	4	2	1	1	1	0
technologies ecofixe	2		13	1	1	0
technologies et service oxx_ro poirier	3	2	1	1	1	0
technologies propres tgwt	4	2	2	1	1	1

Appendix E: References used to build the database

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