Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

Innovation, Sciences et Développement économique Canada
Office de la propriété intellectuelle du Canada

Patented Inventions in Climate Change Mitigation Technologies

Canada

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TABLE OF CONTENTS

ABOUT US

The Canadian Intellectual Property Office (CIPO), a Special Operating Agency (SOA) of Innovation, Science, and Economic Development Canada (ISED), is responsible for the administration and processing of intellectual property in Canada. CIPO contributes to Canada's innovation and economic success by: providing greater certainty in the marketplace through high quality and timely IP rights; fostering and supporting invention and creativity through knowledge sharing; raising awareness to encourage innovators to better exploit IP; helping businesses compete globally through international cooperation and the promotion of Canada's IP interests; and administering Canada's IP system and office efficiently and effectively.[i]

EXECUTIVE SUMMARY

Climate change is a key priority of the Government of Canada. The Canadian federal government has set strict targets that will require Canadians to adopt current energy-saving technologies and develop breakthrough innovations. Patent data is good starting point for analysis of the development of new technologies as it provides important information on the specific technical knowledge embedded in the invention. This report examines patenting activity by Canadian inventors and businesses in the area of Climate Change Mitigation Technologies (CCMT) using designated patent classification codes that identify patents related to climate change. The intent is to highlight the areas where Canadians are most active and areas where we may have a relative advantage globally. Examining Canadian inventors and businesses separately provides a better understanding of the state of innovation in CCMT. Canadian researchers are characterized as being relatively specialized in most CCMT categories. Furthermore, some Canadian researchers are found on patents filed by leading international businesses conducting research and development in the area of CCMT. The results are different for Canadian businesses where Carbon Capture is the only category in which Canadian businesses are specialized. The leading Canadian businesses patenting in CCMT are not among the world leaders. Canadian businesses patent extensively in technologies related to Transport, an area in which they do not have a technological advantage. In general, both Canadian researchers and Canadian businesses are relatively specialized in CCMT technology subgroups related to Hydro Energy, Technologies for the Production of Fuels from Non-Fossil Origin, Nuclear Energy and Carbon Capture. Given the large global demand for climate change mitigating technologies, accelerated innovation could lead to increased access to foreign markets for Canadian companies. It is important to continue to monitor Canadian inventive activity in this technology area considering the economic and environmental implications of achieving the objectives set by the Government of Canada. The policy and economic context for this report was developed in collaboration with Environment and Climate Change Canada and Natural Resources Canada.

INTRODUCTION

Climate change mitigation technology (CCMT) is an exciting and fast-growing sector which is integrally linked to key priorities of the Canadian government. Carbon pricing coupled with investments in research, development, and marketing will build Canada's clean technology sector. Clean energy is already one of the fastest growing sectors of our economy. For example, Canada's clean energy sector has 20 times as much wind energy capacity and 125 times as much solar electricity capacity as it did a decade ago.[ii]

The 2017 Canadian Clean Technology Industry Report, published by Analytica Advisors, found that there are more than 850 Canadian firms engaged in the "pure play" component of the clean technology sector.[iii] "Pure play" companies are those that are primarily engaged in R&D or the manufacture or sale of clean technologies. While only a small fraction of the firms engaged in clean technology, these firms will be important in meeting the government's climate change goals. Employment in the "pure play" component of the clean technology sector grew by 9 percent between 2013 and 2015 for a total of 55,200 jobs, many of which are high-paying, and export-driven. The number of jobs in the "pure play" sector could reach 95,000 in 2022. Global trade in clean technologies grew by 4% annually since 2008. The Canadian clean technology market generated about $13.3 billion in revenue in 2015, with exports accounting for more than half of these revenues.

Climate change has long been a concern of the Canadian federal government, but more recently it has emerged as a key priority. Under the 2015 Paris Agreement on climate change, Canada committed to cutting its greenhouse gas emissions to 30% below 2005 levels by 2030. Meeting this target will require Canadians to adopt current energy-saving technologies and develop breakthrough innovations. Canada has also signed up to clean and low-carbon growth in the subsequent Vancouver Declaration and these policies will be greatly facilitated by the adoption and promotion of CCMT.

In response the provinces, territories and the federal government have agreed to take collective action to address climate change. Together, they have developed the Pan-Canadian Framework on Clean Growth and Climate Change, published in January 2017.[iv] The framework has four pillars, each with a Federal-Provincial-Territorial (FPT) working group to explore the issues and develop recommendations to address them. For this report two important conclusions have emerged. First, the FPT Working Group on Clean Technology, Innovation, and Jobs found that "there is a significant opportunity to better stimulate economic growth and job creation, and improve environmental outcomes across all sectors in Canada by driving clean technology innovation."[v] Second, the FPT Working Group on Specific Mitigation Opportunities noted that "further development of new and transformative technologies will be needed to achieve deep reductions from industrial emissions over the longer term."[vi] New technologies, that is, new inventions, will be needed for Canada's climate strategy to succeed.

On November 30, 2015, the Federal Government announced Canada's participation in Mission Innovation, a global initiative of countries working together to accelerate clean energy innovation. As part of this initiative countries agreed to double their national investments in clean energy innovation over five years, while encouraging greater levels of private-sector investment in transformative clean energy technologies.[vii] Furthermore, in Budget 2017, the government announced that it will commit $14.5 million in funding over four years, starting in 2017-18, for Natural Resources Canada and Innovation, Science and Economic Development Canada to develop a clean technology data strategy to foster innovation, improve knowledge in the private sector and stakeholder communities, and help inform future government decision making.[viii] Overall, due to the large global demand for climate mitigating technologies,

accelerated innovation could create opportunities for Canadian companies to increase their access to foreign markets.

Canada is also taking a longer term approach to position the country to successfully compete globally as it transition to a low-emission economy. In November 2016, the Minister of Environment and Climate Change announced Canada's Mid-Century Strategy, at COP22 in Marrakech, Morocco, that examines emission abatement pathways consistent with net emissions falling by 80% in 2050, from 2005 levels. This strategy, which looks beyond 2030, focuses on meeting climate-change objectives and enabling growth, requiring significant long-term investments in infrastructure to support transformation to a low-carbon economy.[ix] Meeting this target will require a fundamental restructuring of multiple sectors of the economy; in which abatement opportunities will need to be realized from virtually every greenhouse gas emission source and activity. The transition towards a sustainable energy transition is possible with currently deployed or near-commercial technologies, but the long-term transition will be eased with the near-term accelerated deployment of clean energy options or the development of more innovative technologies.[x]

The following patent analytics report presents the patented inventions of Canadian researchers and Canadian businesses in the area of CCMT. The report relies on a special patent classification code that identifies patents that are related to climate change. The intent is to highlight the areas where Canadians are most active and areas where we may have a relative advantage globally. The report is structured as follows. The first section provides the context. The second and third sections present the data and methodology. The fourth section provides a view of patenting at the CCMT level. The seven following sections dive deeper into each of the main categories in CCMT. The final section concludes.

DATA

The EPO's Worldwide Patent Statistical Database (PATSTAT) was the main source of data for generating the report. Historically, it was not possible to quickly examine Climate Change Mitigation Technology patents since specific Cooperative Patent Classification (CPC) codes had not been dedicated to this particular technology field. The United Nations Environment Programme (UNEP) and the European Patent Office (EPO) developed a dedicated tagging scheme for Climate Change and Mitigation Technologies (CCMTs) that was used in their joint-report *Climate Change Mitigation Technologies in Europe – Evidence from Patent and Economic Data*. This effort made it possible to analyse trends in inventive activity and in the global technology market, and to provide evidence to support public and private decision making in the area of CCMT. Futhermore, the report states that this tagging scheme is becoming the de facto international standard for clean innovation studies.

This report is based on the same CPC tagging scheme used to examine the European dataset. The scope of this report is limited to patents tagged to the Y02 CPC subclass and Y04S CPC group[xi] which include groups and subgroups presented in the Annex. Due to similarities between children classifications within the Y02E group, this report aggregates certain CPC codes to form more encapsulating categories such as Renewable Energy, Traditional Energy, and Clean Energy Enablers.[xii] It is interesting to note that the EPO has continued its work in expanding the CPC classes tagged to CCMT technologies. We limit our study to the seven categories based on the CPC classification identified in Appendix A and referred to repeatedly throughout this report as:

1. Transport;
2. Renewable Energy;
3. Buildings;
4. Traditional Energy;
5. Clean Energy Enablers;
6. Smart Grids; and,
7. Carbon Capture.

CCMT technologies related to Transport are designed primarily to help reduce CO_2 emissions. Technologies related to electric vehicles are a typical example of CCMT technologies related to Transport. Renewable Energy includes technologies in areas such as hydro energy, wind energy, solar energy and geothermal energy. In Buildings, emission reductions are gained through better lighting, heating, ventilation systems as well as better elevators, escalators and increased thermal performance in general. Traditional Energy includes improvements in fossil-fuel technologies and alternatives such as nuclear energy. Clean Energy Enablers are technologies related to energy conversion or management systems that are also designed to reduce greenhouse gases. Technologies related to batteries are example of technologies that would fall under this category as batteries are considered an alternative to using other types of energies that are more polluting. Smart Grids are related to the imporvement of technologies related to an electrical supply network using digital communication technology. Using communication technologies to optimize electricity usage ultimately empowers consumers to more effictiently control energy use thereby reducing the likelihood of outages.[xiii] Finally, Carbon Capture related technologies are designed to capture waste CO_2 and other greenhouse gases and inject it into deep underground rock formations for permanent storage.[xiv]

The Canadian researcher data used in this report was obtained from Antoine Dechezleprêtre, Associate Professorial Research Fellow at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics, and co-author of the UNEP and EPO report. The analysis focuses on patent applications filed between January 1st, 2008 and December 31st, 2012. The dataset consists of 7,873 high-value invention (HVI) patent applications with at least one Canadian researcher filed over the time span translating into 2,184 HVI patent families. A patent family represents one or more published patents related to the same invention with a shared priority. This report uses the same fractional counting approach as in the UNEP and EPO report for assigning patented inventions to inventors in cases where multiple inventors from various countries jointly filed a patent. Using the fractional counting approach, the 2,184 HVI patent families equates to 608 HVI patent families. This approach uses information on the inventor's country of residence or origin to determine in which country a patented invention has been developed. For example, in the case where a patent is filed by a Canadian, an American, and a Japanese inventor, Canada would be assigned one third of the ownership of the patent, the United States would also retain one third of the ownership, and Japan would retain the final third of the ownership.

In addition to examining CCMT patenting activity by researchers, this report examines the CCMT patent data from the perspective of business inventive activity. The Derwent Innovation database was used to extract patent families that were filed in more than one country and where the basic patent, or the first member of the patent family, was filed between 2008 and 2012. We refer to these patent families as high-value inventions. The dataset consists of 99,935 high-value inventions in CCMT. The Canadian businesses dataset represents approximately 1%, or 1,140 high-value inventions, of the total number of patent families worlwide involved in CCMT. This is approximately half the size of the Canadian researcher dataset. Similar to the researcher data, the business data is limited to patent filed between January 1st, 2008 and December 31st, 2012. An absolute counting approach is used to assess the patented inventions to businesses. The reason for not using the fractional counting approach for the business analysis is because the IP is associated with the company's country of origin based on its headquarter's location.

Time was spent treating the data to ensure that proper country codes were attributed to businesses. This is due to cases of missing address information as reported by the office where the basic patent was applied. Treatment included creating a database of business names from the dataset and attributing a country code to those businesses that were without a country code but that have already appeared somewhere in the dataset with one. In doing so, the percentage of businesses without an address dropped from 5% to less than 1%.

METHODOLOGY

Patent Analytics

The development and adoption of new technologies are required to meet current and future environmental challenges.[xv] Patent data is a good starting point for analysis of the development of new technologies as it provides important information on the specific innovation in the invention and who the inventors and applicant are. Like any data source patent data has its strengths and weaknesses and if used in the wrong way it can lead to erroneous conclusions and poor policy. The following provides context on the use of patents in understanding innovation.

While patents measure the flow of new ideas, it has been argued that patents may not measure innovation for three important reasons: patents do not include non-patented innovations, not all patents result in commercialization, and many patents are strategic in nature.[xvi] For this reason the analysis is based on patent families that include applications in at least two jurisdictions. This makes it more likely that these patent families will be a higher-valued invention and that the firm expects to commercialize the invention.[xvii]

Another challenge presented is that many innovations or inventions remain hidden as trade secrets. These innovations will be missed in a measure that includes only patents. However, a 2008 study indicates that world-first innovators patent more frequently. Conversely, firms that patent infrequently tend to be imitators.[xviii] In addition, the study finds that firms that protect their intellectual property are more likely to increase their profits than those that do not. In addition, SMEs that patent are more likely to be high-growth firms, which is important for success.[xix] These conclusions are reinforced by a Canadian study that noted that firms that are aggressive innovators, introducing radically new products that involve patent protection, have higher profits.[xx] Finally, while some inventions are not patented, patents are obtained for almost all economically significant inventions.[xxi]

Below are the primary ways to view or interpret patent data.

Market Reach: patent filings in foreign markets are a good indicator of firms accessing those markets. Surveys have shown that firms that hold patents are more likely to be exporters[xxii].

Innovative Activity: when we do not account for filings in multiple jurisdictions we are double and triple counting the number of patented inventions or innovative activities. In order to address this patent data allows for the formation of patent families where by each family includes all related or similar patents in all jurisdictions.

Scientific Strength: it is possible to identify the researchers or scientists, rather than the company or applicant. While these can be the same, they are often different. In this way we can see the inventive activity of Canadian researchers working in other countries or for non-Canadian companies.

Relative Advantage: Canada is a small open-economy. For this reason it is unlikely that our industries or innovators would have an absolute advantage in a particular area, be the most prolific IP users or have the largest global market share. However, there are areas where we have a comparative or relative advantage. Much work has been done in the creation of metrics of relative technological advantage and relative specialization.

Patent Families

The analysis of businesses and institutions is based on Derwent Innovation's patent family data. These families are defined as drawing together patents covering the same invention and their relationship is defined by the priority or application details claimed by each document. A patent family can be tagged to multiple classifications. For this reason, it is important to note that when we say patent, we actually mean a patent linked to the specific classification regardless of if it was tagged to another one.

Similar to the EPO report, the patent family data in this report was used to construct statistics for "high-value" inventions. High-value inventions are defined as patent families that are filed in more than one jurisdiction. Although it can be said that patents are not all of high-value, it is rare to find that a successful invention was not patented. This idea along with our methodology for using only patent families filed in more than one jurisdiction justifies our assumption that the patents in our datasets are high-value inventions. Although it is very difficult to quickly identify the value of patents within a large dataset, it is a safe assumption that patents filed in multiple jurisdictions are likely to be of higher value than patents filed in only one jurisdiction. By omitting patents filed in only one jurisdiction from the dataset, it was possible to limit the dataset to high-value inventions.

Revealed Technological Advantage

In order to gain a better understanding of Canada's strengths in CCMT research, we use the Revealed Technological Advantage (RTA) index, which was developed by the OECD and uses patenting intensity to allow for industries to be compared between countries of different sizes on a relative basis. The index is calculated as a correction for the absolute numbers of HVI patent families in order to account for the fact that some countries file more patent applications than others in all fields of technology. In this report the RTA index is used to determine where Canadians have a comparative advantage over competitors. This report compares Canada's RTA index for each CCMT category to that of the G7 countries along with four other countries, China, Korea, Australia and Denmark. China and Korea are included in the comparison because they are two prolific patenting countries. Australia is also included because of its IPO's similarities with the Canadian IPO in terms of size and activity levels. Finally, Denmark is included because of its specialization in the area of CCMT.

The formula used to calculate the RTA is as follows:

- Numerator: the sum of HVI patent families for a category (or subgroup) in Canada divided by the sum of HVI patent families for the category (or subgroup) in the world
- Denominator: the sum of HVI patent families in Canada divided by the sum of HVI patent families in the world

$$\text{RTA} = \left(\sum_{2008}^{2012} X_{\text{CAD, Category}} \,/\, \sum_{2008}^{2012} X_{\text{world, Category}}\right) / \left(\sum_{2008}^{2012} X_{\text{CAD}} \,/\, \sum_{2008}^{2012} X_{\text{World}}\right)$$

Where *X* represents patents.

An RTA greater than one suggests that the economy has a relative specialization in a particular field while an RTA lower than one suggests the opposite. An RTA equal to one is indicative that an economy's share of patents in that particular field equals its share in all fields, and therefore is not specialized.[xxiii]

As mentioned above, the business-related data was extracted from Derwent Innovation with the exception of HVI patent families for Canada and for the world in all technologies used to calculate the RTA. Instead, foreign-oriented patent family data from the World Intellectual Property Office (WIPO) database is used. The reason WIPO data was used is related to limitations in the size of extraction when using Derwent Innovation making it difficult to precisely extract the total number of HVI patent families for Canada and for the world.

CLIMATE CHANGE MITIGATION TECHNOLOGIES

Researchers

According to the World Economic Forum (WEF) *Global Competitiveness Report 2016-2017*, which is primarily survey-based, Canada ranked 6th in the world in availability of scientists and engineers and 17th in quality of scientific research institutions. Meanwhile, the 2016 INSEAD [xxiv] Global Innovation Index, ranked Canada 13th in the world in researchers per population, while its universities placed 4th. [xxv] A study commissioned by Innovation, Science, and Economic Development (ISED) Canada analyzed US patent data to determine the value of having a Canadian inventor on a US patent. Using an innovative citation-based method for patent importance, the study found that the presence of at least one Canadian co-inventor on the patent was associated with a 13% premium in importance over a typical patent. By contrast, the presence of an average patent with at least one foreign inventor was associated with a 5% reduction in importance. This means that the presence of Canadian inventors is over 18% more valuable than a typically foreign co-inventor on US patents. This suggests that Canadian scientists are focused on highly innovative work.

The level of patenting by researchers from around the world and by Canadians between 2008 and 2012 in CCMT is illustrated in figure 1. Despite experiencing a drop in patent filing in 2012, worldwide patenting activity in CCMT grew 29% over the 2008-2012 period. More specifically, worldwide patenting in CCMT increased at an average annual growth rate of 7%. The trend was similar for Canadian patents except for a drop experienced in 2009. Patenting activity by Canadian researchers fell on average by 2% annually, experiencing negative growth of 8% over the five year period. This negative growth is primarily the result of a decrease in patent filings in 2012.

Figure 1: World and Canadian Inventions by Researchers in CCMT (Fractional Count)

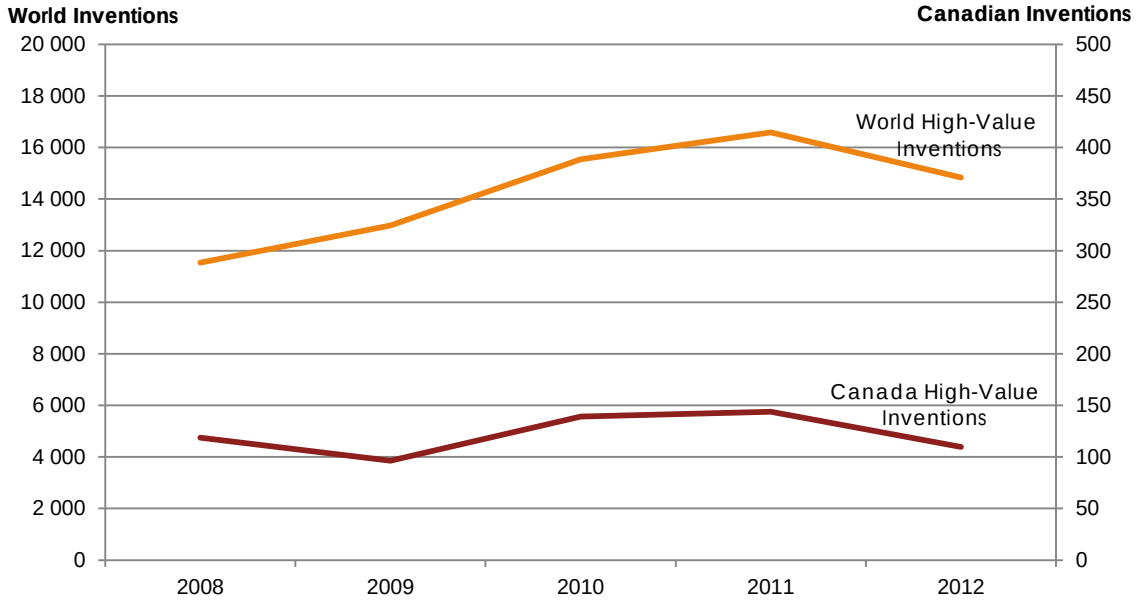
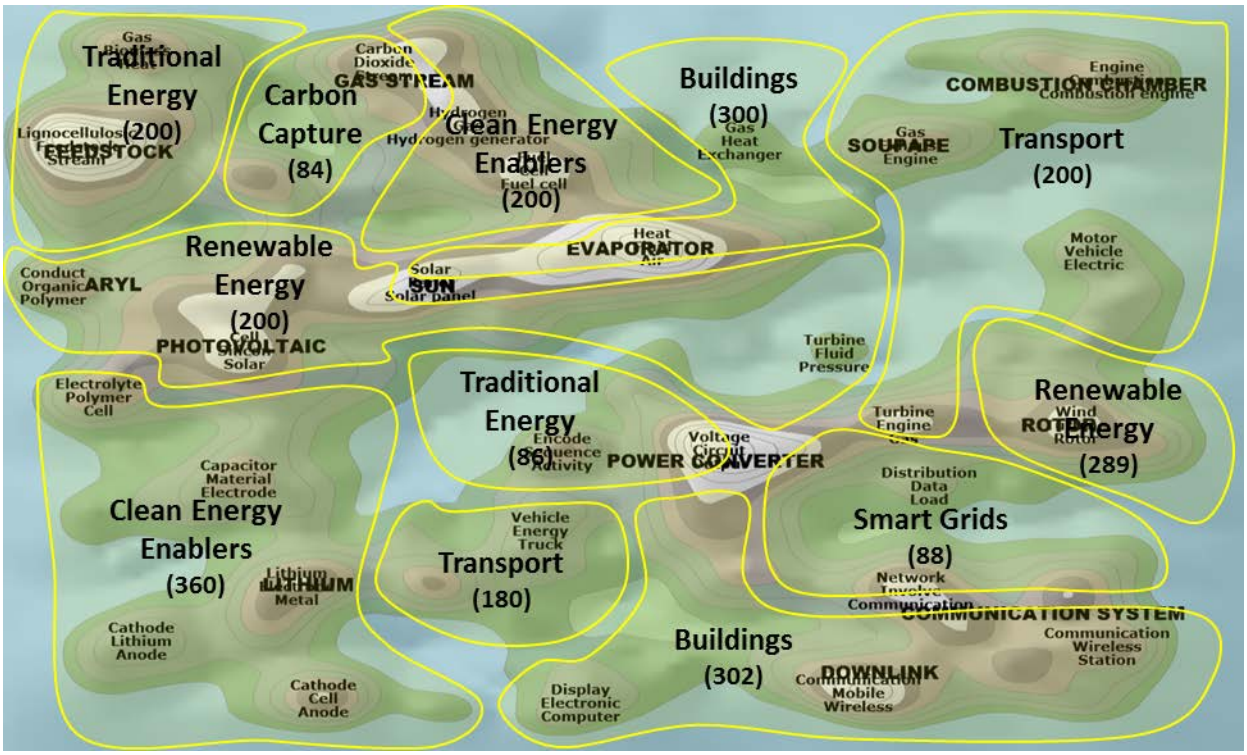


Figure 2 is a patent landscape map that provides a visual representation of the CCMT patent applications filed around the world with at least one Canadian inventor. The map is generated by an algorithm that uses keywords from patent documentation to cluster patents according to shared language. The patents are organized based on common themes and are grouped as 'contours' on the map to identify areas of high and low patenting activity by Canadian researchers. The "snow-capped peaks" represent the highest concentrations of patented inventions, and each peak is labelled with key terms that tie the common themes together. Shorter distances between peaks indicate that the patents they represent share more commonalities relative to those that are further apart. It should be noted that the map presents absolute patented invention counts and does not consider the fact that many other countries excel in the same areas. It should also be noted that calculating the count of patent families in the highlighted areas for each category in the landscape will not equate exactly to the total number of CCMT patent families. The count identified for each category in the highlighted areas is essentially an approximation since patent families for some categories are more scattered than others. Furthermore, calculating the total number of patent families based on the counts identified will also yield a total that is greater than the total number of patent families in the dataset since some patent families are assigned multiple classification codes and therefore double counted.

Figure 2: CCMT Landscape Map of Patent Families Linked to Canadian Researchers



Canadian researchers are active in the areas of Buildings, Clean Energy Enablers, Renewable Energy, Transport and Traditional Energy. To a lesser extent, they are active in Smart Grids and Carbon Capture. As the next sections demonstrate, we may in fact have a relative technological advantage in areas where we patent less.

In order to gain a better understanding of Canadian researchers' strengths in CCMT research, we utilize the Revealed Technological Advantage (RTA) index, described in the Methodology section of this report. First, the RTA indices between Canadian researchers and researchers from other countries are compared to get a better sense of how Canada ranks overall. Then, the indices for Canada are broken down at a more detailed level to focus on the categories in which Canadian researchers are specialized. Figure 3 compares Canada's RTA index for CCMT to that of the G7 countries along with four other leading countries in CCMT, China, Korea, Australia and Denmark. Canada is seen to have a relative advantage over countries such as Japan, China, the United Kingdom, the United States and Australia. Although only a sample of countries is used in the RTA graphs, the numbers are in-line with the results of the World Economic Forum (WEF) Global Competitiveness Report 2016-2017 where Canada ranked 6th in the world in availability of scientists and engineers.

Figure 3: Revealed Technological Advantage (RTA) Index by Origin of Researchers

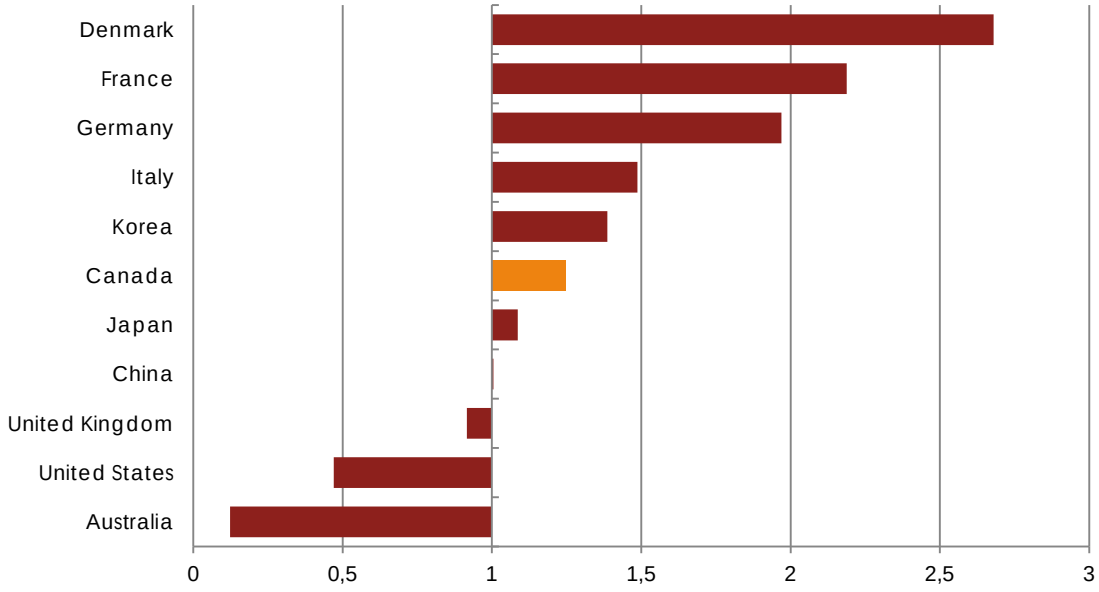
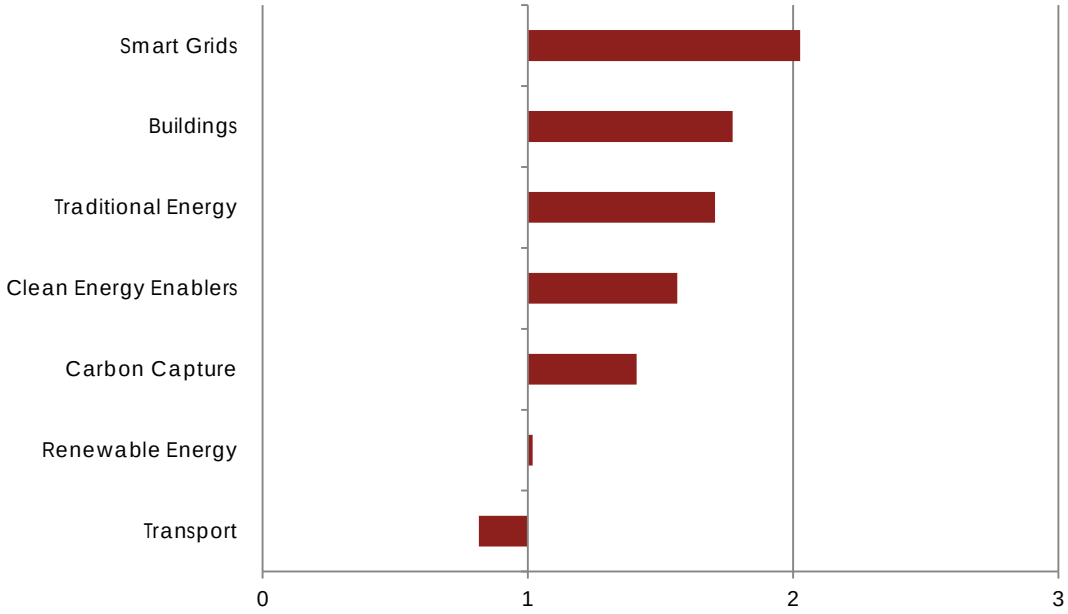


Figure 4 reveals that Canadian researchers are relatively specialized in CCMT technologies that are related to Smart Grids, Buildings, Traditional Energy, Clean Energy Enablers, Carbon Capture and Renewable Energy.

Figure 4: Revealed Technological Advantage (RTA) Index for Canadian Researchers by CCMT Category



The leading Canadian researchers in CCMT, their associated business or institution and their main area of expertise are shown in figure 5 below. As can be seen Canadian researchers are working for companies from around the world.

Figure 5: Top Canadian Researchers

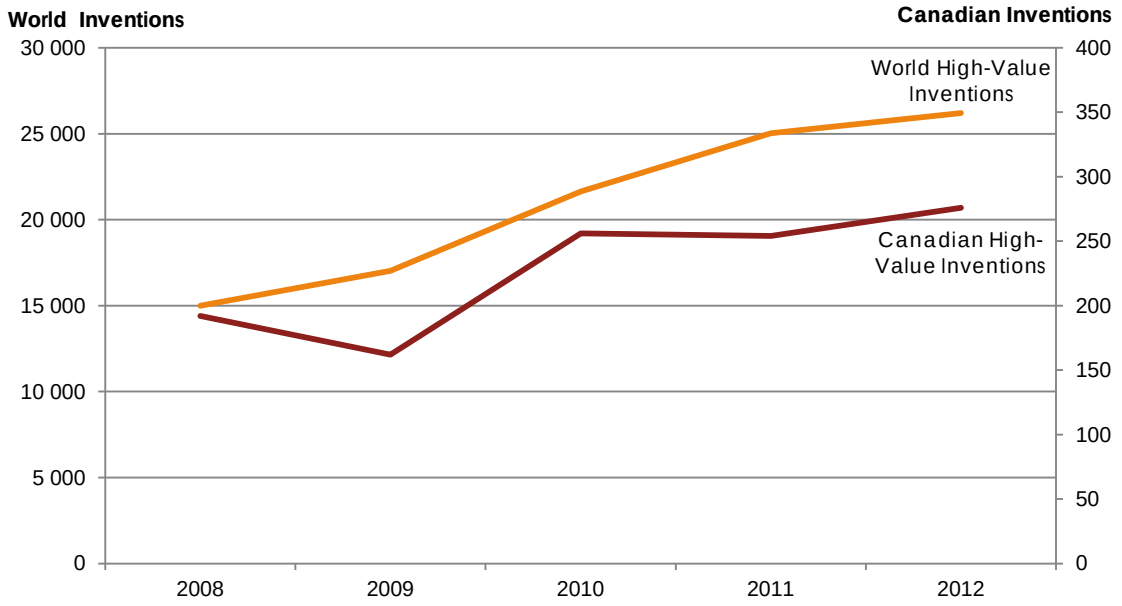
Researchers	Business or Institution	Category
Zaghib, Karim	Hydro-Québec (CA)	Clean Energy Enablers
Rich, David Gerard	BlackBerry Limited (CA)	Clean Energy Enablers
Guerfi, Abdelbast	Hydro-Québec (CA)	Clean Energy Enablers
Burke, Murray	Mascoma Canada Incorporated (CA)	Traditional Energy
Fradette, Sylvie	CO2 Solution Incorporated (CA)	Carbon Capture
Gauthier, Michel	Hydro-Québec (CA)	Clean Energy Enablers
Benech, Régis-Olivier	GreenField Ethanol Incorporated (CA)	Traditional Energy
Benson, Robert A. C.	GreenField Ethanol Incorporated (CA)	Traditional Energy
Sutarwala, Taha Shabbir Husain	BlackBerry Limited (CA)	Clean Energy Enablers
Ashdown, Ian Edward	Koninklijke Philips N.V. (NL)	Buildings
Foody, Brian	Iogen Energy Corporation (CA)	Traditional Energy
McLean, Gerard F.	Société BIC (FR)	Clean Energy Enablers
Schrooten, Jeremy	Société BIC (FR)	Clean Energy Enablers
Veillette, Michel	Trilliant Incorporated (US)	Buildings
Barton, Russell	Intelligent Energy Limited (GB)	Clean Energy Enablers
Donnelly, Frank Wegner	ICR Turbine Engine Corporation (US)	Transport
Michot, Christophe	Hydro-Québec (CA)	Clean Energy Enablers
Morgan, John Paul	Morgan Solar Incorporated (CA)	Renewable Energy
Orr, Raynond Kenneth	Solantro Semiconductor Corporation (CA)	Buildings
Tolan, Jeffrey S.	Iogen Energy Corporation (CA)	Traditional Energy
Wu Chee-Ming, Jimmy	BlackBerry Limited (CA)	Clean Energy Enablers

Businesses and Institutions

In order to gain a better understanding of Canada's business and institutional strengths in patenting in CCMT we analyzed the data from the perspective of the assignee or patent owner. These are most often businesses or institutions. Examining patenting activity from both perspectives, researchers and business, provides a better understanding of the Canadian story. The nature of the patent data gives us the option to perform an inventor type of analysis and an assignee type of analysis. While researchers are more involved in the inventive process, assignees have a more significant impact on the economy of their country of origin.[xxvi] The success gap between Canadian researchers and Canadian businesses is important to asses and could trigger more direct policies towards one or the other. Effectively, although Canadian researchers are world leaders in CCMT, the same cannot be said about Canadian businesses. Comparing the two datasets is useful in showing this gap.

Similar to figure 1 from the previous section, figure 6 compares the level of patenting of high-value CCMT inventions by Canadian businesses with all businesses worldwide between 2008 and 2012. It can be observed that business HVIs in CCMT have been increasing in general. More specifically, HVIs worldwide grew by 75% at an average annual growth rate of 15%. As for Canadian businesses, HVIs experienced 44% growth over the 2008-2012 period, increasing on average 13% annually. The two lines illustrate a deviation in growth starting in 2009 between Canadian and worldwide businesses. A slight decrease in patenting by Canadian businesses is also noticed after 2010. These trends are similar to the trends observed for patenting levels of high-value inventions by Canadian researchers in figure 6 also showing a drop after 2008 and after 2010. The timing of these drops coincides with falling oil prices which could explain the drop in clean-technologies related R&D investments. Clean-technologies are often considered an alternative to energy intensive technologies which become too expensive to use when oil prices are high.

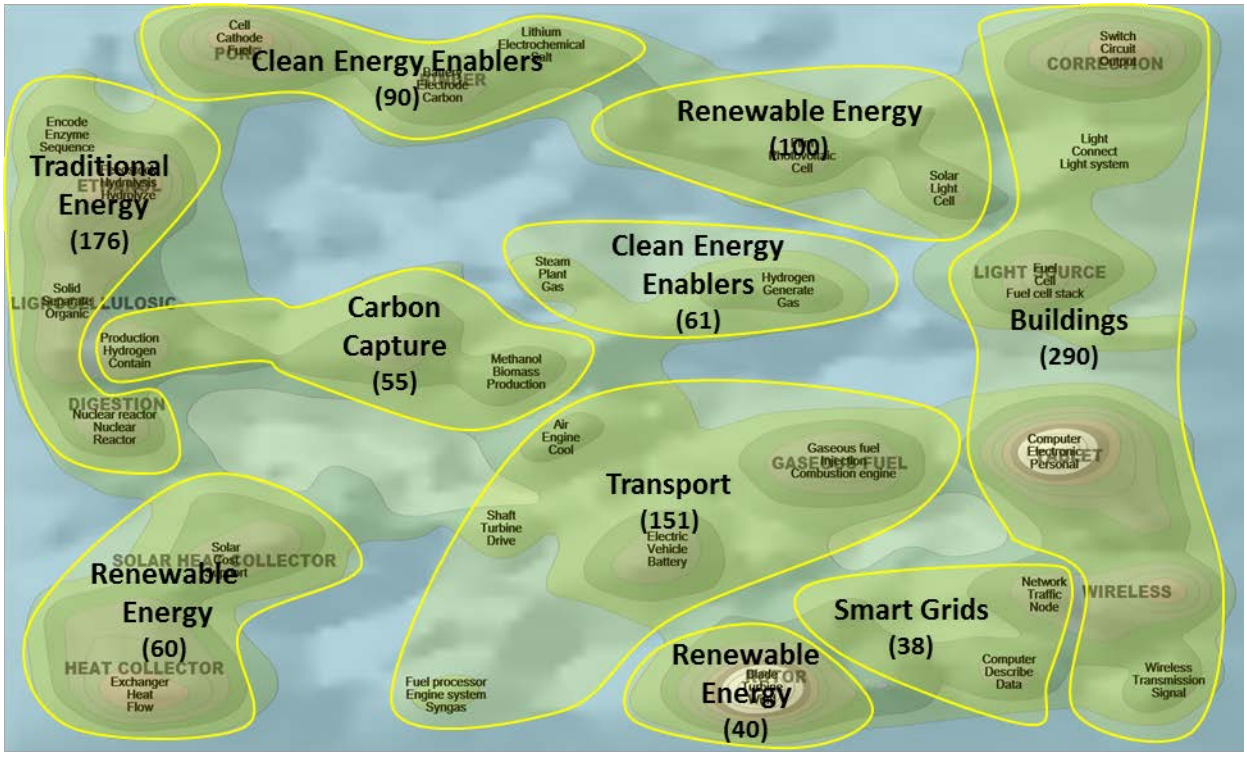
Figure 6: World and Canadian Inventions by Businesses and Institutions in CCMT



Further analysis of Canadian and world high-value inventions shows that CCMT patents represent on average 1.1% of world patents per year. When using foreign-oriented patent family WIPO data for all technologies (i.e. not just CCMT) as a benchmark for comparison, Canadian applicants represented almost 1.9% of worldwide foreign-oriented patent families. This approximate 0.8% difference is indicative of the low level of specialization in CCMT technologies, which is further reflected through the RTA indices.

The "snow-capped peaks" observed in figure 7 represent the highest concentrations of patents within the patent landscape of Canadian businesses. One of the peaks observed associated with Buildings has "Computer", "Electronic" and "Personal" as keywords. This can be associated with Blackberry which patents CCMT inventions mainly in Buildings. Blackberry is a business specialized in wireless telecommunications software and mobile hardware. The proximity between Buildings and Renewable Energy patents in the upper right-hand side of the map can be explained by keywords related to light systems. This is in-line with the need to increase the efficiency of lighting to reduce GHG emissions across the Built Environment, identified as an opportunity in the Specific Mitigation Opportunities Working Group report.[xxvii] In the lower right-hand side, the proximity between Buildings, Transport and Smart Grids can be explained by keyword related to information and communication technologies and electric vehicles. In the Specific Mitigation Opportunities Working Group report, it is mentioned that Canada's electricity grid can incorporate additional clean energy capacity to respond to growth in demand from increased electrification in transportation, industry and buildings.[xxviii]

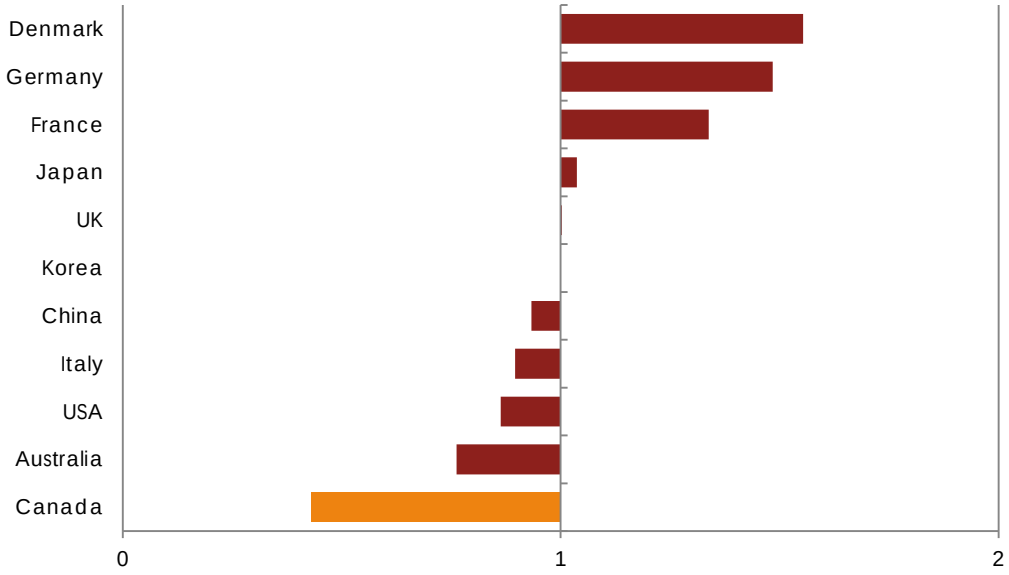
Figure 7: Landscape Map of Patent Families Linked to Canadian Businesses and Institutions



Comparing the Revealed Technological Advantage (RTA) indices and the associated patent volumes for researchers and businesses provides a good sense of the considerable differences between the two in terms of success. While Canadian researchers have contributed to the success of Canadian firms, international firms have also been successful at attracting Canadian talent which limits Canadian firms' ability to benefit from the expertise generated domestically. Not only does this allow international firms to have an edge over Canadian businesses as they compete for resources but it limits their contribution to improving the Canadian economy.[xxix]

Comparing international business RTA indices with the Canadian RTA subset can give us a better picture of where Canada ranks overall. Figure 8 compares Canada's RTA index for CCMT to that of the G7 countries along with four other leading countries in CCMT, China, Korea, Australia and Denmark. For CCMT as a whole, the RTA for Canadian businesses ranks below all of the comparator countries. This is in stark contrast to the ranking for Canadian researchers in figure 3.

Figure 8: Revealed Technological Advantage (RTA) Index by Origin of Businesses or Institutions



This next section compares the RTA indices for each of the seven CCMT categories for Canadian businesses. Figure 9 reveals that the only CCMT category where Canadian businesses have a relative specialization in is Carbon Capture. This is different than the case for Canadian researchers who were relatively specialized in all of the CCMT categories except for Transport.

Figure 9: Revealed Technological Advantage (RTA) Index for Canadian Businesses and Institutions by CCMT Category

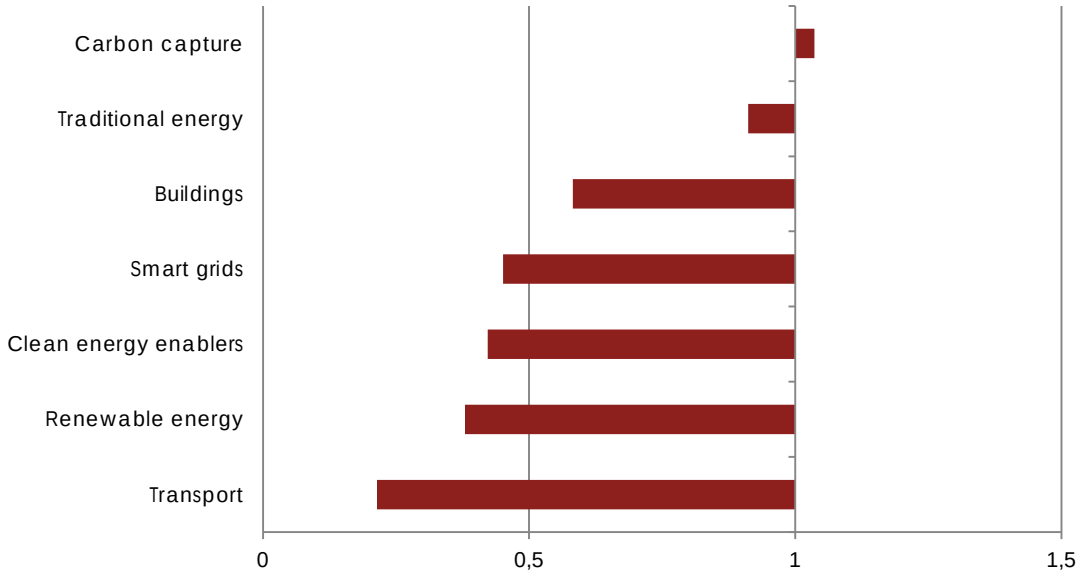


Figure 10 shows the top patenting businesses and institutions in the area of CCMT. The Transport and Renewable Energy categories stand out as the main technologies for which the top businesses worldwide are actively patenting. Interestingly, the transport category is also an area where the leading Canadian patenting businesses are especially active.

Figure 10: Top Worldwide Businesses and Institutions

Business or Institution	Category
Samsung Electronics Limited (KR)	Clean Energy Enablers
General Electric Company (US)	Renewable Energy
GM Global Technology Operations Incorporated (US)	Transport
Robert Bosch GmbH (DE)	Transport
Panasonic Corporation (JP)	Clean Energy Enablers
Mitsubishi Electric Corporation (JP)	Renewable Energy
Siemens AG (DE)	Renewable Energy
Hitachi Limited (JP)	Transport
LG Electronics Incorporated (KR)	Buildings
Honda Motors Company Limited (JP)	Transport
Sanyo Electronic Company Limited (JP)	Renewable Energy
Mitsubishi Electric Corporation (JP)	Renewable Energy
Denso Corporation (JP)	Transport
Sumitomo Corporation (JP)	Clean Energy Enablers
Ford Motor Company (US)	Transport
Airbus Group SE (NL)	Transport
Hyundai Motor Company (KR)	Transport
Toyota Motor Corporation (JP)	Transport
Toshiba Corporation (US)	Buildings
Nissan Motor Company Limited (JP)	Transport
Sony Corporation (JP)	Clean Energy Enablers
Vestas Wind Systems A/S (DK)	Renewable Energy
Sharp Corporation (JP)	Renewable Energy
Qualcomm Incorporated (US)	Buildings
Daimler AG (DE)	Transport

Figure 11 lists the top patenting Canadian businesses and institutions in the area of CCMT. Six of the top Canadian businesses or institutions patent heavily in the area of Transport. Blackberry is the highest ranked Canadian business with inventions primarily in the Buildings category. Iogen Energy Corporation and Atomic Energy of Canada Limited are specialized in Traditional Energy. Clean Energy Enablers is another CCMT category that is well represented by the leading Canadian businesses. Interestingly, many of the leading patenting entities in this category include government and university institutions.

Figure 11: Top Canadian Businesses and Institutions

Business or Institution	Category
Blackberry Limited (CA)	Buildings
Bombardier Incorporated (CA)	Transports
Magna International Incorporated (CA)	Transports
Pratt & Whitney Canada Corporation (CA)	Transports
Westport Power Incorporated (CA)	Transports
Iogen Energy Corporation (CA)	Traditional Energy
National Research Council Of Canada (CA)	Clean Energy Enablers
Angstrom Power Incorporated (CA)	Clean Energy Enablers
Atomic Energy of Canada Limited (CA)	Traditional Energy
Dana Canada Corporation (CA)	Transports
Greenfield Ethanol Incorporated (CA)	Traditional Energy
University of Alberta (CA)	Clean Energy Enablers
University of British Columbia (CA)	Clean Energy Enablers
Morgan Solar Incoporated (CA)	Renewable Energy
W&E International Corporation (CA)	Buildings
Natural Resources Canada (CA)	Traditional Energy
Hydro-Québec (CA)	Clean Energy Enablers
ATI Technologies Incorporated (CA)	Buildings
BDF IP Holdings Limited (CA)	Clean Energy Enablers
NxtGen Emission Controls Incorporated (CA)	Transport
Queen's University (CA)	Buildings
CO2 Solutions Incorporated (CA)	Carbon Capture
OrganoWorld Incoporated (CA)	Renewable Energy
SunOpta Bioprocess Incorporated (CA)	Traditional Energy
University of Western Ontario (CA)	Renewable Energy

The following sections dive deeper into the seven CCMT categories, specifically: Transport, Renewable Energy, Buildings, Clean Energy Enablers, Traditional Energy, Smart Grids and Carbon Capture. Each section looks at patenting from the perspective of Canadian researchers and Canadian businesses and institutions. Within each section the report drills down another level to provide a detailed analysis of areas where Canadian researchers, businesses and institutions are active and may have a relative technological advantage.

Comparing Canadian Researcher and Business Revealed Technological *Advantages*

Figure 12 presents the revealed technological advantage for Canadian researchers and for Canadian businesses and institutions. The comparison reveals that there are only five technology areas where both Canadian researchers and Canadian businesses and institutions have a revealed technological advantage. These are: Fuel of Non-fossil Origin, Hydro Energy, Nuclear Energy, Carbon Capture and Enabling Building Technologies. Appendices B and C provide a graphical representation.

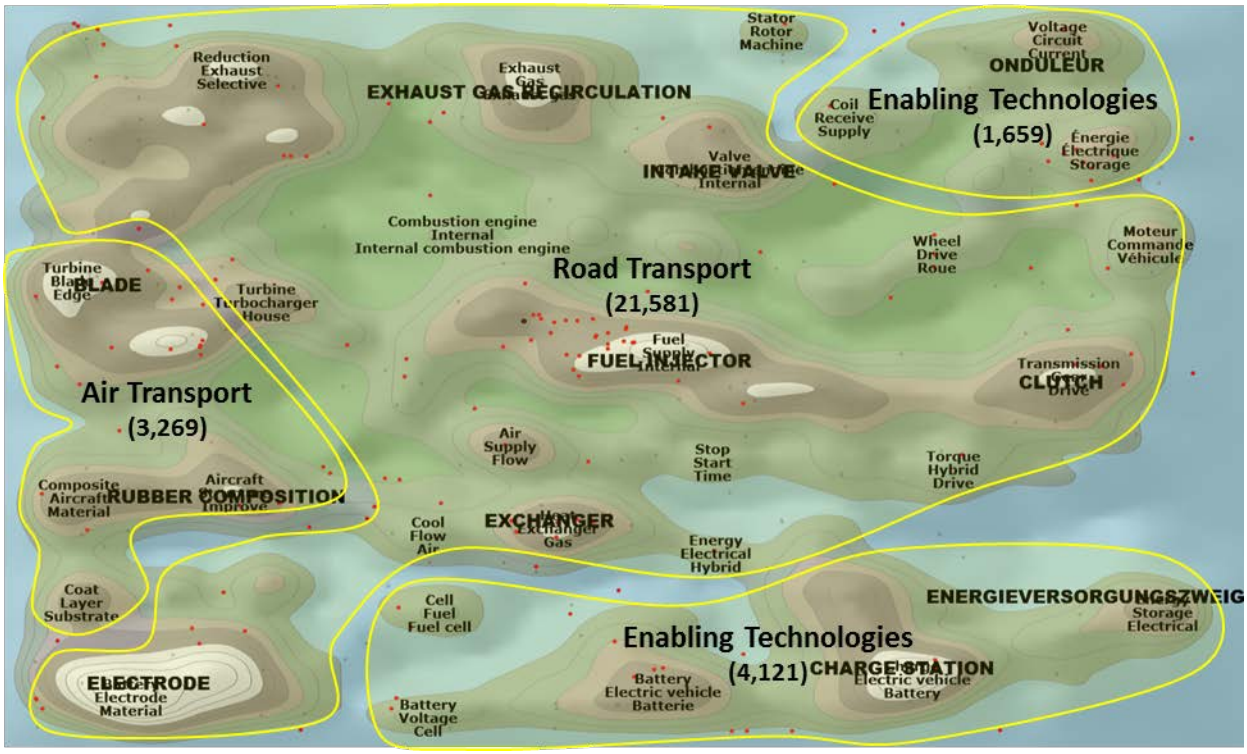
Figure 12: Comparing Revealed Technological Advantages (RTA)

Categories and Subgroups	Researcher RTA	Business RTA
Fuel of Non-fossil Origin	2.0	1.2
Hydro Energy	2.5	1.1
Nuclear Energy	2.8	1.0
Carbon Capture	1.4	1.0
Enabling Building Technologies	4.4	1.0
Traditional Energy	1.7	0.9
Geothermal Energy	6.2	0.9
Maritime Transport	2.0	0.8
Thermal-PV Hybrids	0.7	0.8
Renewable Energy in Buildings	2.2	0.7
Building Thermal Performance	3.2	0.7
ICT Reducing Energy Use	2.0	0.7
Solar Thermal Energy	1.8	0.6
Combustion Technologies	0.9	0.6
Buildings	1.8	0.6
Rail Transport	3.6	0.5
HVAC Efficiency	1.2	0.5
Energy from Sea	3.3	0.5
Energy Efficient Lighting	1.6	0.5
Smart Grids	2.0	0.5
Clean Energy Enablers	1.6	0.4
Renewable Energy	1.0	0.4
Electric Power Management in Buildings	1.1	0.4
Wind Energy	0.9	0.3
Air Transport	1.8	0.3
Home Appliance Efficiency	1.0	0.3
Photovoltaic Energy	0.5	0.3
Transport	0.8	0.2
Road Transport	0.6	0.2
Enabling Transport Technologies	0.7	0.1
Electrical Power Efficiency	1.0	0.1

TRANSPORT

CCMT technologies related to Transport are designed primarily to help reduce CO_2 emissions. Technologies related to electric vehicles are a typical example of CCMT technologies related to Transport. More specifically, the Transport category includes technologies related to all modes of transportation including railways, air, marine and road transport. Most of the patenting activity is occurring in the Air Transport, Road Transport and Enabling Technologies subgroups illustrated in the worldwide Transport patent landscape in figure 13. Inventions related to Rail Transport and Marine Transport are not illustrated since they are not concentrated in specific areas on the map. The landscape map includes more than 27,000 inventions of which patenting activity related to Road Transport accounts for the majority of the activity. The landscape map shows several snow-capped peaks representing the highest concentrations of patents. The entire lower right-hand quadrant primarily captures inventions related to vehicle electrification and is isolated from the rest of the Transport patent landscape. There are two peaks directly next to each other described by keywords linked to battery charging, clearly an area that has generated a significant amount of patenting activity. Areas outside of the vehicle electrification island that have generated a significant amount of patenting activity include combustion control systems and vehicle transmissions, as per the peaks with keywords such as "reduction", "exhaust", "selective", "gas", "transmission", "clutch" and "drive". It is interesting to see that patents related to Canadian businesses, represented by red dots, are mostly concentrated near the snow-capped peak described by the keywords "fuel", "supply" and "internal", an indication that they are somewhat specialized in a technology area related to fuel systems and combustion engines.

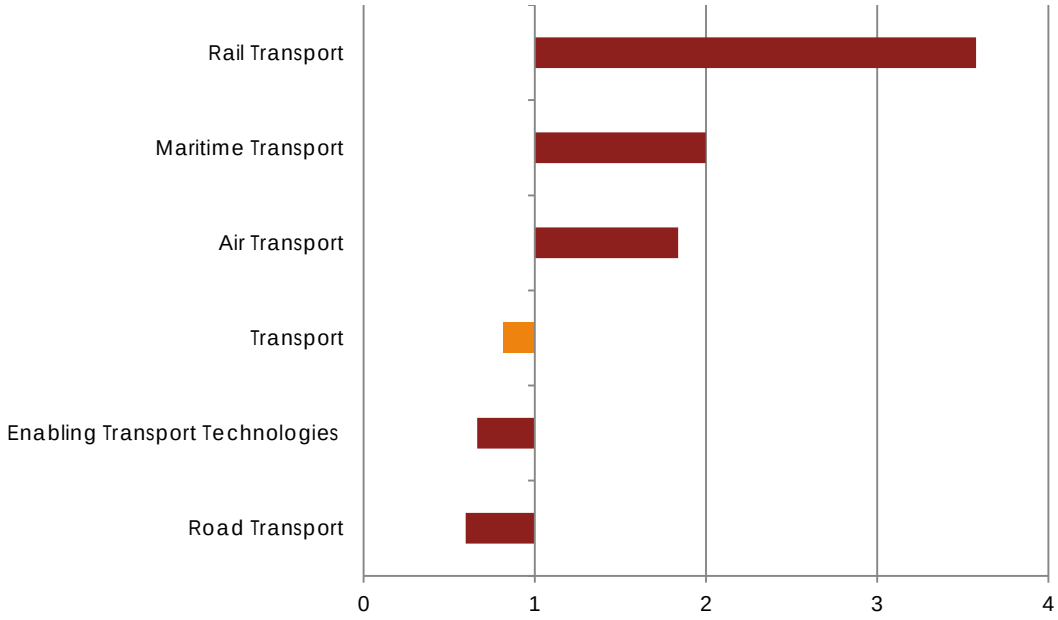
Figure 13: Landscape Map of Worldwide Patenting Activities in Transport



Researchers

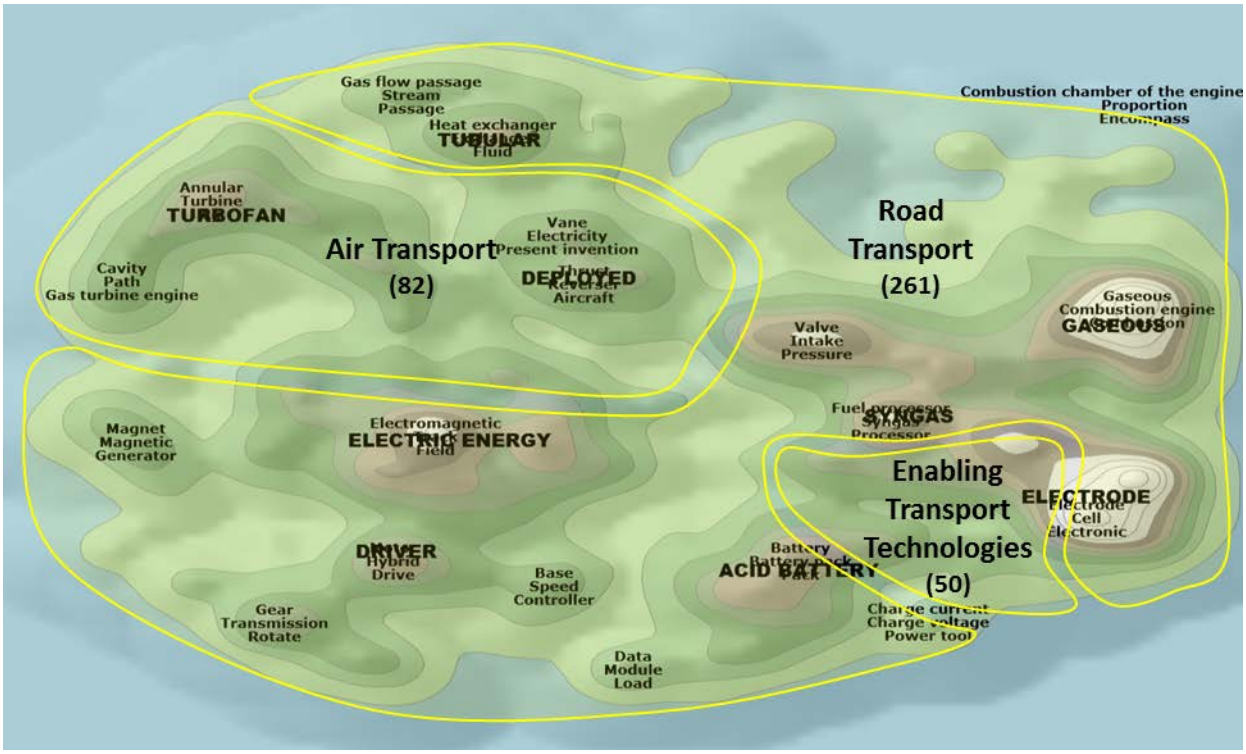
The level of specialization of Canadian researchers in each Transport subgroup is illustrated in figure 14. Despite not having an overall specialization in Transport, some subgroups have an index value above one. Canadian researchers have a relative advantage in technologies related to the transportation of goods or passengers via Railways, Maritime or Waterways Transport, and Air Transport.

Figure 14: Revealed Technological Advantage (RTA) Index for Canadian Researchers in Transport



The landscape map in figure 15 consists of inventions by Canadian researchers and only shows the divide between the Air Transport, Road Transport and Enabling Transport Technologies subgroups of the Transport category where Canadian researchers are primarily active. The other subgroups are not illustrated as they represent a low percentage of inventions in this category. Air Transport is a subgroup in which Canadian researchers are active and in which they specialize.

Figure 15: Transport Landscape Map of Patent Families Linked to Canadian Researchers



Canadian businesses associated with Canadian researchers holding the largest numbers of high-value inventions in the Transport category are listed in figure 16. Most of the companies are Canadian. Pratt & Whitney Canada and Westport Power are associated with multiple top researchers. The next section will demonstrate that these two Canadian businesses associated with top Canadian researchers are also among the top Canadian businesses.

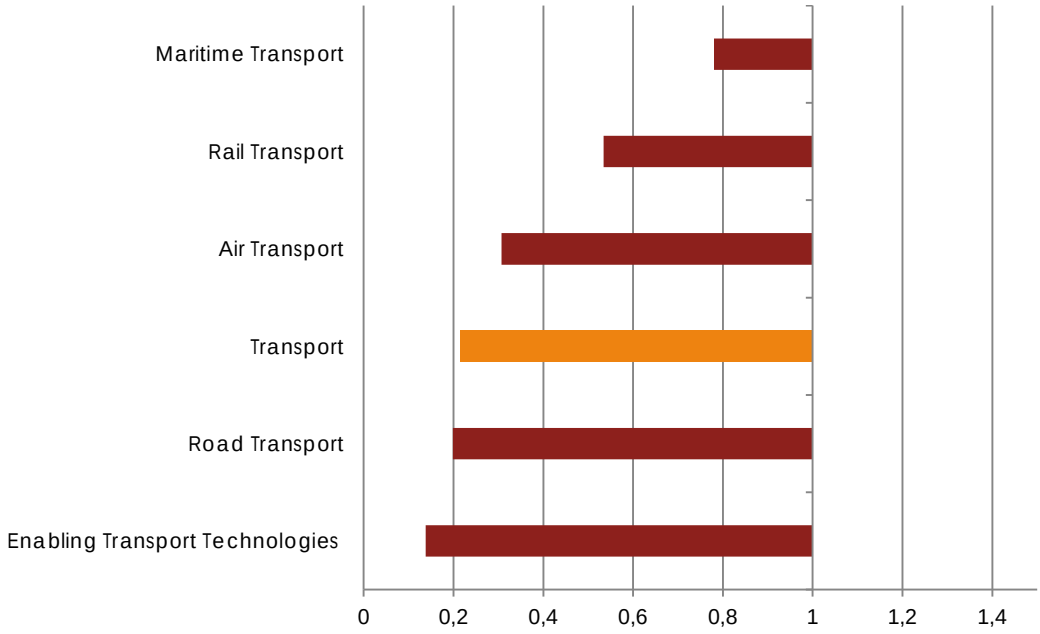
Figure 16: Top Canadian Researchers in Transport

Top Canadian Researchers	Associated Business or Institution
Donnelly, Frank Wegner	ICR Turbine Engine Corporation (US)
Alecu, Daniel	Pratt & Whitney Canada Corporation (CA)
Neels, Jacobus	Westport Power Incorporated (CA)
Eleftheriou, Andreas	Pratt & Whitney Canada Corporation (CA)
Barnett, Barry	Pratt & Whitney Canada Corporation (CA)
Lebastard, Olivier	Westport Power Incorporated (CA)
Batenburg, Greg	Westport Power Incorporated (CA)
Mumford, David	Westport Power Incorporated (CA)
Liu, Xiaoliu	Pratt & Whitney Canada Corporation (CA)
Macchia, Enzo	Pratt & Whitney Canada Corporation (CA)
Dooley, Kevin Allan	Pratt & Whitney Canada Corporation (CA)
Li, Xuantian	Westport Power Incorporated (CA)
McTaggart-Cowan, Gordon	Westport Power Incorporated (CA)
Balsdon, David William	Continental Automotive Systems Incorporated (US)

Businesses and Institutions

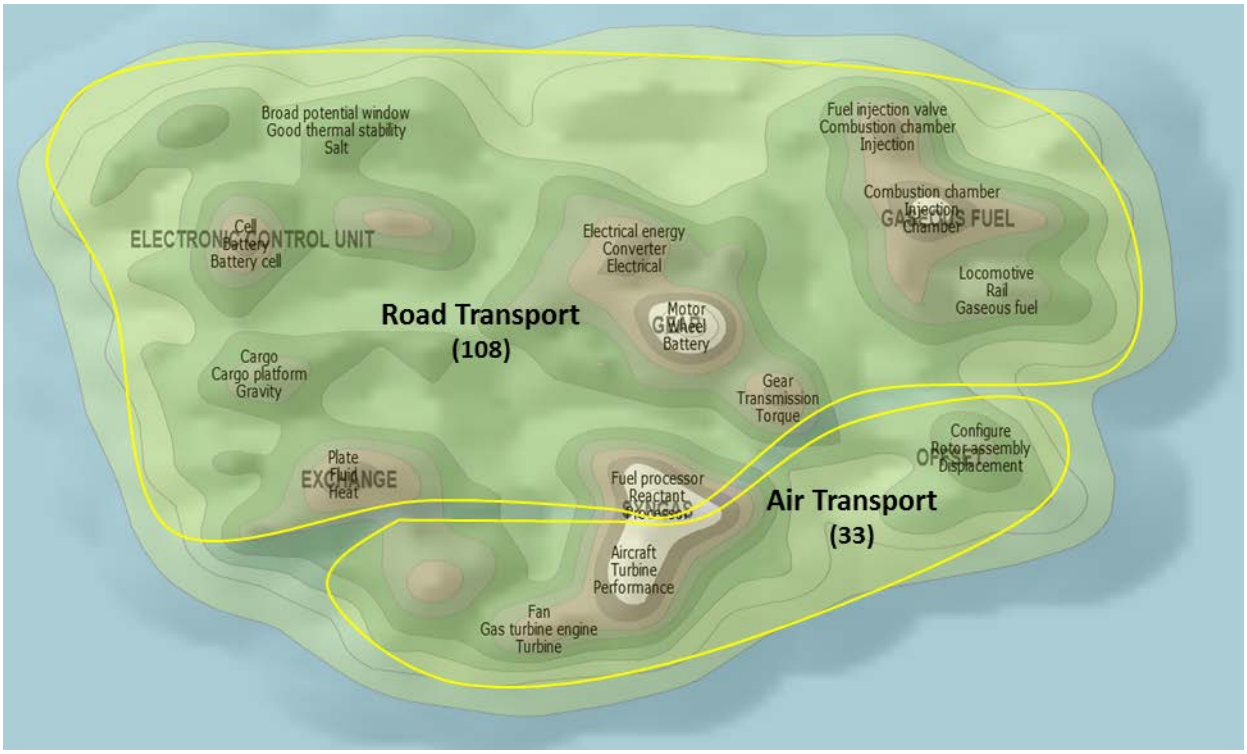
The RTA index in Transport and its related subgroups for Canadian businesses this time is illustrated in figure 17. Canadian businesses are not specialized in any of the Transport related technology areas.

Figure 17: Revealed Technological Advantage (RTA) Index for Canadian Businesses in Transport



The landscape map in figure 18 illustrates the inventions by Canadian businesses. The landscape map only includes the Air and Road Transport subgroups because they represent most of the inventions in this category. Similar to the worldwide landscape map in figure 13, Road Transport is the main subgroup where businesses are active. The other subgroups are not illustrated in this map as they represent a low percentage of inventions in this category. The common keywords in both landscape maps associated with snow-capped peaks are related to fuel and gas whereas the keywords for the Air Transport technologies are related to turbines. The snow-capped peak shared by the previously mentioned subgroups is linked to keywords such as "fuel processor", "reactant", "processor", "aircraft", "turbine" and "performance". Pratt & Whitney Canada, Bombardier and NxtGen Emission Controls all have inventions around this peak. The patents in this technology area are likely related to emission reduction systems and methods of operating fuel processors. In the Road Transport subgroup on the map, a snow-capped peak related to keywords such as "motor", "wheel" and "battery" can be seen. Patents in this peak are related to electric and hybrid vehicles.

Figure 18: Transport Landscape Map of Patent Families Linked to Canadian Businesses



The top 10 Canadian businesses or institutions patenting Transport related inventions are identified in figure 19. Pratt & Whitney Canada Corporation and Westport Power Incorporated are both associated with multiple top Canadian researchers identified in figure 16. With respect to inventive activity, Hydro-Québec, for example, has patents related to electric vehicle recharging systems. Dana Canada, a vehicle industry company, specializes in heat exchanger systems.

Figure 19: Top Canadian Businesses or Institutions in Transport

Business or Institution
Bombardier Incorporated (CA)
Magna International Incorporated (CA)
Pratt & Whitney Canada Corporation (CA)
Westport Power Incorporated (CA)
Dana Canada Corporation (CA)
NxtGen Emission Controls Incorporated (CA)
Hydro-Québec (CA)
Bathium Canada Incorporated (CA)
Université Laval (CA)
Advanced Lithium Power Incorporated (CA)

The top worldwide businesses or institutions patenting Transport related inventions are identified in figure 20. Most of the companies listed are car manufacturers. For example, GM, Honda, Ford, Hyundai and Nissan figure in the table. The companies are mostly American and Japanese. Some European companies are also among the list of top companies.

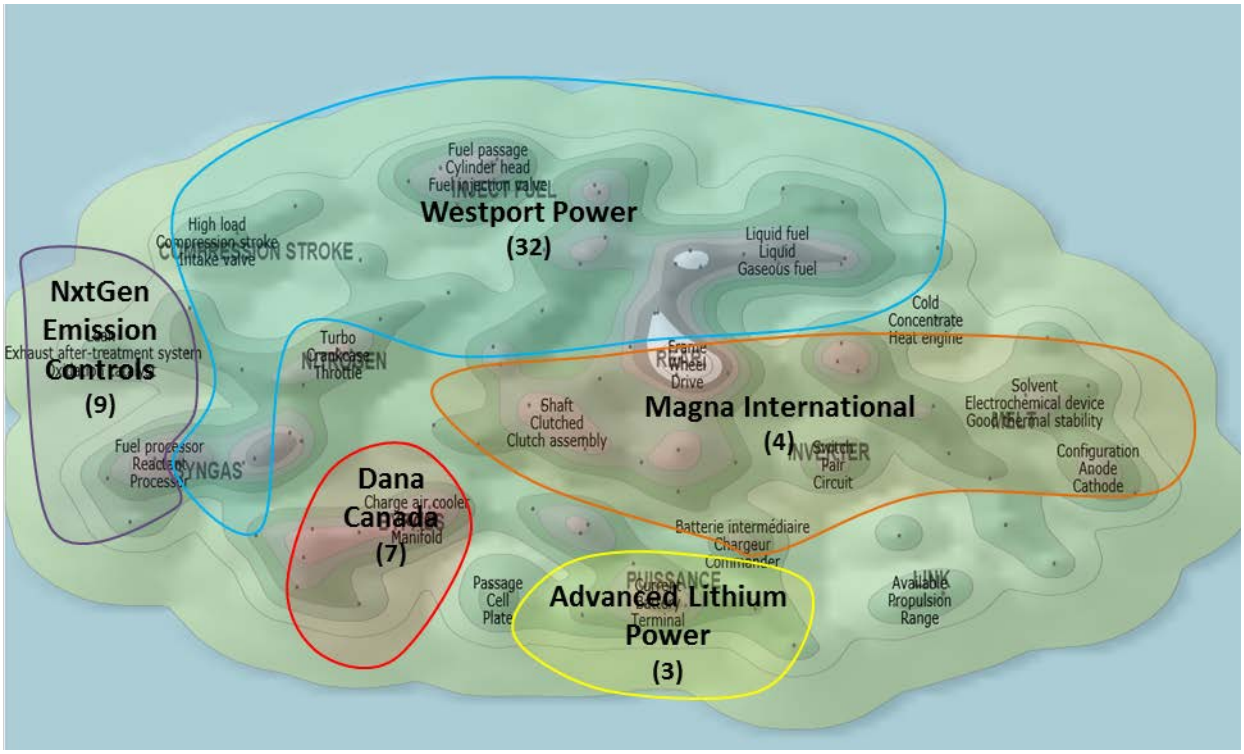
Figure 20: Top Worldwide Businesses or Institutions in Transport

Business or Institution
GM Global Technology Operations Incorporated (US)
Robert Bosch GmbH (DE)
Honda Motors Company Limited (JP)
Ford Motor Company (US)
Denso Corporation(JP)
Airbus Group SE (NL)
Hitachi Limited (JP)
General Electric Company (US)
Hyundai Motor Company (KR)
Nissan Motor Company Limited (JP)

Road Transport

Road Transport is a subgroup in which Canadian researchers are specialized. It is also the Transport subgroup that accounts for most of the patenting activity worldwide and domestically. As seen in the patent landscape map in figure 21 which highlights the inventions by Canadian businesses, Westport Power is a Canadian top player in Road Transport. The patents around the snow-capped peak with keywords such as "wheel" and "drive" where Westport Power is active relate to fuel injectors and calibration. Advanced Lithium Power specializes in battery management systems and NxtGen Emission Controls specializes in fuel processors reducing carbon emissions.

Figure 21: Landscape Map of Canadian Businesses with Road Transport Inventions



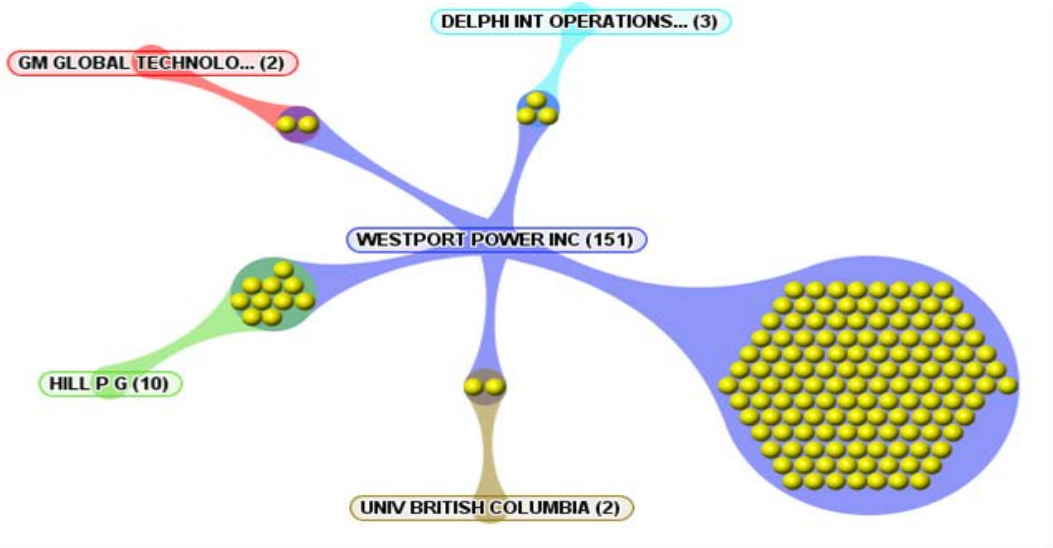
Westport Innovations Inc. – A University Spin-off Success Story[xxx]

Westport Innovations Inc., a spin-off company from the University of British Columbia (UBC), is ranked among the top Canadian patenting businesses in the Transport technology area. The company was established in 1994 following a licensing agreement with UBC's University Industry Liaison Office (UILO). The research underlying Westport's technology dates back to Dr. Philip G. Hill's research around High Pressure Direct Injection conducted at UBC in 1982.[xxxi] David Demers, an investor in Dr. Hill's research, founded Westport Research and entered into an exclusive worldwide licensing agreement with UBC. The company leveraged programs and partners such as: National Research Council (NRC) of Canada's Industrial Research Assistance Program (IRAP), Sustainable Development Technology Canada (STDC), the Science Council of British Columbia and the California Air Resource Board.

Westport purchased the technology developed by Dr. Hill from the UILO in 1998. Westport's growth accelerated after targeting international markets for its High Pressure Direct Injection technology. Westport targeted trucking and bus companies to use their technology on commercial vehicles. Part of the company's expansion strategy included forming joint ventures with large diesel engine manufacturers and strategic alliances with players along the value chain such as General Motors and Delphi International.[xxxii]

Westport is a perfect example of a Canadian company leveraging its intellectual property and UBC's Technology Transfer Office's services to spin-off, establish itself and continue to grow. It did so by leveraging government funding and seeking private investment to become a global player. In 2016, Westport merged with Fuel Systems Solutions Inc. to form Westport Fuel Systems Inc., a global company for the engineering, manufacturing and supply of alternative fuel systems and components.[xxxiii]

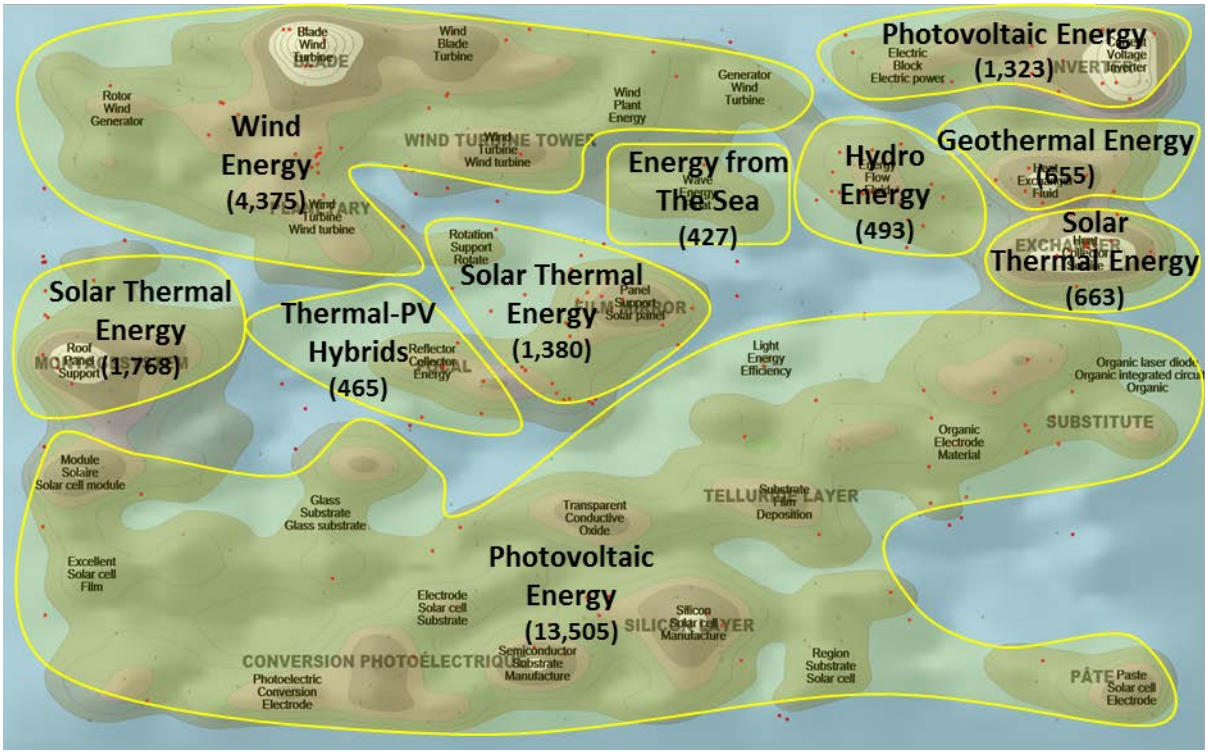
Figure 22: Collaboration Map for Westport Innovations



RENEWABLE ENERGY

The Renewable Energy category includes Hydro Energy, Wind Energy, Solar Thermal Energy, Photovoltaic (PV) Energy, Thermal-PV Hybrids, Energy from the Sea and Geothermal Energy. These subgroups are all alternatives to energy used with fossil fuels partly responsible for CO_2 and other greenhouse gases emissions. These subgroups are illustrated in figure 23 depicting the worldwide patent landscape of more than 20,000 inventions in the Renewable Energy category. It is apparent that patenting activity related to Wind Energy and Photovoltaic Energy account for the bulk of the activity. Solar Thermal Energy is another technology area with a large number of patents but not to the same extent as the previously mentioned areas. It is interesting to see that patents related to Canadian businesses, represented by red dots, are concentrated in areas near peaks where significant patenting is occurring. This is indicative of the level of involvement in more competitive CCMT subgroups. The landscape map shows several snow-capped peaks representing the highest concentrations of patents. In the upper left-hand quadrant of the map where Wind Energy related inventions are situated, there is a snow-capped peak with keywords such as "blade", "wind" and "turbine". Inventions in this space are related to methods and apparatus for mounting wind turbine blades, providing more power from wind turbine and rotor blade arrangements. Another snow-capped peak in the right-hand quadrant of the map in the Solar Thermal Energy area includes keywords such as "heat", "collector" and "solar" and is related to thermal solar systems for heating buildings, solar collectors and more.

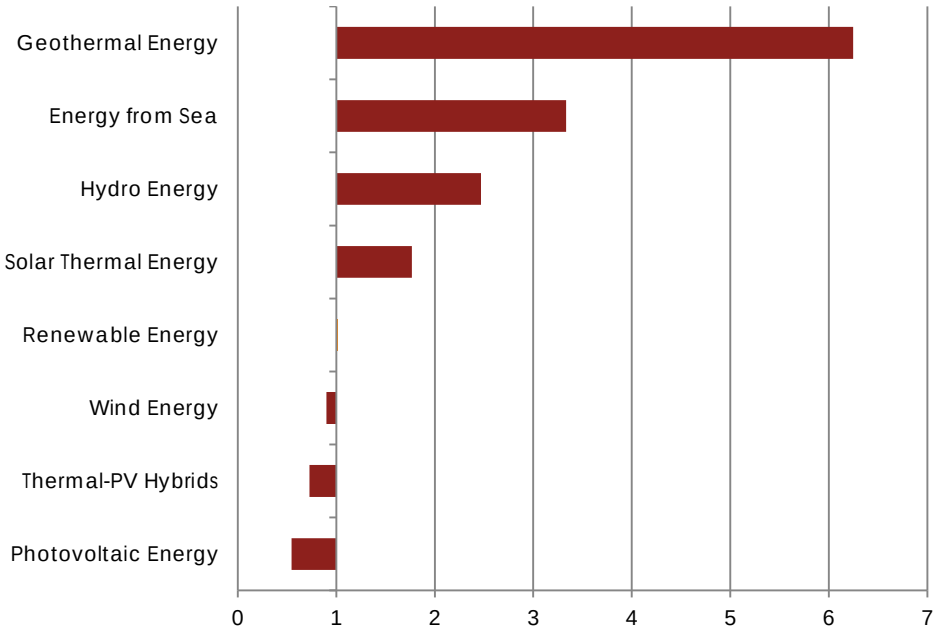
Figure 23: Landscape Map of Worldwide Patenting Activities in Renewable Energy



Researchers

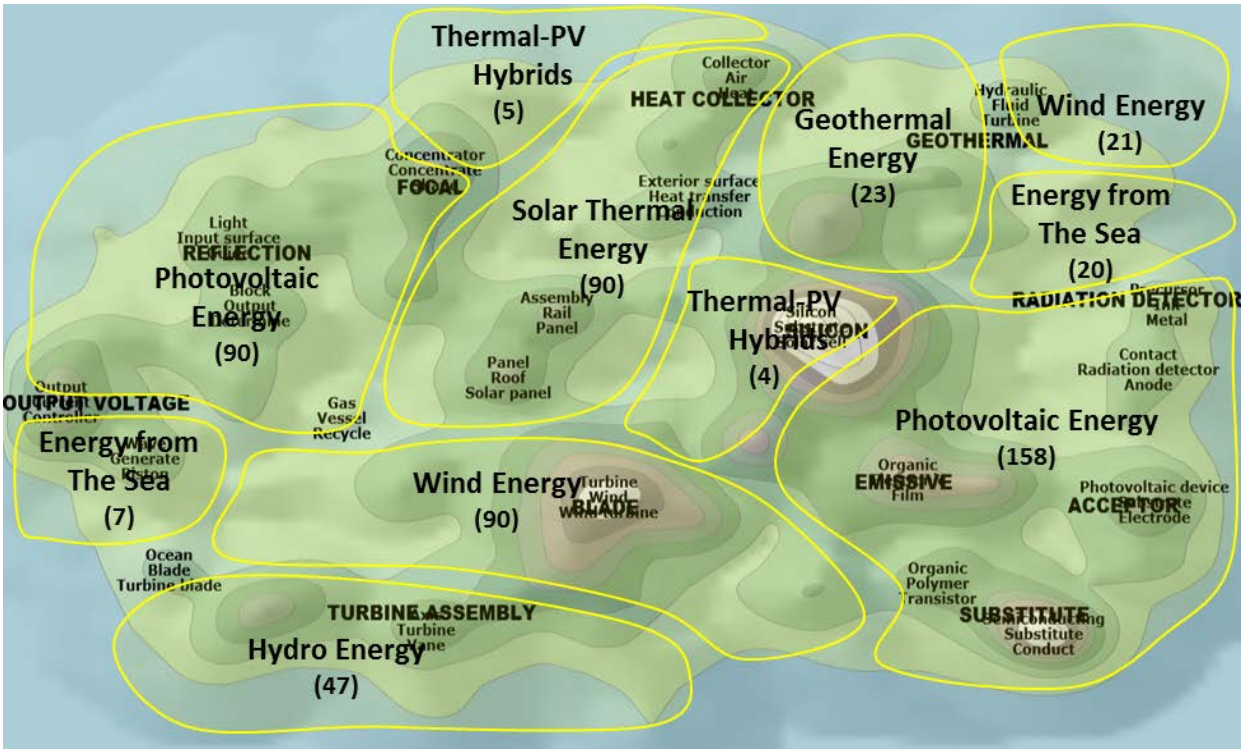
The Revealed Technological Advantage (RTA) index shows that Canadian researchers have contributed to technological advancements in Renewable Energy as the overall RTA index presented in figure 24 is slightly greater than one; an indication that a specialization exists. It can be seen that Geothermal Energy, Energy from the Sea, Hydro Energy and Solar Thermal Energy are subgroups where Canadian researchers have a relative specialization.

Figure 24: Revealed Technological Advantage (RTA) Index for Canadian Researchers in Renewable Energy



The landscape map in figure 25, which illustrates the inventions by Canadian researchers, highlights the Renewable Energy subgroups. Patenting activity by Canadian researchers related to Photovoltaic Energy and Wind Energy account for the bulk of the activity. This is similar to what was found in the worldwide landscape map in figure 23. Snow-capped peaks are found in the areas of Wind Energy, Photovoltaic Energy and Thermal-PV Hybrids. The snow-capped peak in Wind Energy has keywords such as "turbine" and "wind" related to wind generator which is similar to the peak found in the worldwide landscape map in figure 23 related to keywords such as "blade", "wind" and "turbine" also related to wind generators.

Figure 25: Renewable Energy Landscape Map of Patent Families Linked to Canadian Researchers



The leading Canadian businesses associated with Canadian researchers holding the largest numbers of high-value inventions in the Renewable Energy category are listed in figure 26. It can be seen that most of the businesses associated with a Canadian researcher are Canadian and American. In the next section, we will see that some of the Canadian businesses or institutions associated with a top Canadian researcher are also among the top Canadian businesses.

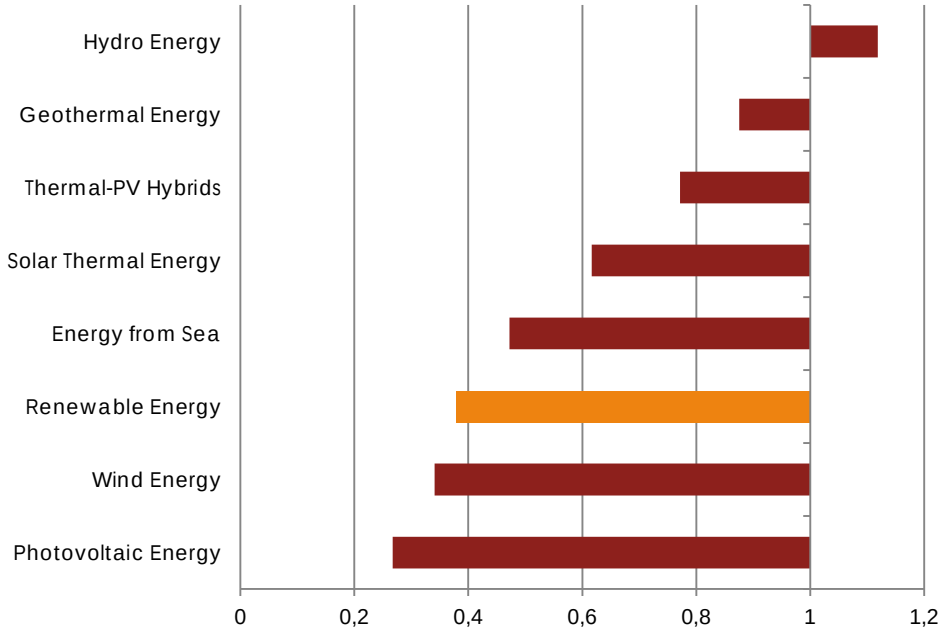
Figure 26: Top Canadian Researchers in Renewable Energy

Top Canadian Researchers	Associated Business or Institution
Morgan, John Paul	Morgan Solar Incorporated (CA)
Fafard, Simon	Cyrium Technologies Incorporated (CA)
Churchill Frédérick	OrganoWorld Incorporated (CA)
Werner, Mark	Magna International Incorporated (CA)
Desmeules, Alain	Pretech (CA)
Ferguson, Frederick	Magna International Incorporated (CA)
Burger, Martin	Blue Energy Canada Incorporated (CA)
Garabandic, Djordje	Schneider Electric USA Incorporated (US)
Hu Nan-Xing	Xerox Corporation (US)
Kleiman, Rafael Nathan	Arise Technologies Corporation (CA)
Klenkler, Richard	Xerox Corporation (US)
Davies, Micheal	Sixtron Advanced Materials (CA)
Wootton, Gerald	ATS Automation Tooling Systems Incorporated (CA)
Mironov, Gabriel	Suzhou Red Maple Wind Blade Mould Company Limited (CN)
Huazi, Lin	W&E International Canada Corporation (CA)
Yuen, Avery	Xerox Corporation (US)
Sabourin, Michel	Alstom Technology Limited (CH)
Vachon, Christian	Enerconcept Technologies Incorporated (CA)
Bamsey, Nathan	Xerox Corporation (US)
Vettese, Sharolyn	Wind Simplicity Incorporated (CA)
Wu, Yiliang	Xerox Corporation (US)
Ding, Zhifeng	University of Western Ontario (CA)

Businesses and Institutions

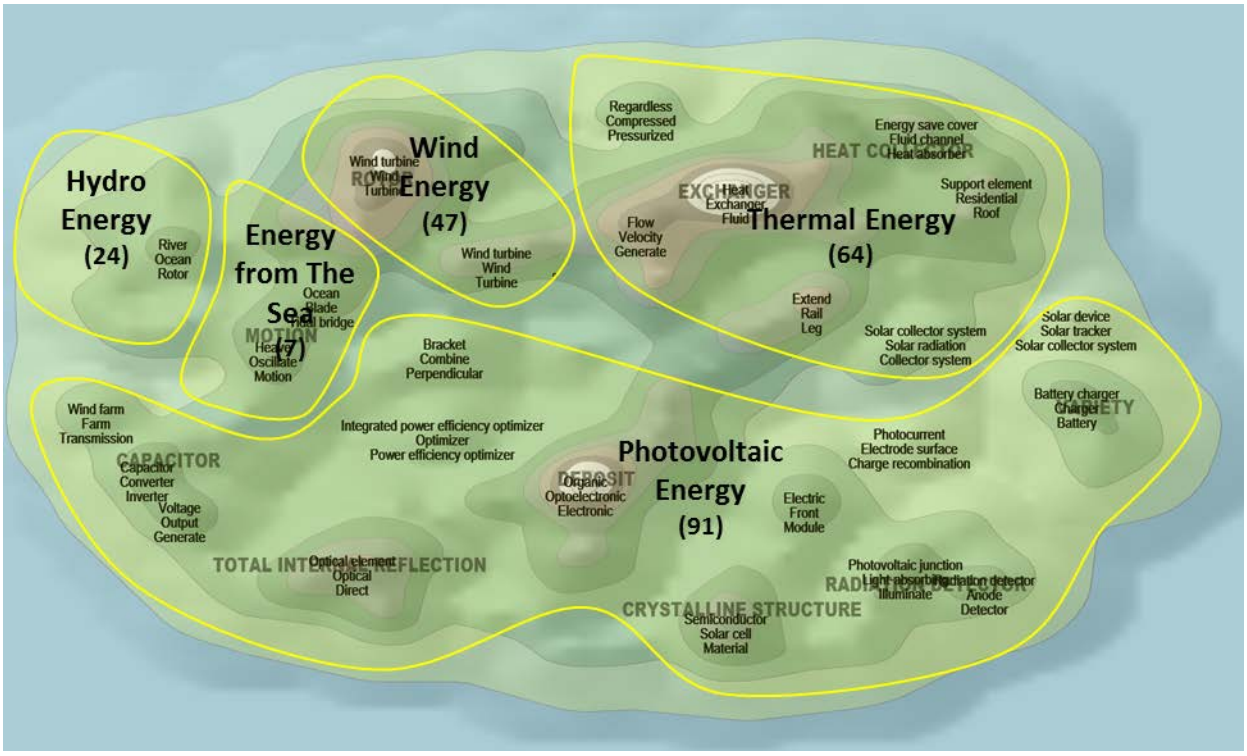
The RTA index for Renewable Energy and its related subgroups for Canadian businesses is illustrated in figure 27. It can be observed that Hydro Energy is the only subgroup related to the Renewable Energy category where Canadian businesses are specialized. Hydro Energy is also a subgroup where Canadian researchers are specialized. Canadian researchers also have a specialization in Geothermal Energy, Energy from the Sea and Solar Thermal Energy which is not the case for Canadian businesses.

Figure 27: Revealed Technological Advantage (RTA) Index for Canadian Businesses in Renewable Energy



The distribution of patenting activity by Canadian businesses in the area of Renewable Energy depicted in figure 28 is not that different from the landscape map presented previously in figure 23. This is despite representing only 1% of worldwide Renewable Energy patents by businesses. Patents related to Photovoltaic Energy represent a significant portion of the patents. Similar to the worldwide landscape map and the Canadian researchers' landscape map, a snow-capped peak is found in the Wind Energy area related to wind turbines. Another snow-capped peak is found in the Thermal Energy area where Geothermal Energy, Thermal-PV Hybrids and Solar Thermal Energy are clustered together. This cluster relates to keywords such as "heat", "exchanger" and "fluid" and the inventions are related to geothermal energy transfer systems, solar thermal energy capture systems and more. The snow-capped peak in the area of Photovoltaic Energy related to keywords such as "organic", "optoelectronic" and "electronic" is a peak where governmental and university inventions are found. More specifically, inventions filed by The National Research Council of Canada (NRC), Université Laval, University of Waterloo, University of Alberta and Simon Fraser University are included around this peak.

Figure 28: Renewable Energy Landscape Map of Patent Families Linked to Canadian Businesses



Magna International and Morgan Solar are among the top Canadian businesses with patents in CCMT technologies specialized in Renewable Energy. Their patenting levels are nevertheless significantly lower than that of the top patenting companies from foreign jurisdictions. Magna, Morgan Solar and OrganoWorld are examples of top Canadian businesses also associated with top Canadian researchers identified in figure 26. Magna International is an automotive parts manufacturing company also involved in the solar market.[xxxiv] The company has inventions related to solar panels and solar reflectors assembly. Morgan Solar, as its name suggests, also specializes in Solar Energy.

Figure 29: Top Canadian Businesses or Institutions in Renewable Energy

Business or Institution
Magna International Incorporated (CA)
Morgan Solar Incorporated (CA)
W&E International Corporation (CA)
National Research Council (CA)
OrganoWorld Incorporated (CA)
Day4 Energy Incorporated (CA)
Cyrium Technologies Incorporated (CA)
University of British Columbia (CA)
University of Western Ontario (CA)
University of Alberta (CA)

The leading companies in terms of patenting levels in the area of Renewable Energy presented in figure 30 include Siemens AG, General Electric, Vestas Wind Systems, and Sanyo Electronic. Most of the companies are either German or Asian, and primarily from Japan and Korea.

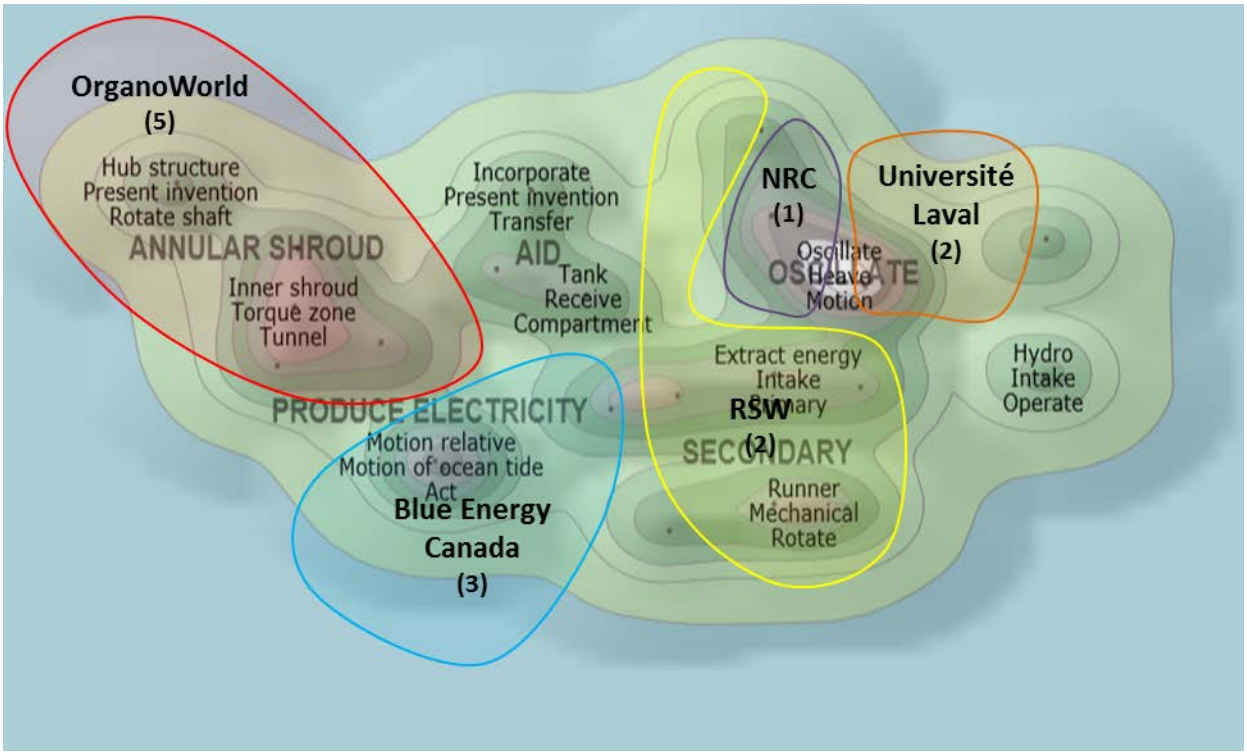
Figure 30: Top Business or Institution Names in Renewable Energy

Business or Institution
Siemens AG (DE)
General Electric Company (US)
Vestas Wind Systems A/S (DK)
Sanyo Electronic Company Limited (JP)
Sharp Corporation (JP)
LG Electronics Incorporated (KR)
Samsung Electronics Limited (KR)
Mitsubishi Electric Corporation (JP)
Robert Bosch GmbH (DE)
Fujifilm Corporation (JP)

Hydro Energy

Canada is a top producer and one of the few net exporters of hydroelectricity in the world. It also has the cleanest and most renewable electricity system of the G8 countries.[xxxv] Despite having very few inventions, Hydro Energy is the only subgroup in which both Canadian researchers and businesses are specialized. The landscape map in figure 31 highlights the top Canadian players in Hydro Energy. OrganoWorld Incorporated is a leading company in Hydro Energy and also has inventions in most of the CCMT categories. RSW Incorporated was a 550-employee leading service provider to clients in key end markets, including hydro power, and transmission and distribution. It was acquired in 2010 by AECOM Technology, an American company.[xxxvi] The snow-capped peak related to keywords such as "oscillating", "heave" and "motion" is associated with inventions from Université Laval and The National Research Council of Canada (NRC). These inventions include oscillating foil turbine which is a more renewable alternative to traditional, horizontal axis turbines that are currently more commonly used for wind and tidal energy generation.[xxxvii]

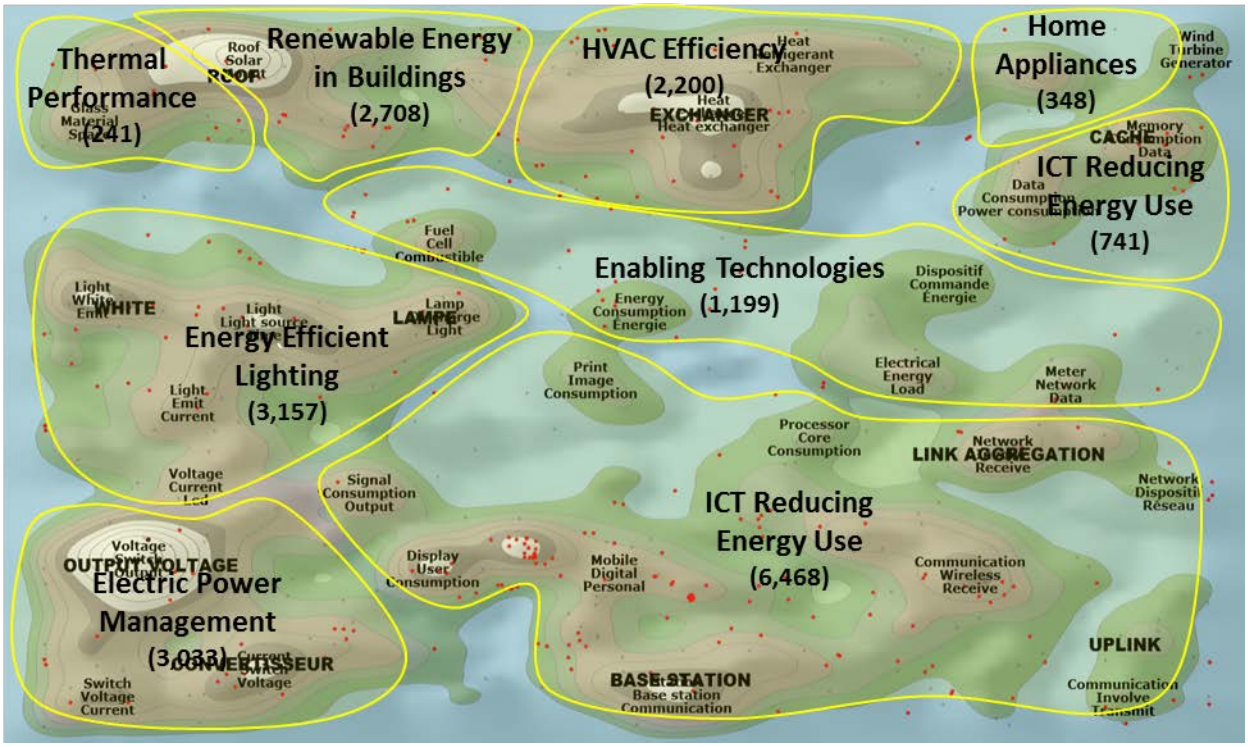
Figure 31: Landscape Map of Canadian Businesses with Hydro Energy Inventions



BUILDINGS

CCMT technologies related to Buildings are designed primarily to help reduce CO_2 emissions through more efficient use of energy in all aspects of buildings. The subgroups included in this category include Enabling Building Technologies, Building Thermal Performance, Renewable Energy in Buildings, Information and Communications Technologies (ICT) Reducing Energy Use, Energy Efficient Lighting, Heating, Ventilation and Air Conditioning (HVAC) Efficiency, Electric Power Management in Buildings and Home Appliance Efficiency. These subgroups are identified in figure 32 in a landscape map showing worldwide patenting activities in Buildings. The landscape map represents approximately 20,000 inventions. The highest level of activity is in technologies related to ICT Reducing Energy Use. Other areas of significant activity are in technologies related to Electric Power Management, Energy Efficient Lighting, Renewable Energy and HVAC efficiency. The red dots depicting inventions by Canadian businesses are dispersed across the map. Canadians are especially active in technologies related to ICT Reducing Energy Use. A snow-capped peak related to Electrical Power Management and linked to keywords such as "voltage" and "switch" is located in the bottom left hand corner of the map. This peak includes patents related to power conversion methods and apparatus for a more efficient energy use. The landscape map includes another snow-capped peak in the upper left hand corner of the map relating to technologies around Renewable Energy in Buildings characterised by keywords such as "roof", "solar" and "mount". The patents around this area are mainly related to equipment for installing solar modules on roofs.

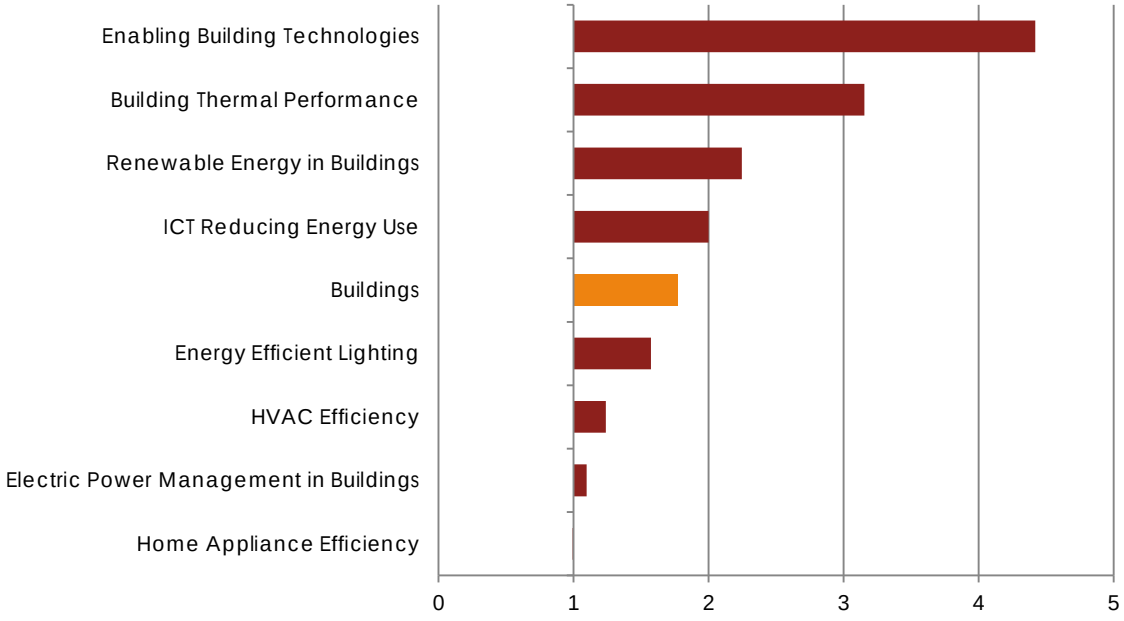
Figure 32: Landscape Map of Worldwide Patenting Activities in Buildings



Researchers

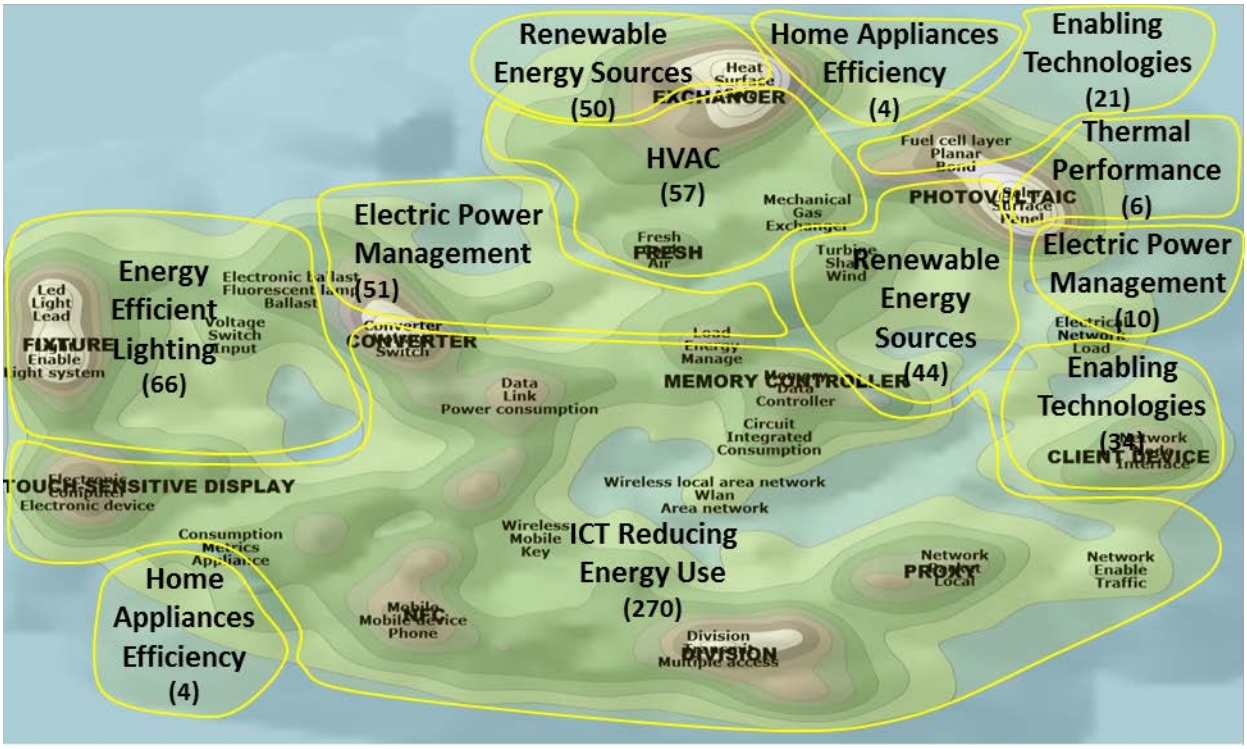
The level of specialization of Canadian researchers in the Buildings category and its related subgroups is shown in figure 33. The Revealed Technological Advantage (RTA) indices are greater than one for all but one of the subgroups, Home Appliance Efficiency. This is indicative of the level of specialization of Canadian researchers in this category. Home Appliance Efficiency is also a subgroup that has generated less activity worldwide relative to the other subgroups.

Figure 33: Revealed Technological Advantage (RTA) Index for Canadian Researchers in Buildings



The landscape map in figure 34 highlights the patenting activity by Canadian researchers. Similar to the worldwide landscape map in figure 32, there is a significant amount of patenting activity in the ICT Reducing Energy Use technology area. In the bottom of the map where ICT Reducing Energy Use related patents are mostly situated, lies a snow-capped peak linked to keywords such as "division", "transmit" and "multiple access". The inventions around this peak are associated with companies such as Qualcomm and Blackberry, and are related primarily to methods and apparatus for controlling transmission power in a communications network. The snow-capped peak in the center left-hand quadrant of the map where Energy Efficient Lighting related patents are mostly situated, is characterized by keywords such as "led", "light", "lead", "enable" and "light system".

Figure 34: Buildings Landscape Map of Patent Families Linked to Canadian Researchers



The leading Canadian researchers along with their associated companies or institutions are identified in figure 35. More than half are associated with Blackberry. The remaining Canadian researchers work for Canadian, American and European companies. In the business section, we will see that Blackberry is also among the top Canadian companies.

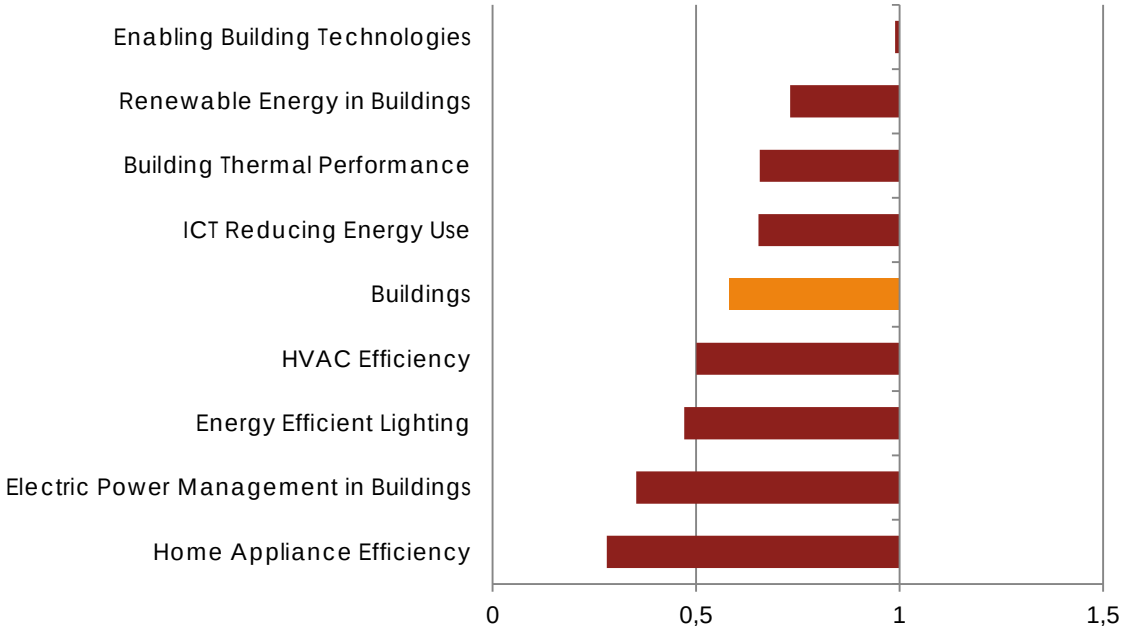
Figure 35: Top Canadian Researchers in Buildings

Top Canadian Researchers	Associated Business or Institution
Rich, David Gerard	BlackBerry Limited (CA)
Wu, Chee-Ming Jimmy	BlackBerry Limited (CA)
Ashdown, Ian Edward	Koninklijke Philips N.V. (NL)
Mo-Han, Fong	BlackBerry Limited (CA)
Veillette, Michel	Trilliant Incorporated (US)
Samson, Eric	Intel Corporation (US)
Kholaif, Ahmad Mohammad Mohammad	BlackBerry Limited (CA)
Islam, Muhammad Khaledul	BlackBerry Limited (CA)
Orr, Raynond Kenneth	Solantro Semiconductor Corporation (CA)
Zhu, Lizhong	BlackBerry Limited (CA)
Poirier, Christian	General Electronic (US)
Mankaruse, George Soliman	BlackBerry Limited (CA)
Boros, Mircea Cristian	Potentia Semiconductor Corporation (CA)
Nguyen, Truong-Khoa	General Electronic (US)
Corrigan, Michael Stephen	BlackBerry Limited (CA)
Griffin, Jason Tyler	BlackBerry Limited (CA)
Liu, Yan-Fei	Queen's Univeristy (CA)
Moosavi, Vahid	BlackBerry Limited (CA)
Sutarwala, Taha Shabbir Husain	BlackBerry Limited (CA)
Jain, Praveen K.	Sparq Systems Incorporated (CA)

Businesses and Institutions

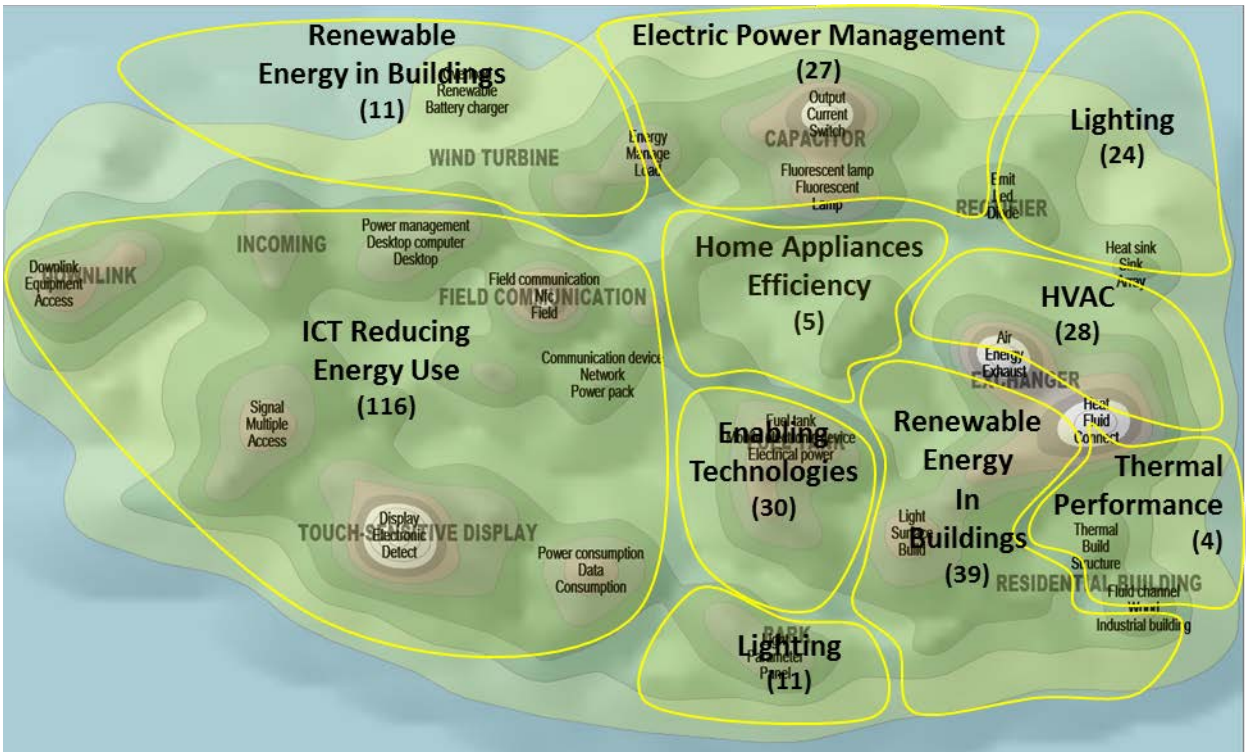
The Canadian businesses RTA index for Buildings and its related subgroups is illustrated in figure 36. As opposed to Canadian researchers, where almost all subgroups have an RTA index above one, Canadian businesses have an index below one in all subgroups suggesting they are not specialized. The Enabling Building Technologies subgroup which was a highly specialized subgroup for Canadian researchers is the subgroup with an RTA closest to one, but nevertheless falls short. This suggests that although there is no specialization, the level of patenting is almost equal to the share of patenting in all technologies.

Figure 36: Revealed Technological Advantage (RTA) Index for Canadian Businesses in Buildings



The landscape map in figure 37 illustrates the patenting activity by Canadian businesses. A significant portion of the patenting activity relates to the ICT Reducing Energy Use subgroup, similar to the worldwide landscape map and to the Canadian researchers landscape map. A snow-capped peak linked to keywords such as "display", "electronic" and "detect" is found in the space where most of the patents are filed by Blackberry. The Renewable Energy Sources subgroup is also an area relatively active for both Canadian businesses and researchers. Snowed-capped peaks can be found in the HVAC subgroup relating to keywords such as "air", "energy", "exhaust", "heat", "fluid" and "connect". The patents around these peaks are related to heat exchangers and temperature control methods and apparatus.

Figure 37: Buildings Landscape Map of Patent Families Linked to Canadian Businesses



The top 10 Canadian businesses or institutions patenting Buildings related inventions are identified in figure 38. Blackberry, the top Canadian applicant, was associated with multiple top Canadian researchers as indicated in figure 35. Blackberry specializes primarily in inventions related to ICT Reducing Energy Use. Other leading Canadian companies patenting in Buildings related inventions include W&E International Canada and ATI Technologies. W&E International Canada has patents related to building elements using solar energy for heating and cooling and ATI Technologies specializes in methods and apparatus for power management.

Figure 38: Top Canadian Businesses or Institutions in Buildings

Business or Institution
Blackberry Limited (CA)
W&E International Canada Corporation (CA)
ATI Technologies Unlimited Liability Corporation (CA)
Nortel Networks Limited (CA)
Queen's University (CA)
Angstrom Power Incorporated (CA)
Carmanah Technologies Corporation (CA)
Bombardier Incorporated (CA)
Magna International Incorporated (CA)
dPoint Technologies Incorporated (CA)

The top worldwide companies or institutions patenting Buildings related inventions are identified in figure 39. Interestingly, these companies come from a wide range of countries, most of which are Asian. Although there are no Canadian companies among the top worldwide companies identified, one Canadian researcher is associated with Koninklijke Philips, a top worldwide company in this patent area.

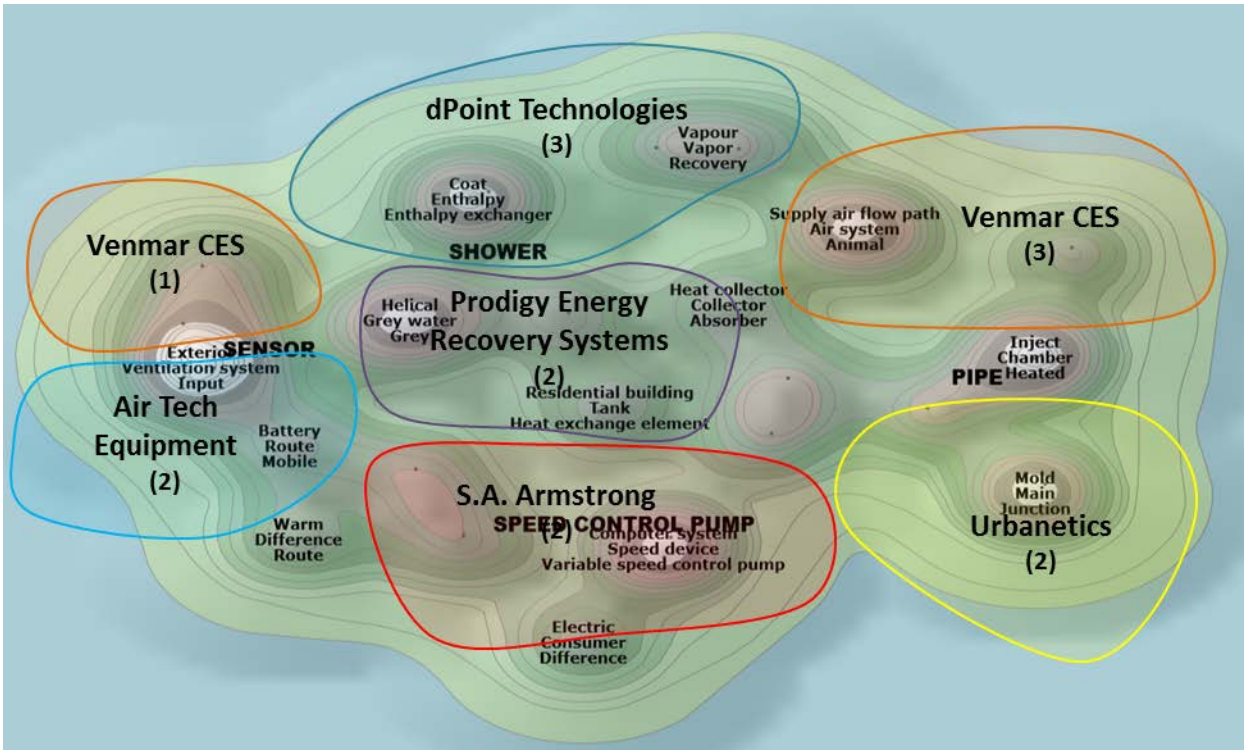
Figure 39: Top Worldwide Businesses or Institutions in Buildings

Business or Institution
Samsung Electronics Limited (KR)
Panasonic Corporation (JP)
Qualcomm Incorporated (US)
LG Electronics Incorporated (KR)
Fujitsu Limited (JP)
Huawei Technology Company Limited (CN)
Koninklijke Philips N.V. (NL)
Toshiba Corporation (JP)
ZTE Corporation (CN)
Hitachi Limited (JP)

Enabling Building Technologies

In the previous sections, we saw that Canadian researchers have a relatively high level of specialization in the Enabling Building Technologies subgroup. Canadian businesses have an RTA almost equal to one, meaning that although there is no specialization, the country's share of patents in the subgroup almost equals its share in all fields. The landscape map in figure 40 provides an indication of the patenting activity within this subgroup of 30 inventions. dPoint Technologies is a top player patenting inventions related to Enabling Building Technologies. It is also among the top Canadian players in Buildings related inventions in CCMT as seen in figure 38. dPoint Technologies specializes in the development and manufacture of membranes for enthalpy recovery systems and is a global market leader in this field. The membrane is the centrepiece of systems which transfer both heat and humidity, thereby significantly increasing both the comfort and energy efficiency of buildings.[xxxviii] In 2015, dPoint Technologies was acquired by Zehnder Group, a Swiss company.[xxxix] Venmar CES, another leading company in this technology space, is a manufacturer of energy saving ventilators.[xl] Its presence around snow-capped peaks with keywords such as "air system" and "ventilation system" is therefore expected.

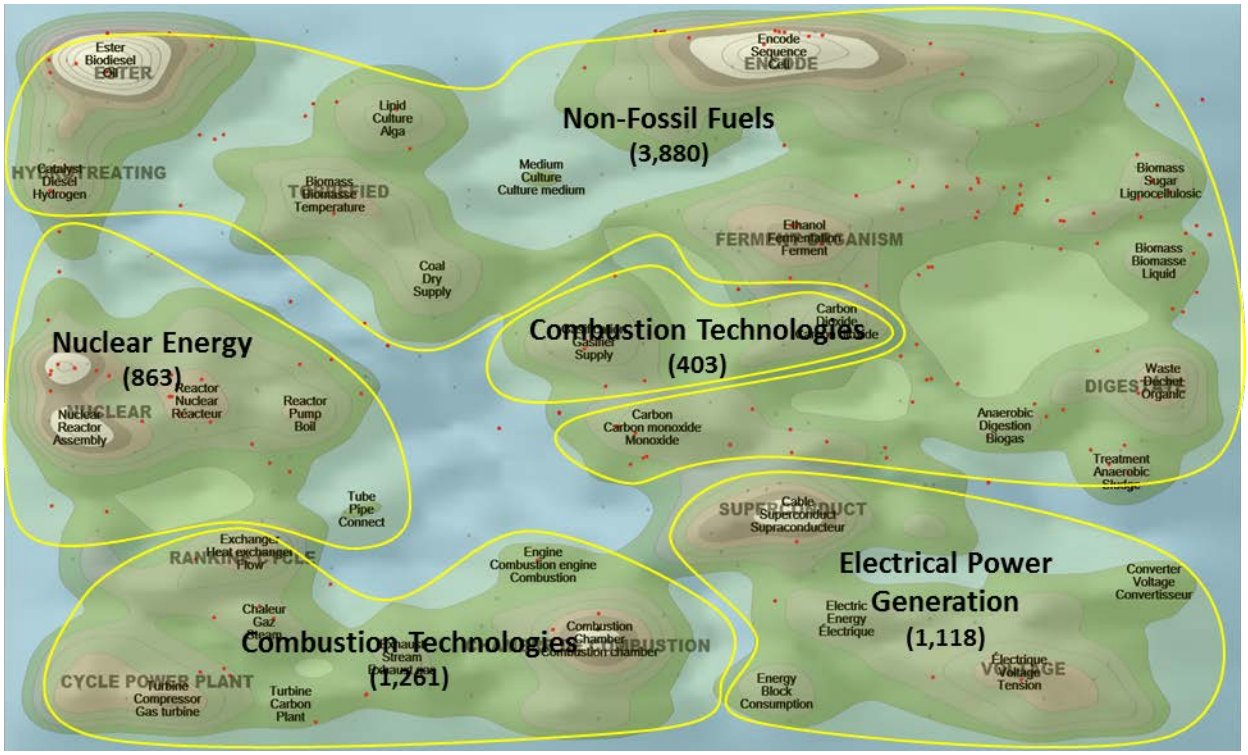
Figure 40: Landscape Map of Canadian Businesses with Enabling Building Technologies Inventions



TRADITIONAL ENERGY

The Traditional Energy category encompasses inventions related to the use of energy considered as alternatives to energy produced using fossil fuels which are responsible for emitting CO_2 and other greenhouse gases. This category includes Combustion Technologies with Mitigation Potential, Nuclear Energy, Electrical Power Efficiency and Technologies for the Production of Fuels of Non-Fossil Origin. These subgroups are identified in the landscape map in figure 41 showing worldwide patenting activities in Traditional Energy. The landscape map includes more than 7,000 inventions. Technologies for the Production of Fuels from Non-Fossil Origin is a subgroup in which most of the activity occurs. The red dots depicting inventions by Canadian business are dispersed across the map suggesting that they are not specialized in one specific technology area relating to Traditional Energy. Snowed-capped peaks indicate where significant patenting is occurring. They appear in all the subgroups. It is interesting to see that the red dots are concentrated near peaks in the Nuclear Energy subgroup and the Non-Fossil Fuels subgroups.

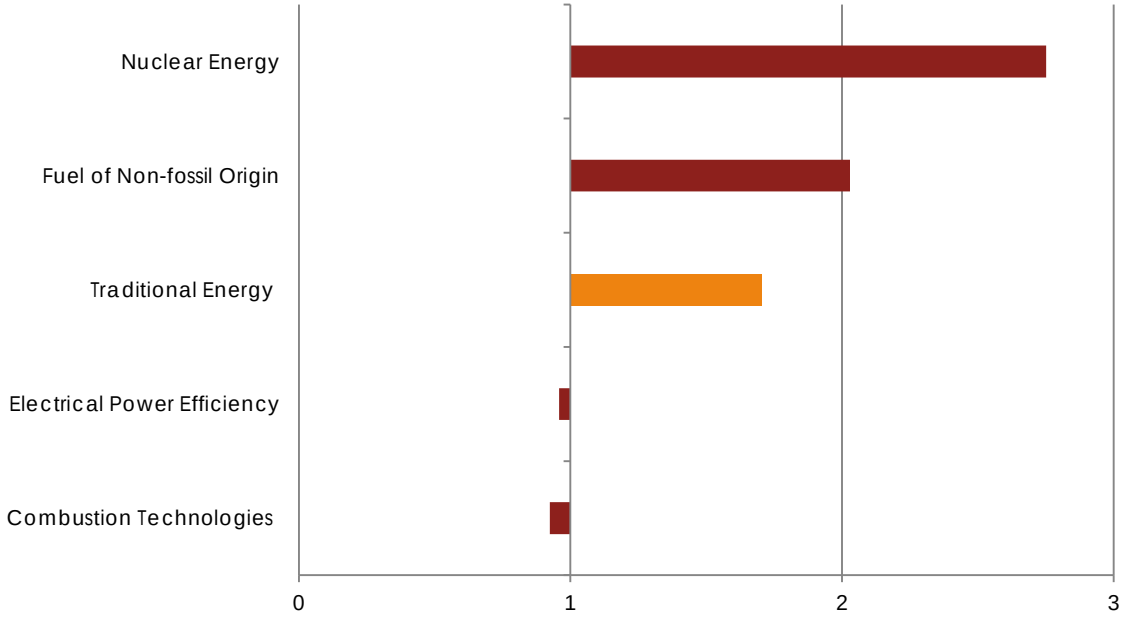
Figure 41: Landscape Map of Worldwide Patenting Activities in Traditional Energy



Researchers

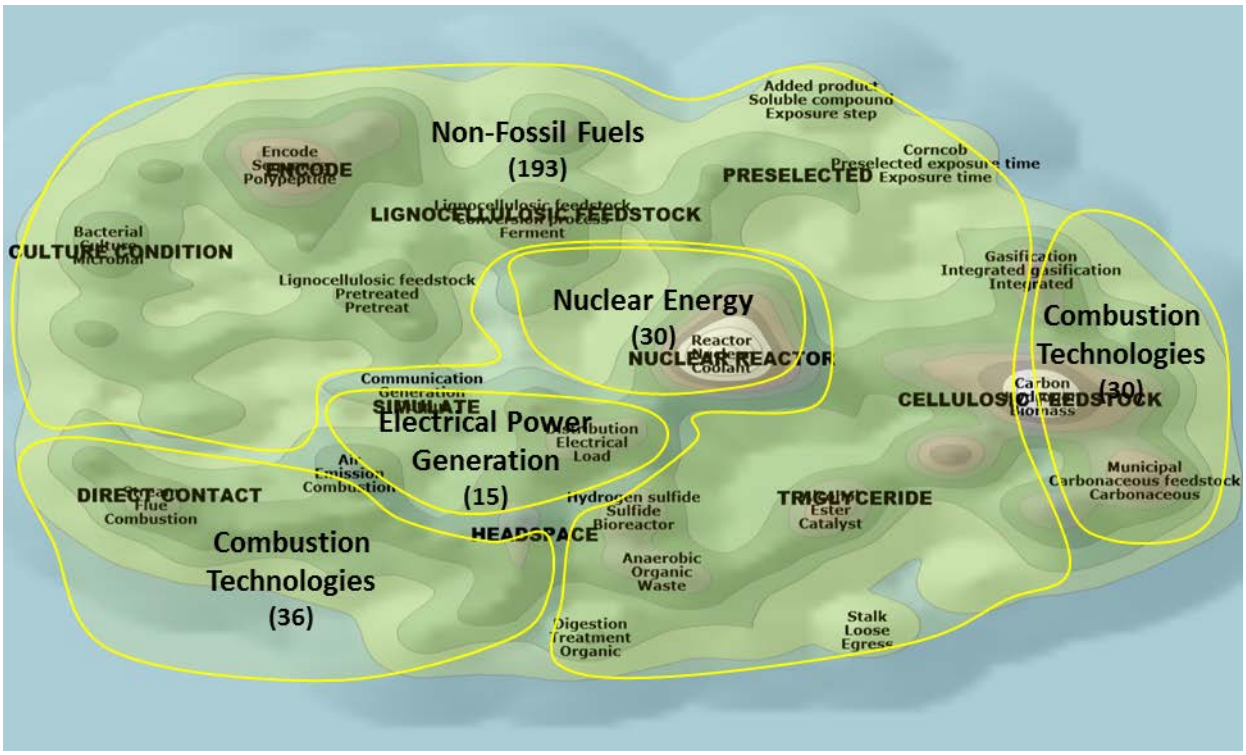
The Revealed Technological Advantage (RTA) index in Traditional Energy and its related subgroups for Canadian businesses is illustrated in figure 42. The Nuclear Energy and the Non-Fossil Fuels subgroups are areas in which Canadian researchers are specialized. The Electrical Power Efficiency and Combustion Technologies subgroups have RTA indices slightly lower than one indicating no specialization. Overall, the net effect is a specialization in the Traditional Energy category for Canadian researchers.

Figure 42: Revealed Technological Advantage (RTA) Index for Canadian Researchers in Traditional Energy



The landscape map in figure 43 shows the patenting activities of Canadian researchers. Similar to figure 41, most of the activity occurs in the Non-Fossil Fuels subgroup. The snow-capped peak in the right-hand side of the map encompasses inventions related to methods for producing biofuels and the removal of carbon emissions intensity from fuel. The Nuclear Energy related snow-capped peak at the center of the map is related to nuclear reactors. This is related mainly to the Canadian Deuterium-Uranium (CANDU) reactor, a Canadian invention that resulted in follow-on innovation and patenting in Canada and around the world. A more detailed analysis is produced on the Nuclear Energy subgroup at the end of the section.

Figure 43: Traditional Energy Landscape Map of Patent Families Linked to Canadian Researchers



The leading Canadian researchers along with their affiliated businesses or institutions found on the associated patent records are identified in figure 44. Almost all of the top researchers are associated with Canadian companies. Furthermore, Mascoma, GreenField Ethanol, Iogen Energy, Plasco Energy Group and Atomic Energy of Canada are associated with several top researchers. In the business section, we will see that they are also among the top Canadian businesses patenting in Traditional Energy.

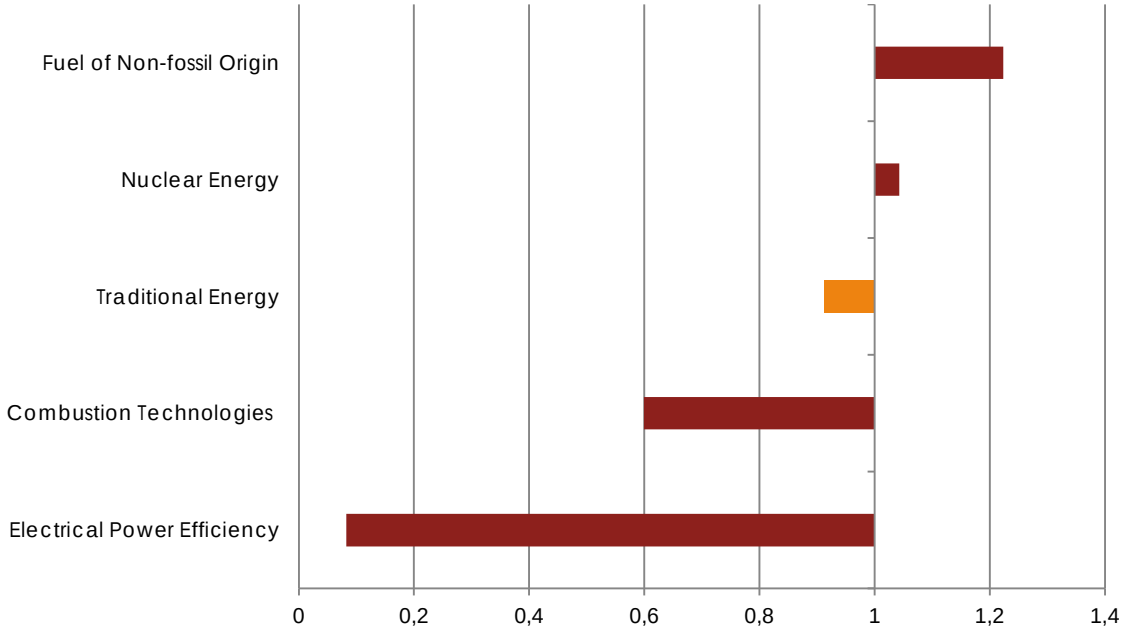
Figure 44: Top Canadian Researchers in Traditional Energy

Top Canadian Researchers	Associated Business or Institution
Burke, Murray J.	Mascoma Canada Incorporated (CA)
Benson, Robert Ashley Cooper	GreenField Ethanol Incorporated (CA)
Benech, Régis-Olivier	GreenField Ethanol Incorporated (CA)
Foody, Brian	Iogen Energy Corporation (CA)
Tolan, Jeffrey S.	Iogen Energy Corporation (CA)
Dottori, Frank A.	GreenField Ethanol Incorporated (CA)
Hillier, Sunalie	Mascoma Canada Incorporated (CA)
Marceau, Pascale Bonnie	Plasco Energy Group Incorporated (CA)
Tsangaris, Andreas	Plasco Energy Group Incorporated (CA)
Tomashek, John	Iogen Energy Corporation (CA)
Kuran, Sermet	Atomic Energy of Canada Limited (CA)
Anand, Vijay Kumar	Iogen Energy Corporation (CA)
Basham, Scott Douglas	Plasco Energy Group Incorporated (CA)
Berlin, Alex	Lignol Energy Corporation (CA)
Campbell, Kenneth Craig	Plasco Energy Group Incorporated (CA)
Scott, Brian R.	Iogen Energy Corporation (CA)
Rahme, Ziyad	Iogen Energy Corporation (CA)
Maclachlan, John Ross	Lignol Energy Corporation (CA)
Swain, Margaret	Plasco Energy Group Incorporated (CA)
Tsangaris, Andreas	Plasco Energy Group Incorporated (CA)
Foody, Patrick	Iogen Energy Corporation (CA)
Chornet, Esteban	Enerkem Incorporated (CA)
Boubcher, Mustapha	Atomic Energy of Canada Limited (CA)
Cottrell, Cathy	Atomic Energy of Canada Limited (CA)
Hill, Christopher	Iogen Energy Corporation (CA)

Businesses and Institutions

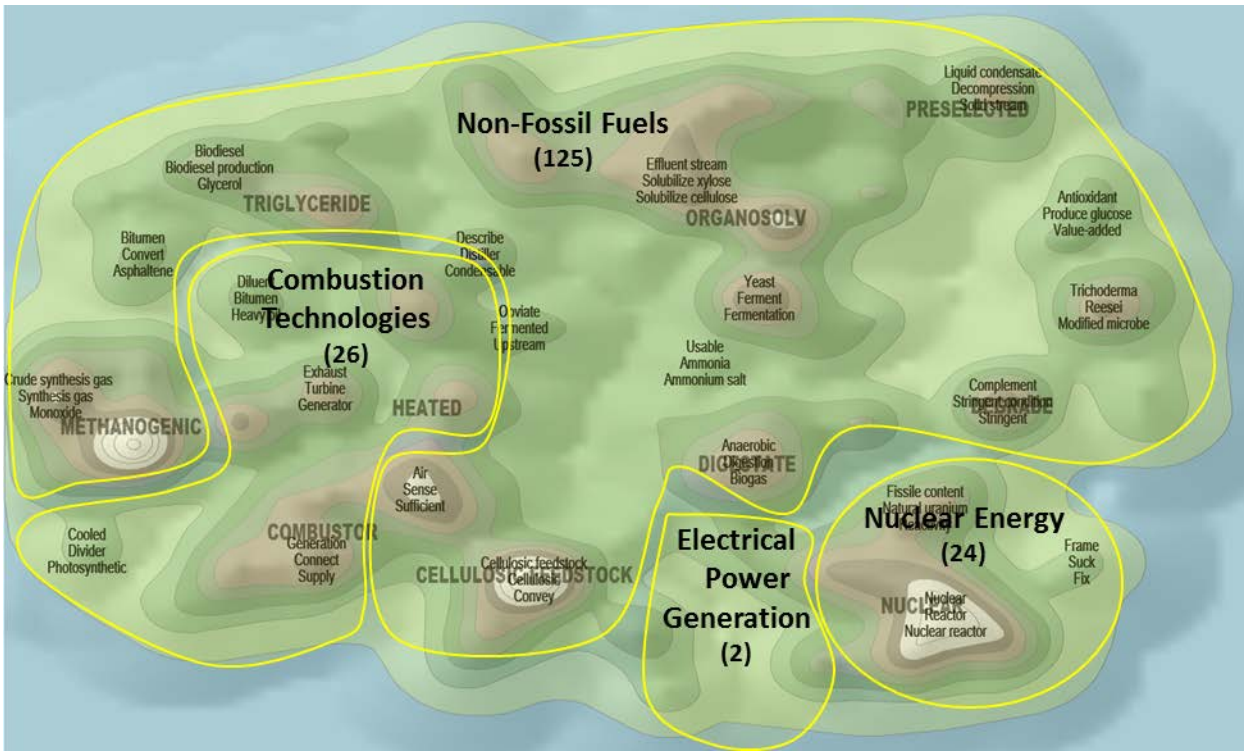
The RTA index for Traditional Energy and its related subgroups for Canadian businesses is illustrated in figure 45. Similar to the RTA index for Canadian researchers, Nuclear Energy and Fuels of Non-Fossil origin are areas in which Canadian businesses specialize. The RTA index is also lower than one for the Combustion Technologies and Electric Power Efficiency subgroups. As opposed to the results for Canadian researchers, Canadian businesses have an overall index that is lower than one, indicating no specialization in the Traditional Energy category.

Figure 45: Revealed Technological Advantage (RTA) Index for Canadian Businesses in Traditional Energy



The landscape map in figure 46 illustrates Canadian businesses' patenting activity. Once again, most of the activity occurs in the Non-Fossil Fuels subgroup similar to the worldwide landscape map and to the Canadian researchers landscape map. The snow-capped peak in the lower left-hand quadrant includes patents related to processes for the sequestration of carbon dioxide and methods for gas production from a reservoir. An invention from the University of Western Ontario and from the National Research Council of Canada is found around this peak. Another snow-capped peak can be found in the Nuclear Energy grouping, similar to the Canadian researchers landscape map in figure 43, relating to nuclear reactors.

Figure 46: Traditional Energy Landscape Map of Patent Families Linked to Canadian Businesses



The top Canadian businesses or institutions patenting Traditional Energy related inventions are identified in figure 47. They are closely associated with the top Canadian researchers identified in figure 44. Iogen Energy and Greenfield Ethanol are example of companies mainly specialized in the Non-Fossil Fuels subgroup of the Traditional Energy category in which Canada is specialized in both the researcher and business side. Atomic Energy of Canada is specialized in Nuclear Energy. The following section gives more details on this subgroup.

Figure 47: Top Canadian Businesses or Institutions in Traditional Energy

Business or Institution
Iogen Energy Corporation (CA)
Atomic Energy of Canada Limited (CA)
Greenfield Ethanol Incorporated (CA)
SunOpta BioProcess Incorporated (CA)
Natural Resources Canada (CA)
Lignol Innovations Limited (CA)
Enerkem Incorporated (CA)
Mascoma Canada Incorporated (CA)
Plasco Energy Group Incorporated (CA)

The leading worldwide companies or institutions patenting inventions related to Traditional Energy are identified in figure 48. Most of the companies are American and Japanese. Canadian companies are not among the top worldwide companies identified. Also, none of the top Canadian researchers are associated with the top companies listed.

Figure 48: Top Business or Institution in Traditional Energy

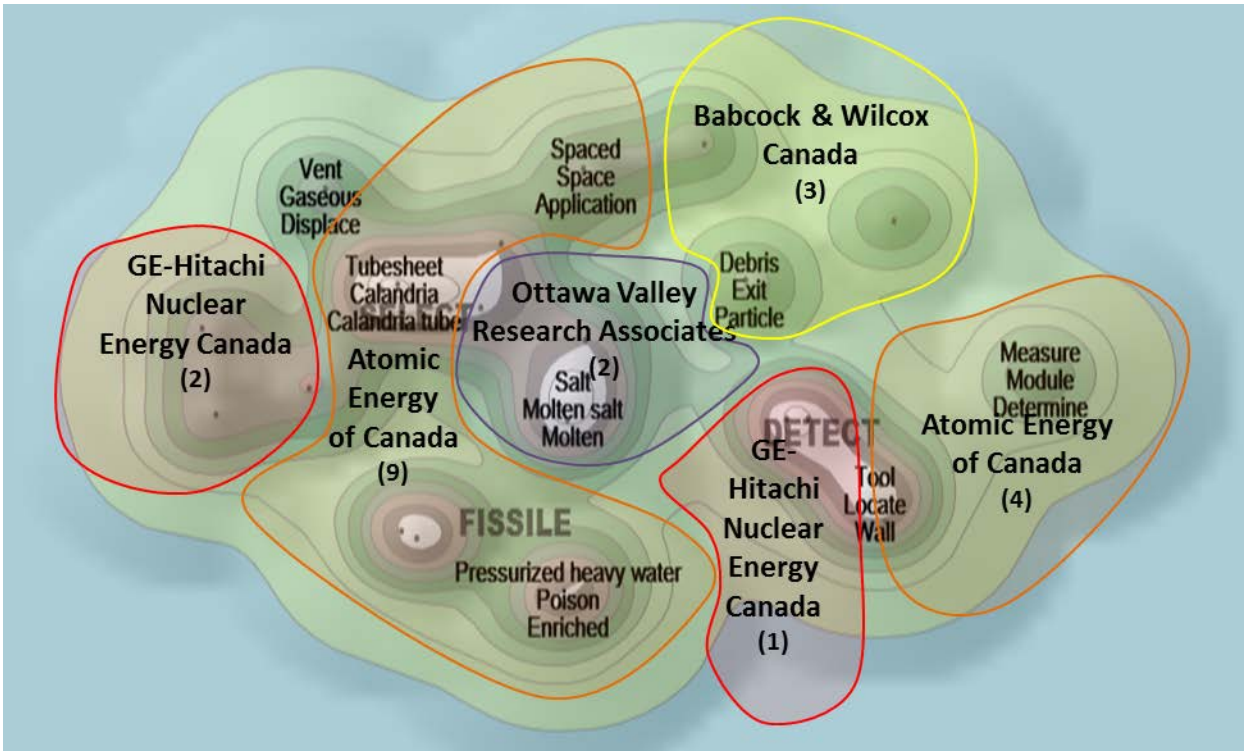
Business or Institution
General Electric Company (US)
Siemens AG (DE)
Mitsubishi Electric Corporation (JP)
Novozymes Incorporated (US)
Alstom Technology Limited (CH)
Toshiba Corporation (US)
Westinghouse Electric Company LLC (US)
Hitachi Limited (JP)
Commissariat à l'Énergie Atomique et aux Énergies Alternatives (FR)
E. I. du Pont de Nemours and Company (US)

Nuclear Energy

In the previous section, we found that both Canadian researchers and businesses were specialized in the area of Nuclear Energy. We also identified, on all the landscape maps, snow-capped peaks related to Nuclear Reactors indicating a high level of activity. This is mostly linked to the Canadian Deuterium-Uranium (CANDU) reactor invented in Canada. Following its invention, the CANDU resulted in follow-on innovation and patenting all over the world and the technology has significantly evolved since then.[xli] In Canada, all 22 nuclear power reactors in the five power plants are Canadian Deuterium-Uranium (CANDU) reactors.[xlii] According to the World Nuclear Association, Canadian nuclear reactors contribute to $6.6 billion per year to GDP, provide $1.5 billion in revenues to the government and generate $1.2 billion in exports.[xliii] In this context, the patents represented in the landscape maps, related to Nuclear Energy, are of great value despite the fact that they represent a smaller percentage of Traditional Energy patents. Atomic Energy of Canada is illustrated as a top Canadian patenting business as seen in figure 49. This is of no surprise considering the Crown Corporation was, in cooperation with other Canadian companies, responsible for the development of the CANDU reactor.[xliv] Atomic Energy of Canada was privatized and acquired by another Canadian company, SNC-Lavalin, however the intellectual property rights remain property of the Government.[xlv]

The landscape map which represents the Canadian inventions in Nuclear Energy, identifies Atomic Energy of Canada as a main player in the area. As mentioned, it was privatized and acquired by a Canadian company. GE-Hitachi Nuclear Energy Canada, another top player, was acquired by BWX Canada, a Canadian subsidiary of BWX Technologies Incorporated, an American company. Babcock & Wilcox Canada is also identified as a top player and is a subsidiary of the Babcock & Wilcox Company which is also American. Finally, the Ottawa Valley Research Associates is a Canadian company founded by a Canadian researcher. It specializes in molten salt reactor technologies.[xlvi]

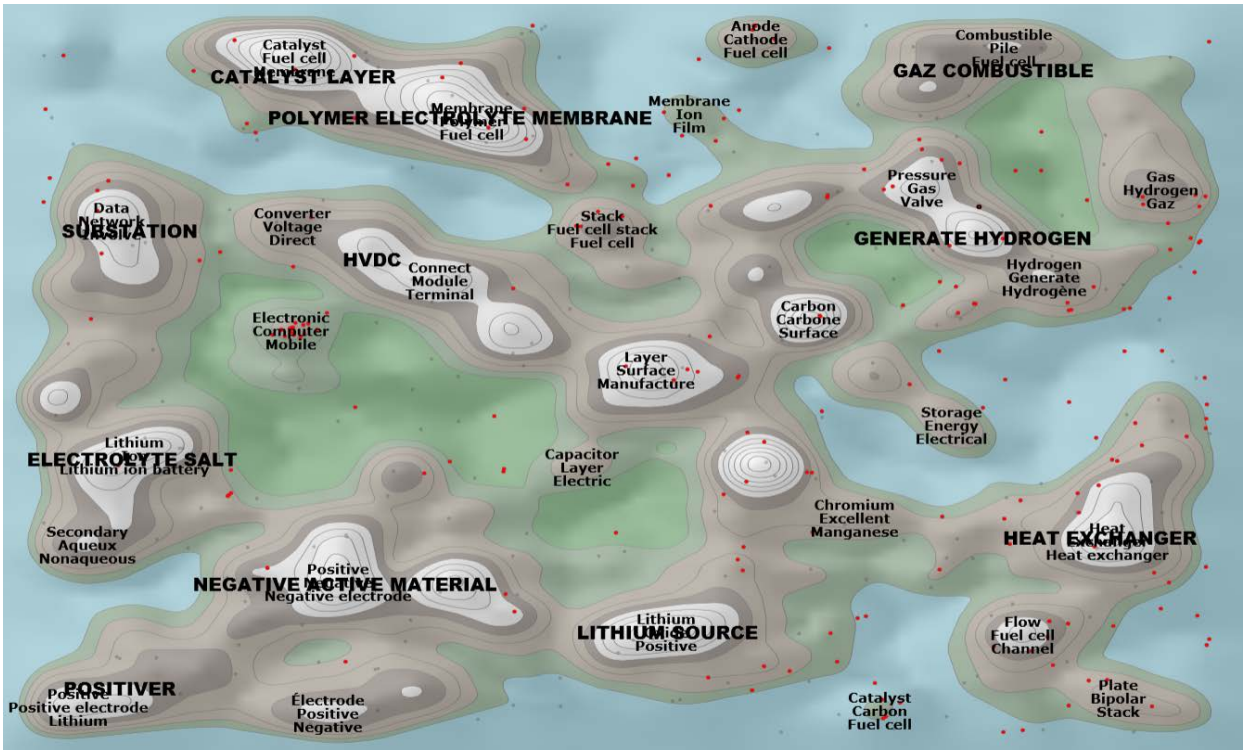
Figure 49: Landscape Map of Canadian Businesses with Nuclear Energy Inventions



CLEAN ENERGY ENABLERS

Clean Energy Enablers are technologies related to energy conversion or management systems that are also designed to reduce greenhouse gases. Batteries are examples of technologies that would fall under this category as they are considered an alternative to using other types of energy sources that are more polluting. Figure 50 illustrates the Clean Energy Enablers' worldwide patent landscape which consists of more than 17,000 inventions. Multiple snow-capped peaks illustrating the level of activity can be found in this map. The peninsula in the upper left-hand quadrant of the map is linked to fuel cells. Fuel cells are similar to batteries; they provide energy but they have the advantage of being environmentally friendly as they do not produce air pollutants.[xlvii] Inventions by companies such as Samsung Electronics, LG Chemicals and GM Global Technology are found in this peak. The large peak in the lower right-hand quadrant of the map is linked to solar heating storage, solar heat controllers and heat transfer methods to name a few. Several other snow-capped peaks are linked to different types of batteries and their components. The red dots depicting inventions by Canadian business are dispersed across the map. Canadians are especially active in technologies characterized by keywords such as "electronic", "computer" and "mobile" in an area not represented by a snow capped peak on the map. This could suggest that Canadians are actively patenting in an area that is not as competitive.

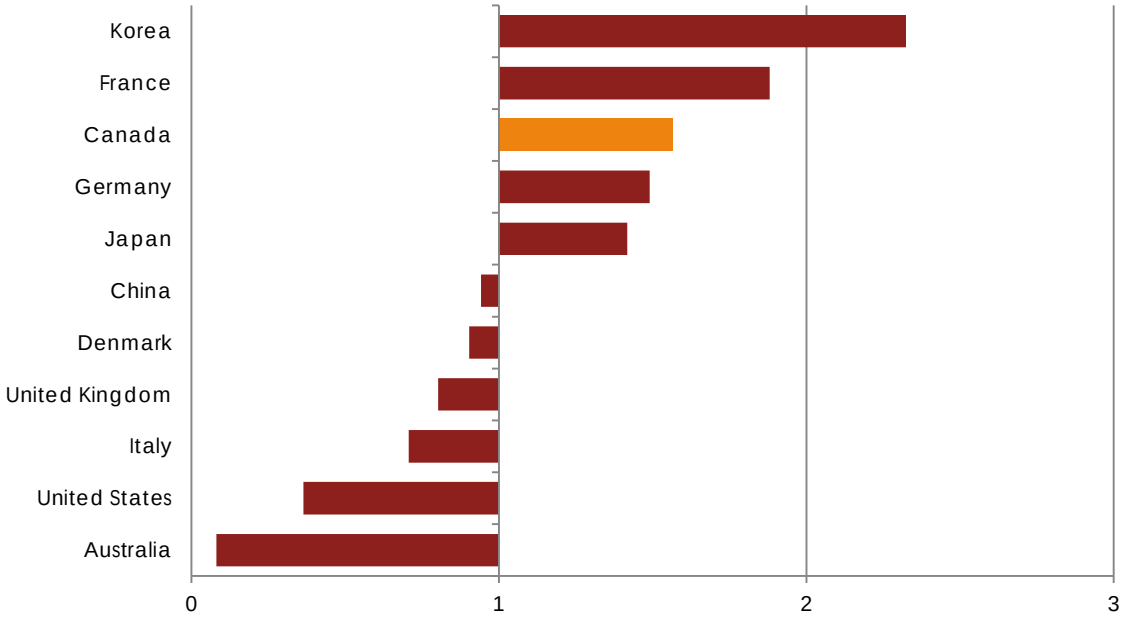
Figure 50: Landscape Map of Worldwide Patenting Activities in Clean Energy Enablers



Researchers

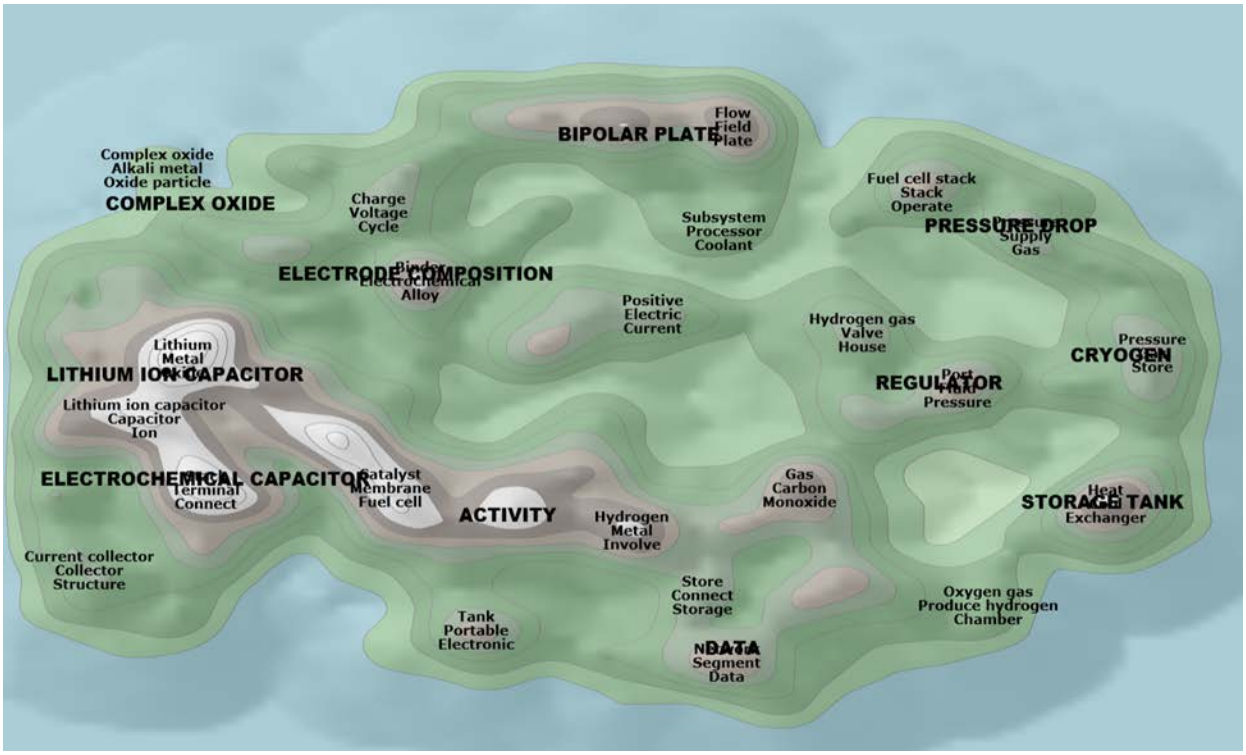
Figure 51 compares the Revealed Technological Advantage (RTA) index for Canadian researchers in the Clean Energy Enablers category to that of the researchers from the G7 countries along with four other leading countries in CCMT, China, Korea, Australia and Denmark. Canadian researchers have an RTA index greater than one indicating a specialization. Among the selected countries, Canada ranks third following Korea and France.

Figure 51: Revealed Technological Advantage (RTA) Index by Origin of Researchers in Clean Energy Enablers



The landscape map in figure 52 illustrates the areas in which Canadian researchers are active in the Clean Energy Enablers category. A snow-capped peak can be found in the center-left part of the map that is related to keywords such as “lithium”, “metal”, “oxide”, “lithium ion capacitor”, “stack”, “terminal” and “connect”. The inventions are mostly related to chemical components of different types of batteries for purposes such as enhanced life-cycle or optimized energy storage.

Figure 52: Clean Energy Enablers Landscape Map of Patent Families Linked to Canadian Researchers



Canadian researchers holding the largest numbers of inventions in the Clean Energy Enablers category and the associated Canadian businesses are listed in figure 53. The majority of the associated companies are Canadian and European. Interestingly, the Canadian Minister of Innovation Science and Economic Development announced a $10-million non-repayable contribution to the Automotive Fuel Cell Cooperation Corporation (AFCC), a Burnaby-based joint venture with Daimler AG and Ford Motor Company. Through this joint venture, the companies are developing new fuel cell modules for the automotive industry.[xlviii] It is interesting to observe that multiple top Canadian researchers are associated with the Automotive Fuel Cell Cooperation Corporation (AFCC). Société BIC, BlackBerry, Hydro-Québec and the Automotive Fuel Cell Cooperation Corporation are other companies associated with multiple top researchers in this category.

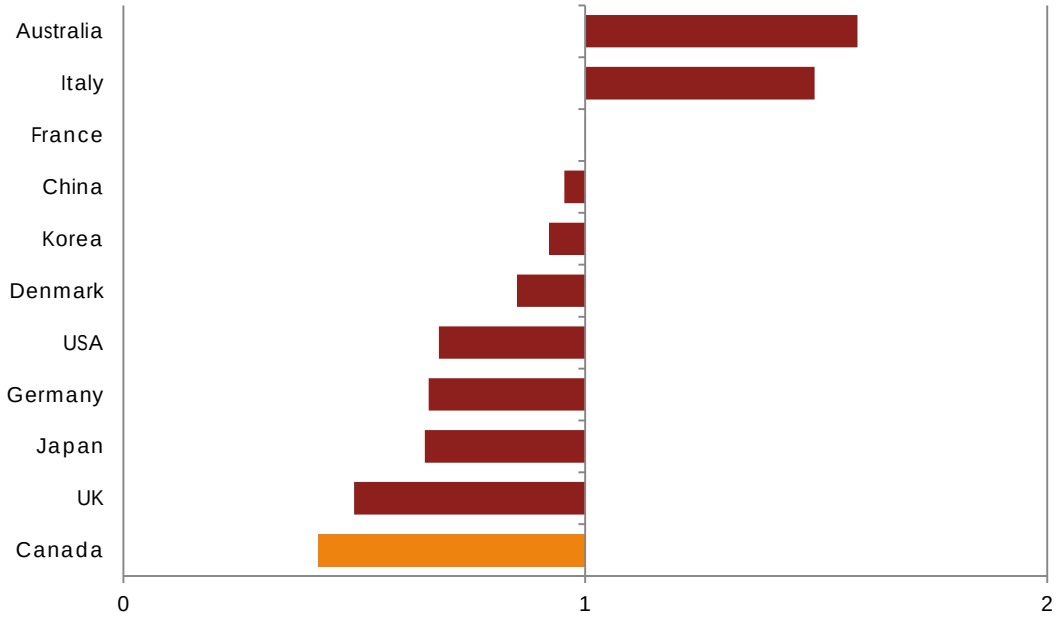
Figure 53: Top Canadian Researchers in Clean Energy Enablers

Top Canadian Researchers	Associated Business or Institution
Zaghib, Karim	Hydro-Québec (CA)
Rich, David Gerard	BlackBerry Limited (CA)
Guerfi, Abdelbast	Hydro-Québec (CA)
Gauthier, Michel	Hydro-Québec (CA)
Sutarwala, Taha Shabbir Husain	BlackBerry Limited (CA)
McLean, Gerard F	Société BIC (FR)
Schrooten, Jeremy	Société BIC (FR)
Barton, Russell	Intelligent Energy Limited (UK)
Michot, Christophe	Hydro-Québec (CA)
Zimmermann, Joerg	Société BIC (FR)
Wu, Chee-Ming Jimmy	BlackBerry Limited (CA)
Chen, Pu	University of Waterloo (CA)
Haas, Herwig	Automotive Fuel Cell Cooperation Corporation (CA)
Farrington, Simon	Automotive Fuel Cell Cooperation Corporation (CA)
Fellows, Richard	Automotive Fuel Cell Cooperation Corporation (CA)
Procter, Michael	Automotive Fuel Cell Cooperation Corporation (CA)
Ravet, Nathalie	Phostech Lithium Incorporated (CA)
Kremliakova, Natalia	Automotive Fuel Cell Cooperation Corporation (CA)
Liang, Guoxian	Clariant Canada Incorporated (CA)
Vallee, Alain	Bathium Canada Incorporated (CA)
Dahn, Jeffrey	Dalhousie University (CA)
McDermid, Scott	Automotive Fuel Cell Cooperation Corporation (CA)
Sobejko, Paul	Société BIC (FR)
Lev, Frank	Applied Intellectual Capital (UK)
Wilkinson, David	University of British Columbia (CA)
Charest, Patrick	Hydro-Québec (CA)

Businesses and Institutions

Figure 54 compares the Revealed Technological Advantage (RTA) index of Canadian businesses in the Clean Energy Enablers category to that of the businesses from the G7 countries along with four other leading CCMT countries, China, Korea, Australia and Denmark. Canadian businesses have an RTA index below one indicating no specialization. Canada is also ranked at the bottom, among the selected countries. This is the opposite of what is seen for researchers in figure 51 where Canada is highly specialized relative to the other countries.

Figure 54: Revealed Technological Advantage (RTA) Index by Origin of Businesses in Clean Energy Enablers



The leading Canadian businesses or institutions patenting Clean Energy Enablers inventions are identified in figure 55. It is interesting to see a mix of Canadian companies, governmental entities and universities involved in Clean Energy Enablers among the leading patenting entities. Blackberry, Hydro-Québec and the University of British Columbia are also associated with top Canadian researchers as seen in figure 53.

Figure 55: Top Canadian Businesses or Institutions in Clean Energy Enablers

Business or Institution
Blackberry Limited (CA)
Angstrom Power Incorporated (CA)
Ballard Power Systems Incorporated (CA)
National Research Council (CA)
BDF IP Holdings Limited (CA)
Hydro-Québec (CA)
University of Alberta (CA)
University of British Columbia (CA)
Dana Canada Corporation (CA)
Phostech Lithium Incorporated (CA)
Université Laval (CA)

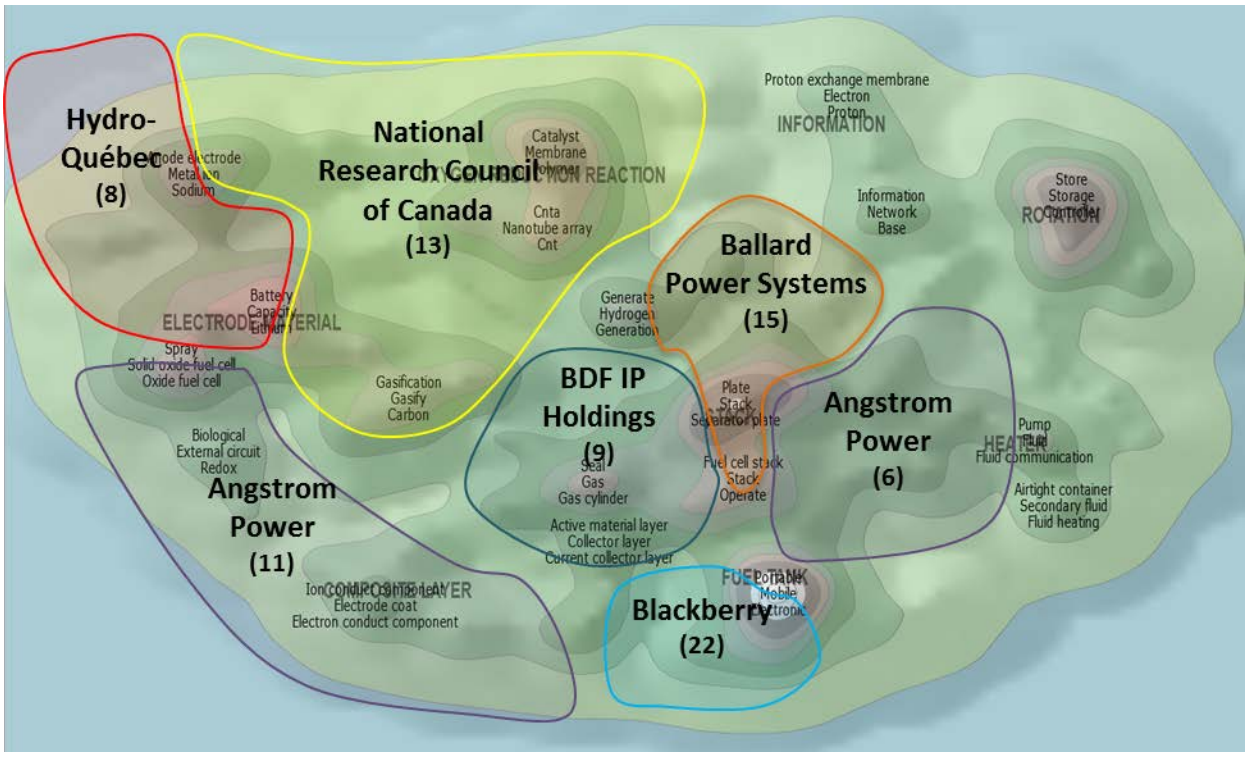
The top worldwide businesses or institutions patenting Clean Energy Enablers inventions are listed in figure 56. The companies are from Japan, Korea, the United States and France.

Figure 56: Top Businesses or Institutions in Clean Energy Enablers

Business or Institution
Samsung Electronics Limited (KR)
Panasonic Corporation (JP)
GM Global Technology Operations Incorporated (US)
Sanyo Electronic Company Limited (JP)
Honda Motors Company Limited (JP)
Sumitomo Corporation (JP)
Nissan Motor Company Limited (JP)
Hitachi Limited (JP)
LG Electronics Incorporated (KR)
Commissariat à l'Énergie Atomique et aux Énergies Alternatives (FR)

The Canadian businesses patent landscape map in figure 57 identifies some of the top Canadian businesses or institutions patenting in Clean Energy Enablers. Blackberry has multiple inventions around the snow-capped peak with keywords such as "portable", "mobile" and "electronic". The company has inventions around this peak linked to the use of fuel cells in mobile devices and hybrid battery systems for portable electronic devices. Ballard Power Systems and the National Research Council (NRC) are also active in the area of fuel cells. Hydro-Québec primarily works in the field of hydroelectricity but is also involved in rechargeable batteries for electric vehicles.[xlix] According to the Canadian Hydrogen and Fuel Cell Association (CHFCA), due to increased international demand in hydrogen and fuel cells, the Canadian sector has passed from an R&D phase to a commercialization phase. The organization also stated that 90% of Canadian hydrogen and fuel cell technology is exported, meaning that this technology sector, comprised of small and medium-sized enterprises and research organizations employing 2,000 Canadians, is promising for Canada.[l]

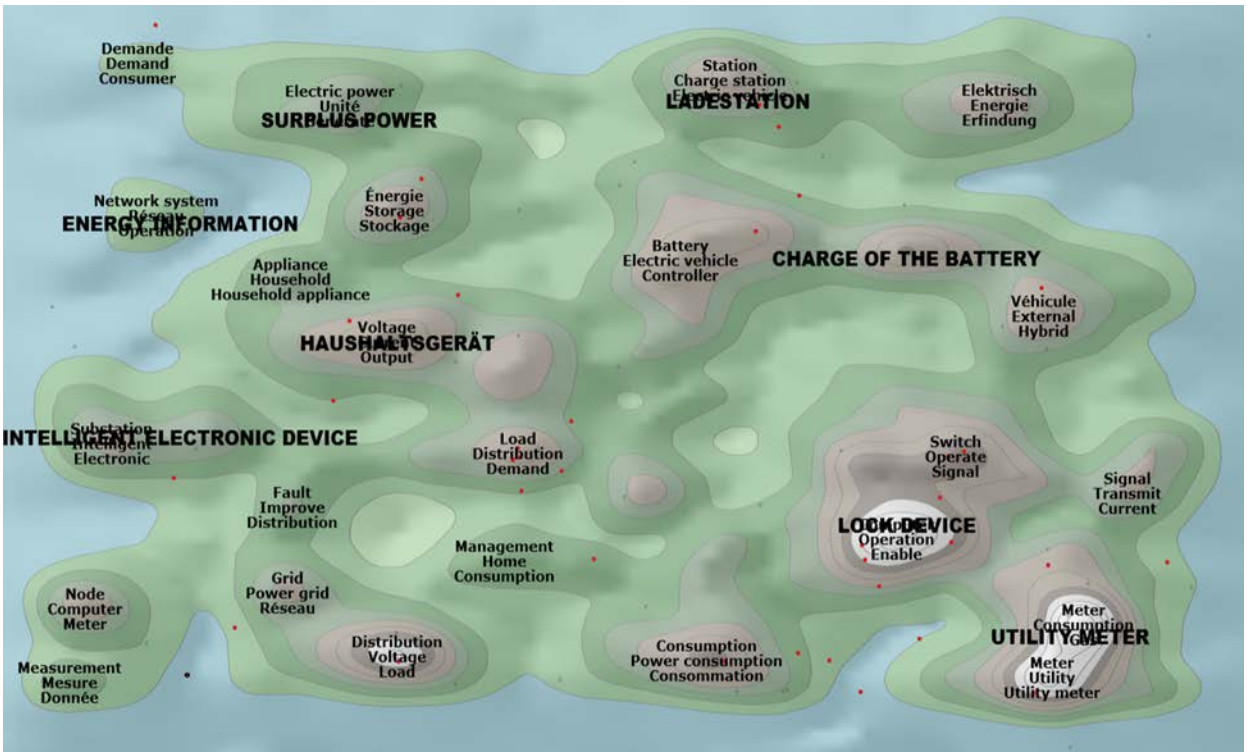
Figure 57: Landscape Map of Canadian Businesses with Clean Energy Enabling Inventions



SMART GRIDS

Smart Grids are related to the improvement of technologies related to an electrical supply network using digital communication technologies. Using communication technologies to optimize electricity usage ultimately empowers consumers to more efficiently control energy use thereby reducing the likelihood of outages.[li] This CCMT category is relatively new and compared to categories such as Transport and Buildings, Smart Grids has a lower level of patenting activity. Figure 58 illustrates the worldwide patent landscape map representing more than 3,000 inventions related to Smart Grids. The red dots depicting inventions by Canadian business are dispersed across the map suggesting that they are not specialized in one specific technology area relating to Smart Grids. Two snow-capped peaks can be found in the lower right-hand quadrant of the landscape map. The first is related to keywords such as "computer", "operation" and "enable" and includes inventions linked to data transfer methods for controlling energy services, data collection scheme for wireless networks and more. A second peak found in the lower right-hand quadrant of the map has keywords such as "meter", "consumption" and "gas" and covers inventions related to methods and apparatus related to technologies such as: consumption meters, smart meters enabling demand responses and measuring devices. Another snow-capped peak is joined to this second peak and is associated with similar keywords such as "meter", "utility", and "utility meter". Another peak is found in the lower left-hand quadrant of the map and is associated with keywords such as "distribution", "voltage" and "load". The inventions in this grouping relate to monitoring and controlling power distribution systems, adjusting voltage in a distribution system and more.

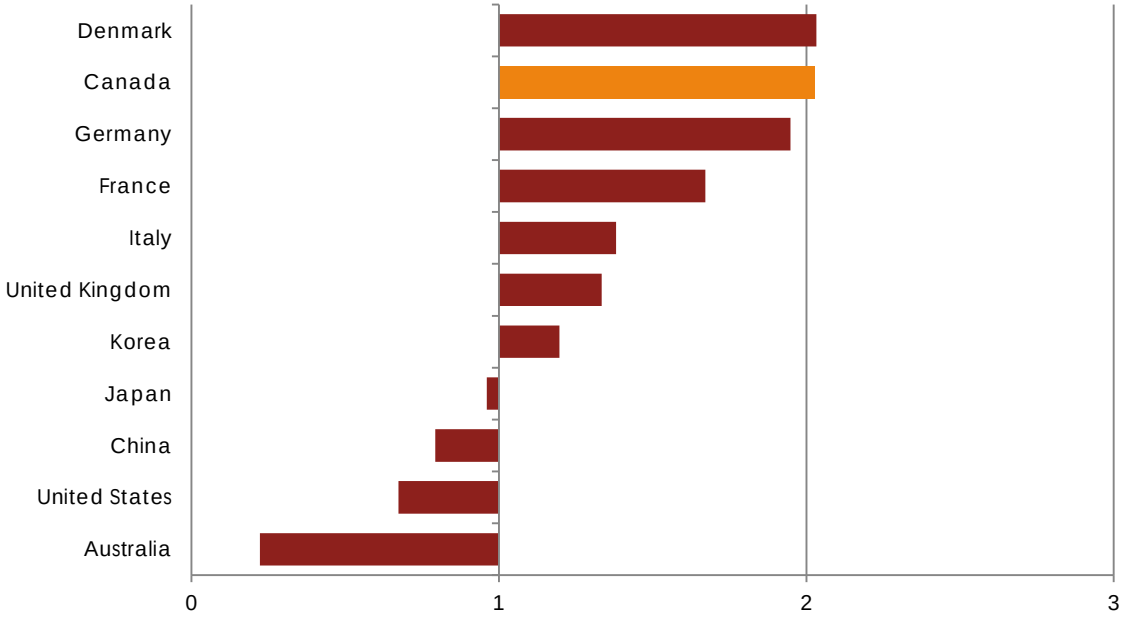
Figure 58: Landscape Map of Worldwide Patenting Activities in Smart Grids



Researchers

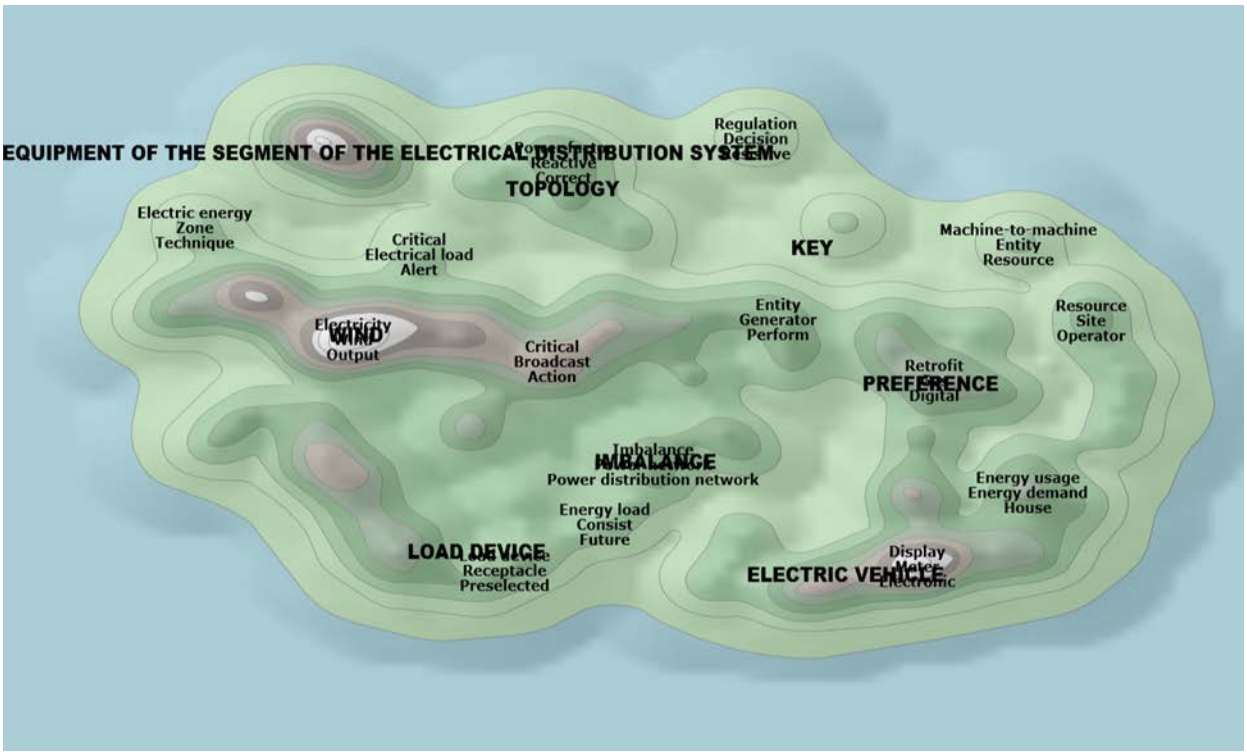
Canadian researchers have contributed to the advancement of this relatively new category. Figure 59 compares the Revealed Technological Advantage (RTA) index of Canadian researchers in the Smart Grids category to that of the researchers from the G7 countries along with four other countries, China, Korea, Australia and Denmark. Canadian researchers have an RTA index greater than one indicating a specialization. They also rank second among the selected countries.

Figure 59: Revealed Technological Advantage (RTA) Index by Origin of Researchers in Smart Grids



The landscape map in figure 60 illustrates the areas in which Canadian researchers are active in the Smart Grids category. A snow-capped peak can be found on the middle-left side of the map and is related to keywords such as "electricity", "wind" and "output". The inventions in this area are associated with electrical energy consumption reducing devices and systems for monitoring autonomously powered lights, security systems and parking meters. Another peak located at the bottom-right of the map associated with keywords such as "display", "meter" and "electronic" covers inventions related to methods and systems for monitoring and managing energy consumption.

Figure 60: Smart Grids Landscape Map of Patent Families Linked to Canadian Researchers



The Canadian businesses linked to Canadian researchers associated with more than one invention in the Smart Grids category are illustrated in figure 61. Most of the companies are American and few are Canadian. Schneider Electric USA and 2D2C for example, are associated with multiple Canadian researchers. The next section will show that many of these Canadian businesses associated with top Canadian researchers are also among the top Canadian businesses.

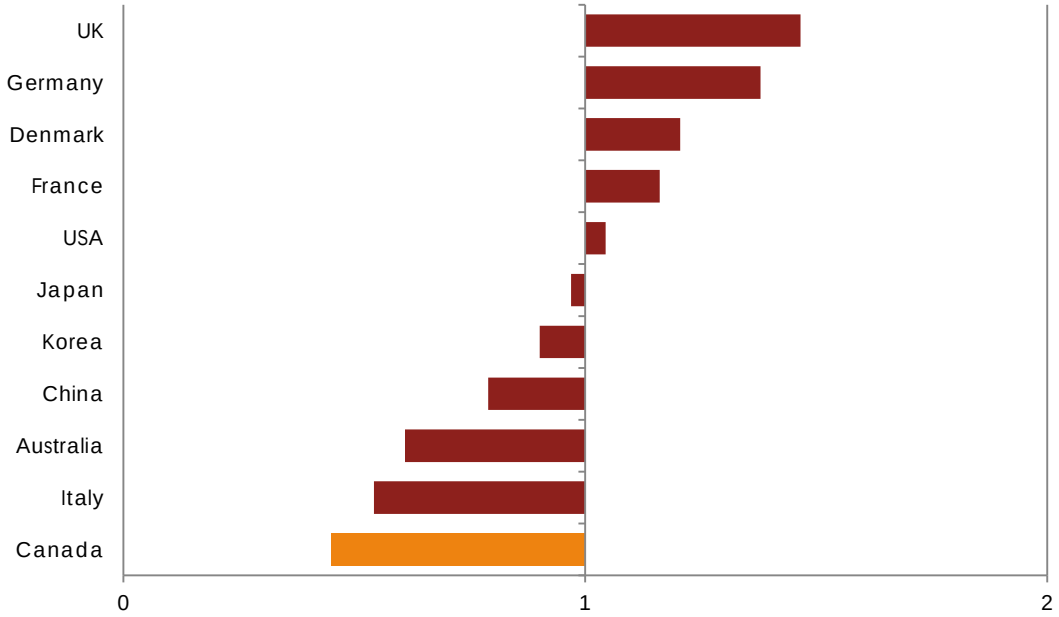
Figure 61: Top Canadian Researchers in Smart Grids

Top Canadian Researchers	Associated Business or Institution
Veillette, Michel	Trilliant Networks Incorporated (US)
Du Toit, Willem Hendrik	General Electric Company (US)
Klimek, Andrzej	Alstom (FR)
Hancock, Martin	Schneider Electric USA Incorporated (US)
Hirschbold, Markus	Schneider Electric USA Incorporated (US)
McSheffrey, William	Sine Slice Incorporated (CA)
Tremblay, Louis	AddÉnergie Technologies Incorporated (CA)
Metcalfe, Malcolm Stuart	Enbala Power Networks Incorporated (CA)
Jones, Nicolas	2D2C Incorporated (US)
Montgomery, Steven	2D2C Incorporated (US)
Kasztenny, Bogdan	General Electric Company (US)

Businesses and Institutions

Figure 62 compares the Revealed Technological Advantage (RTA) index of Canadian businesses in the Smart Grids category to that of the businesses from the G7 countries along with four other countries, China, Korea, Australia and Denmark. Canadian businesses have an RTA index below one indicating no specialization. Canada is ranked at the bottom among the selected countries. This is the opposite of what is seen in figure 59 where Canada is highly specialized relative to the other countries.

Figure 62: Revealed Technological Advantage (RTA) Index by Origin of Businesses in Smart Grids



The leading worldwide businesses or institutions patenting inventions related to Smart Grids are identified in figure 63. Many are well known electronics or car companies. More than half of the companies listed are Asian and primarily from Japan. Canadian companies do not appear in the list but two top Canadian researchers are associated with General Electric, a top business with Smart Grids inventions.

Figure 63: Top Worldwide Businesses or Institution in Smart Grids

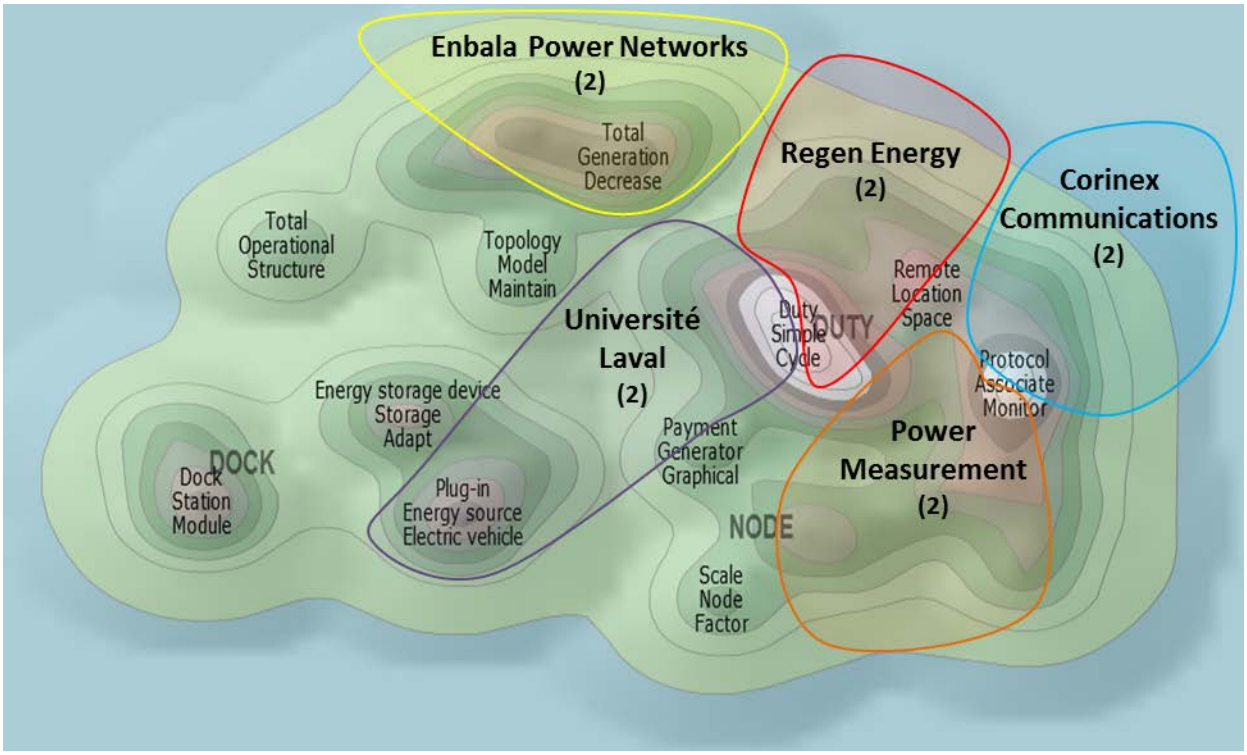
Business or Institution
Siemens AG (DE)
General Electric Company (US)
Panasonic Corporation (JP)
Toyota Motor Corporation (JP)
Hitachi Limited (JP)
ABB Technology AG (CH)
LG Electronics Incorporated (KR)
Toshiba Corporation (US)
Sony Corporation (JP)
Robert Bosch GmbH (DE)

The top Canadian businesses or institutions with Smart Grids related invention are identified in figure 64. These companies are identified in the landscape map in figure 65. Enbala Power Networks is a smart grid platform that enables industrial, commercial and municipal partners to be financially rewarded for the flexibility of their electrical equipment.[lii] Power Measurement Limited, which specializes in technologies for energy management and conservation, was acquired by Schneider Electric, a French company.[liii] It had previously received $1.7 million in funding from Sustainable Development Technology Canada (SDTC).[liv] Regen Energy, now called Encycle, is specialized in wireless systems for electrical demand management, demand response and load scheduling.[lv] Corinex Communications is a broadband over power lines company.[lvi]

Figure 64: Top Canadian Businesses or Institutions in Smart Grids

Business or Institution
Université Laval (CA)
Corinex Communications Corporation (CA)
Enbala Power Networks Incorporated (CA)
Power Measurement Limited (CA)
Regen Energy Incorporated (CA)

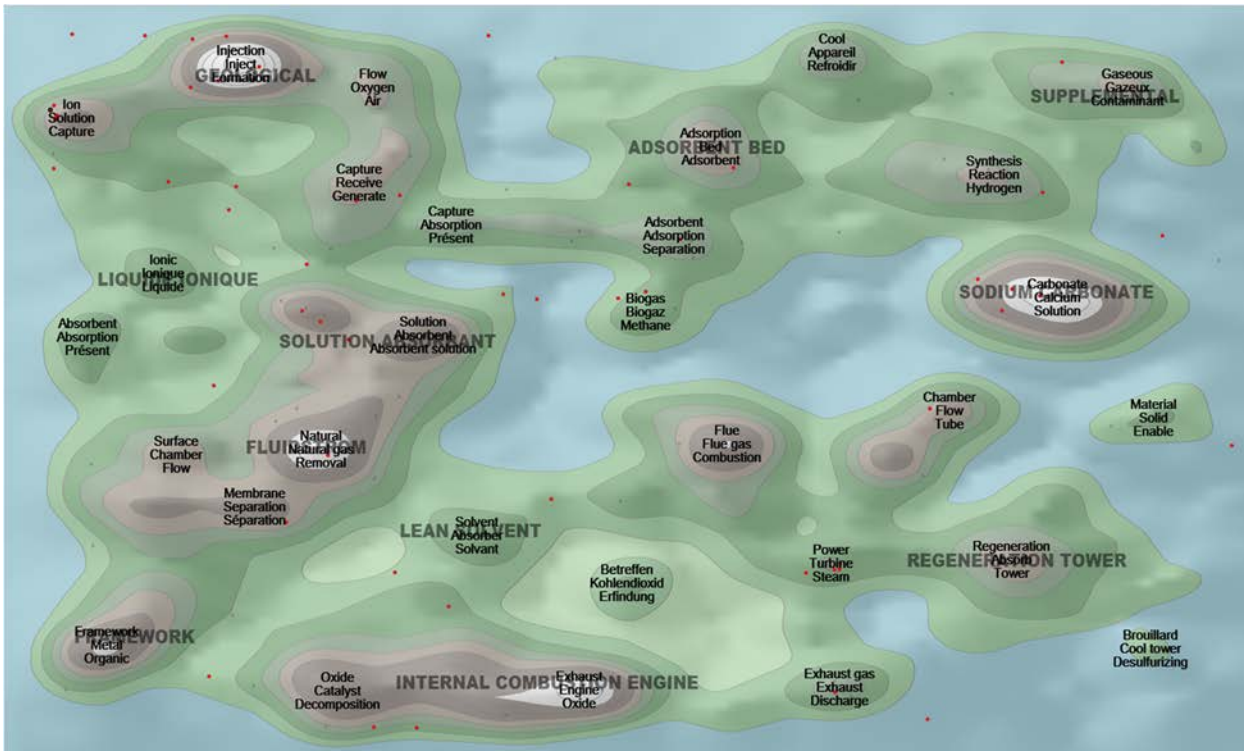
Figure 65: Landscape Map of Canadian Businesses with Smart Grids Inventions



CARBON CAPTURE

Carbon Capture related technologies are designed to capture waste, CO_2 and other greenhouse gases emitted from industrial facilities, transport it and prepare it for permanent storage.[lvii] Carbon Capture plays an important role in the area of climate change as it is considered an immediate solution for large emitters of greenhouse gases.[lviii] Carbon Capture methods were recently used by oil and gas industries in Norway, Canada and Algeria.[lix] Figure 66 illustrates the worldwide patenting landscape for Carbon Capture technologies which includes approximately 2,000 inventions. A snow-capped peak in the upper left-hand quadrant of the map related to keywords such as "injection", "inject" and "formation" is associated to inventions related to the geological sequestration of carbon dioxide. Another snow-capped peak in the bottom of the map related to keywords such as "exhaust", "engine" and "oxide" is linked to exhaust gas treatment systems and exhaust emission control devices for internal combustion engine. The red dots depicting inventions by Canadian businesses are dispersed across the map suggesting that they are not specialized in one specific technology area relating to Carbon Capture. The degree to which Canadian businesses are involved in important developments related to Carbon Capture technologies is questionable based on the visual representation in the landscape map considering the limited presence of Canadian patents around the snow-capped peaks.

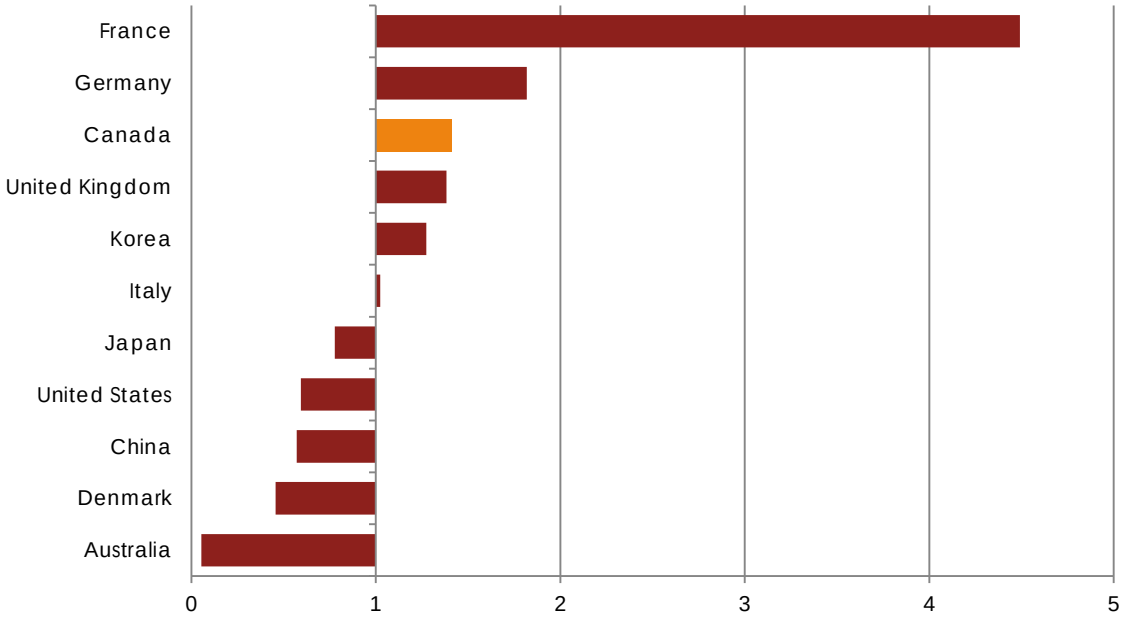
Figure 66: Landscape Map of Worldwide Patenting Activities in Carbon Capture



Researchers

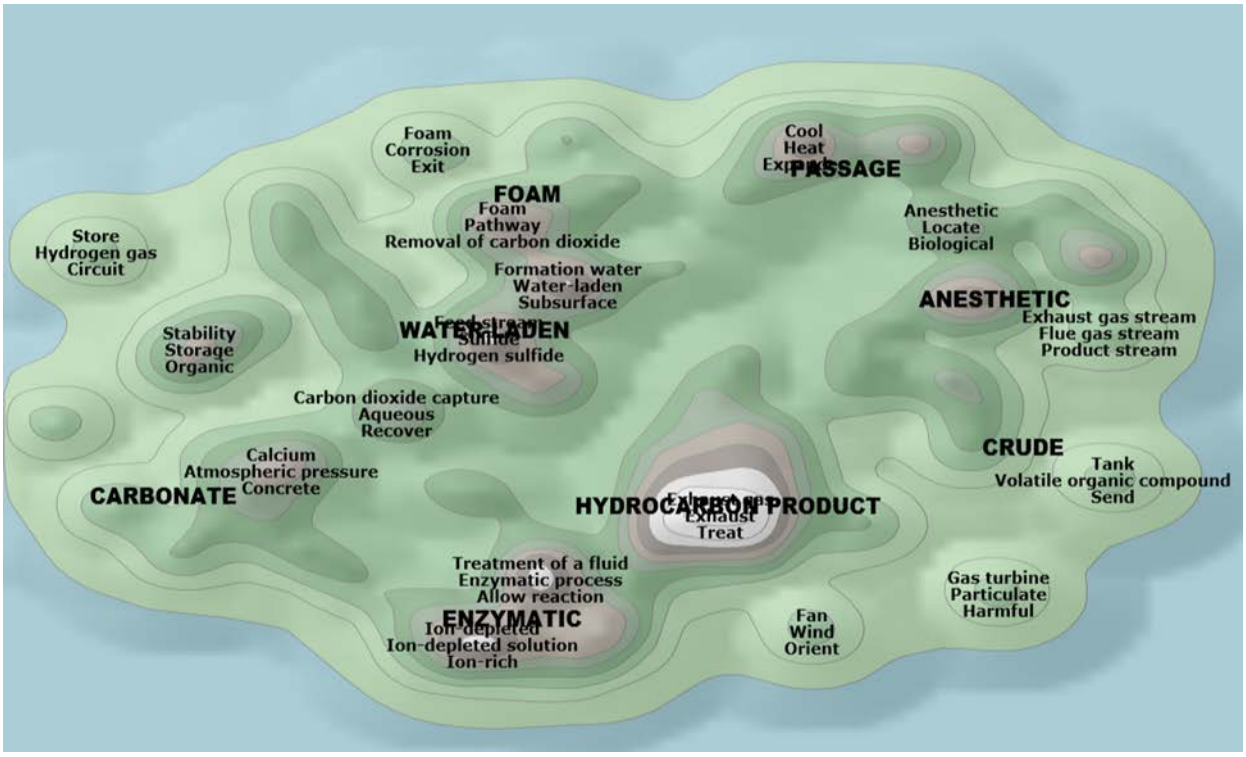
Figure 67 compares the Revealed Technological Advantage (RTA) index for Canadian researchers in the Carbon Capture category to that of researchers from G7 countries along with four other countries, China, Korea, Australia and Denmark. Canadian researchers have an RTA index greater than one indicating a specialization. Among the selected countries, Canada ranks third following France and Germany.

Figure 67: Revealed Technological Advantage (RTA) Index by Origin of Researchers in Carbon Capture



The landscape map in figure 68 illustrates the areas in which Canadian researchers are active in the Carbon Capture category. A large snow-capped peak can be found in the lower part of the map related to keywords such as “exhaust gas”, “exhaust” and “treat”. Some inventions around this peak are related to processes for the reduction of the carbon emission intensity of fuels.

Figure 68: Carbon Capture Landscape Map of Patent Families Linked to Canadian Researchers



Canadian researchers holding more than one invention in the Carbon Capture category and the associated businesses are listed in figure 69. All the associated companies are Canadian except for one. Multiple top Canadian researchers are associated with CO2 Solutions, Osum Oil Sands and Carbon Engineering. The next section will show that they are also top Canadian businesses.

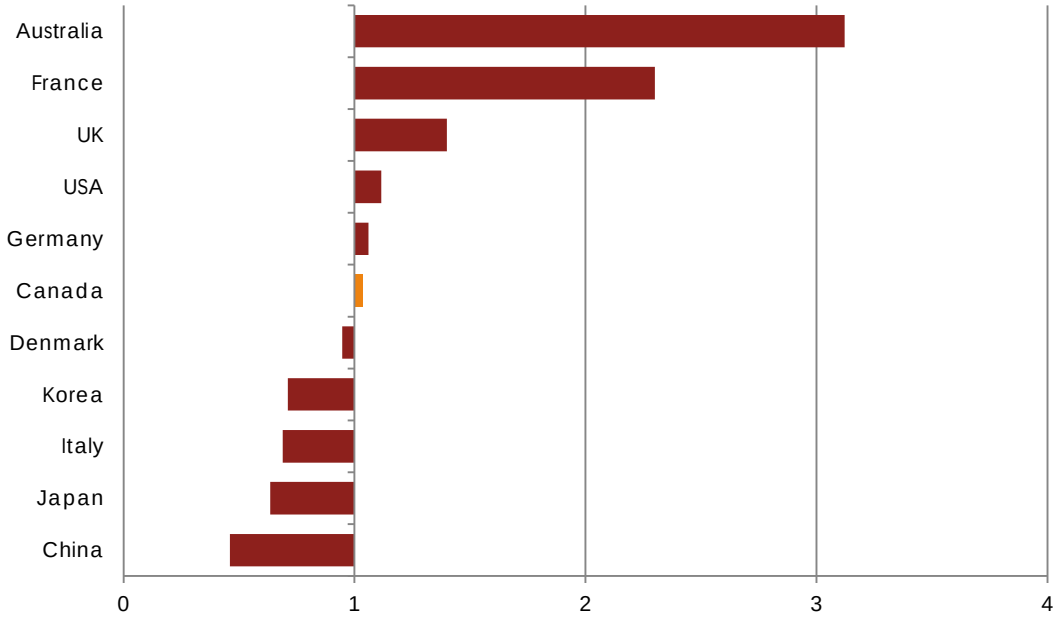
Figure 69: Top Canadian Researchers in Carbon Capture

Top Canadian Researchers	Associated Business or Institution
Fradette, Sylvie	CO2 Solutions Incorporated (CA)
Carley, Jonathan	CO2 Solutions Incorporated (CA)
Ceperkovic, Olivera	CO2 Solutions Incorporated (CA)
Kelly, Glenn	CO2 Solutions Incorporated (CA)
Gil, Henry	Osum Oil Sands Corporation (CA)
Keith, David	Carbon Engineering Limited Partnership (CA)
Peters, Eddy	Carbon Sink Incorporated (US)
Dusseault, Maurice	University of Waterloo (CA)
Gingras, Julie	CO2 Solutions Incorporated (CA)
Squires, Andrew	Osum Oil Sands Corporation (CA)
Parent, Carmen	CO2 Solutions Incorporated (CA)
Keefer, Bowie	QuestAir Technologies Incorporated (CA)
Babicki, Matthew	G4 Insights Incorporated (CA)
Belzil, Anne Levis	CO2 Solutions Incorporated (CA)
Bilak, Roman	Terralog Technologies Incorporated (CA)
Kuznicki, Steven	University of Alberta (CA)
Madore, Eric	CO2 Solutions Incorporated (CA)
Mahmoudkhani, Maryam	Carbon Engineering Limited Partnership (CA)
Moisan, Michel	Université de Montréal (CA)
Ouimet, Michel	Cansolv Technologies Incorporated (CA)

Businesses and Institutions

Figure 70 compares the Revealed Technological Advantage (RTA) index for Canadian businesses in the Carbon Capture category to that of businesses from G7 countries along with four other countries, China, Korea, Australia and Denmark. Canadian businesses, ranking 6th overall, have an RTA index greater than one indicating a specialization. It is interesting to see that both Canadian businesses and researchers have a specialization in this category.

Figure 70: Revealed Technological Advantage (RTA) Index by Origin of Businesses in Carbon Capture



The Canadian businesses or institutions with more than one Carbon Capture related invention are identified in figure 71. It is interesting to see that Canadian companies along with the Federal Government department of Natural Resources Canada and the University of Regina are involved in inventions from this category. CO2 Solutions and Osum Oil Sands are associated with multiple top Canadian researchers as seen in figure 69.

Figure 71: Top Canadian Businesses or Institutions in Carbon Capture

Business or Institution
CO2 Solutions Incorporated (CA)
Schlumberger Canada Limited (CA)
Osum Oil Sands Corp. (CA)
University of Regina (CA)
Natural Resources Canada (CA)
Shell Canada Limited (CA)

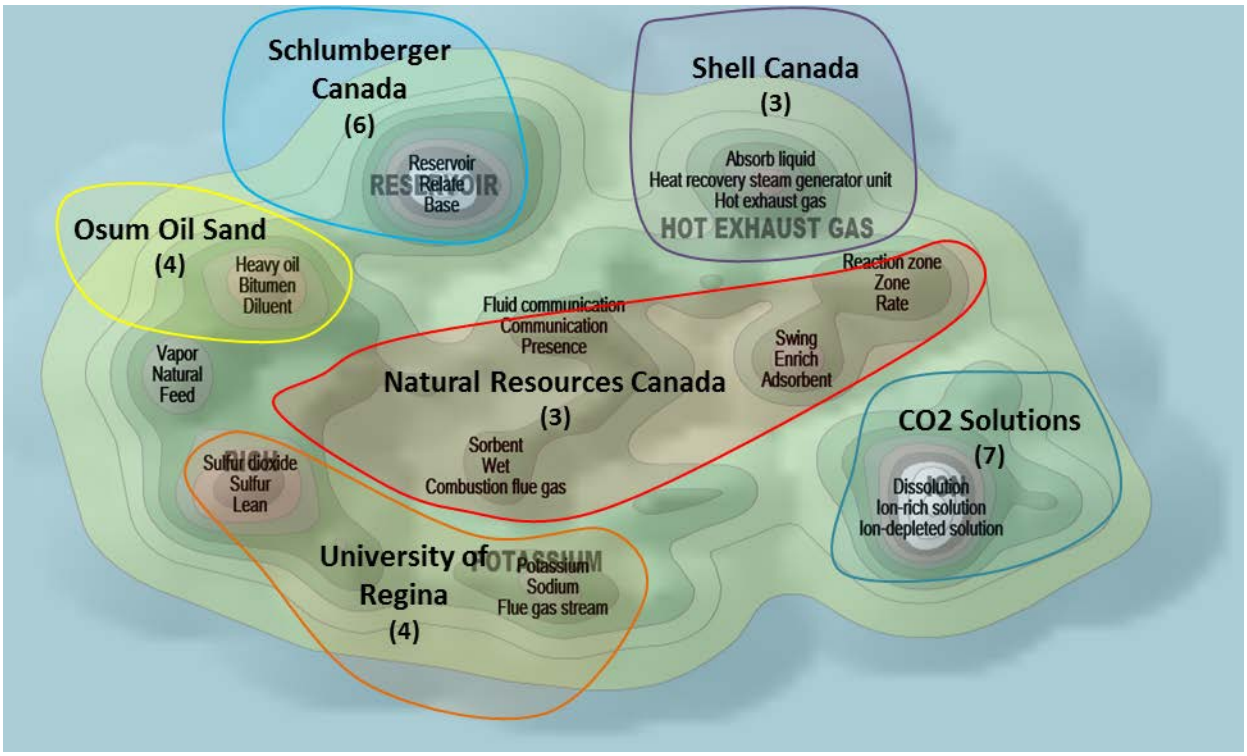
The leading worldwide businesses or institutions patenting Carbon Capture related inventions are listed in figure 72. Many of the leading companies or institutions patenting Carbon Capture inventions are from Europe, the United States and Asia. Despite Canadian businesses having a specialization in Carbon Capture, there are no Canadian companies listed.

Figure 72: Top Worldwide Businesses or Institutions in Carbon Capture

Business or Institution
Air Liquide (FR)
Alstom Technology Limited (CH)
Mitsubishi Electric Corporation (JP)
SHELL Internationale Research Maatschappij B.V. (NL)
General Electric Company (US)
Siemens AG (DE)
ExxonMobil Research and Engineering Company (US)
Linde AG (DE)
Honeywell UOP Limited Liability Company (US)
BASF SE (DE)

The top Canadian businesses or institutions are identified in the patent landscape map in figure 73. CO2 Solutions has inventions related to processes for carbon dioxide capture. Schlumberger Canada has inventions related to a methodology for underground storage of carbon dioxide and the department of Natural Resources Canada has inventions related to a gas separation system for carbon dioxide capture and compression. According to Natural Resources Canada, Canada has a world-class geological storage potential for carbon dioxide. The country is also involved in multiple commercial and demonstration projects. Saskatchewan's Weyburn project, for example, is one or the first large-scale projects related to capturing carbon dioxide in the world.[lx] This could explain the involvement of the University of Regina.

Figure 73: Carbon Capture Landscape Map of Patent Families Linked to Canadian Businesses

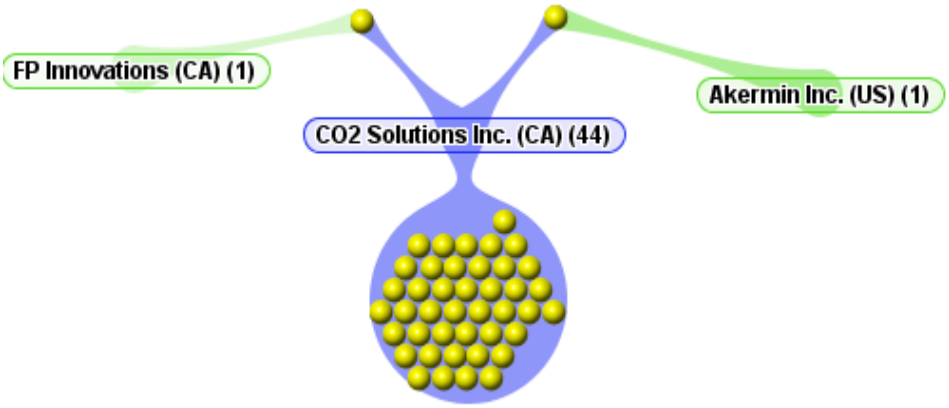


CO2 Solutions – a Canadian Success Story

CO2 Solutions is among the top Canadian patenting businesses in Carbon Capture. The Quebec-based company has built an extensive patent portfolio covering the use of carbonic anhydrase for the efficient post-combustion capture of carbon dioxide. In 2012 and 2013, CO2 Solutions received $5.2 million in grants from the Government of Canada's ecoEnergy Innovation Initiative and the Alberta Government Climate Change and Emissions Management Corporation (CCEMC) for a $7.5 million project to optimize and pilot the technology for carbon dioxide capture from oil sands production.[lxi] The company also received $348,000 in funding from the National Research Council (NRC) of Canada's Industrial Research Assistance Program (IRAP) and $2.4 million grant from Sustainable Development Technology Canada (SDTC).[lxii]

CO2 Solutions has collaborated with multiple companies through patenting, licensing or for business in general. The collaboration map in figure 74 shows links to Akermin Inc., a former American competitor and FP innovation, a Canadian non-for-profit company specializing in the development of innovative solutions to support the Canadian forest sector.[lxiii] Akermin Inc. appears in the collaboration map because CO2 Solutions purchased intellectual property owned by Akermin Inc. for $400,000.[lxiv] CO2 Solutions has collaborated with FP Innovations on an invention related to a gas purification apparatus and a process using biofiltration and enzymatic reactions. CO2 Solutions also announced a collaboration agreement with Hatch Ltd., a global consulting and engineering firm, whereby CO2 Solutions will license its proprietary technology.[lxv] The company also collaborated with multiple other Canadian and foreign companies integrating CO2 Solutions' proprietary technology in large scale industrial environments.[lxvi]

Figure 74: Collaboration Map for CO2 Solutions



CONCLUSION

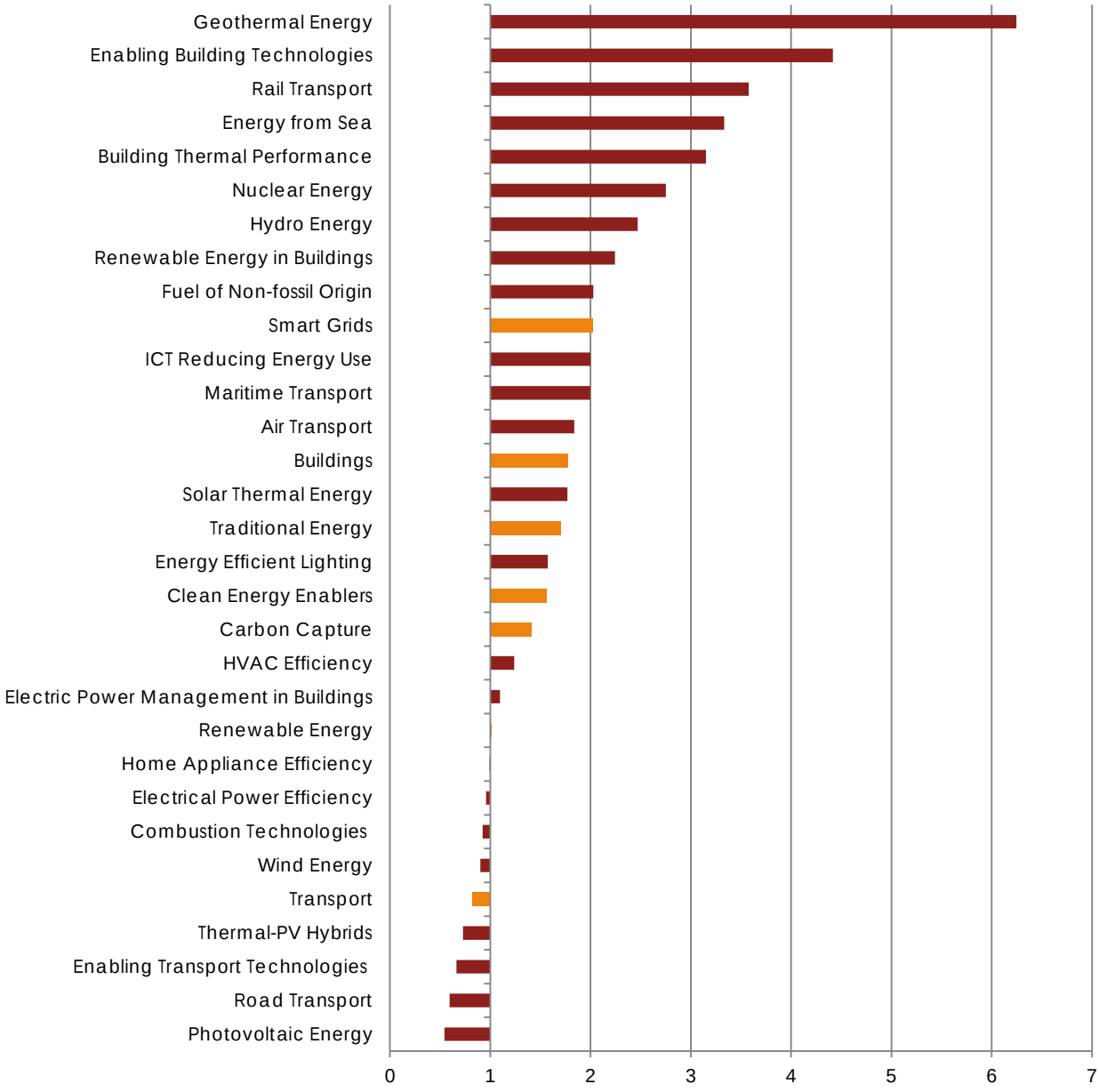
In this report, we investigate the patenting activity of Canadian researchers and Canadian businesses in the field of Climate Change Mitigation Technologies (CCMT). The EPO patent classification tagging scheme is used to identify CCMT patents in the Buildings, Renewable Energy, Traditional Energy, Carbon Capture, Smart Grids, and Transport categories and subgroups. The analysis is provided from two perspectives, one examining patenting activity by Canadian researchers and the other examining patenting activity by Canadian businesses. Canadian researchers are characterized as being relatively specialized in all CCMT categories except Transport. The results are significantly different for Canadian businesses where Carbon Capture is the only category in which Canadian businesses are specialized. Furthermore, the leading Canadian businesses patenting in CCMT are not among the world's top businesses. Canadian businesses patent extensively in the subgroups related to Transport, a technology area in which they do not have a technological specialization. In general, both Canadian researchers and Canadian businesses are relatively specialized in CCMT technologies related to Hydro Energy, Technologies for the Production of Fuels from Non-Fossil Origin, Nuclear Energy and Carbon Capture. Finally, separating researchers and businesses in the analysis provides a better understanding of the state of innovation in CCMT. Having an understanding of Canada's technological strengths from the perspective of researchers and businesses helps policymakers develop targeted policies that can be designed to increase our strength in specific technology fields with the ultimate objective of advancing innovation in climate change mitigation technologies.

APPENDIX A : Patent Classification Codes

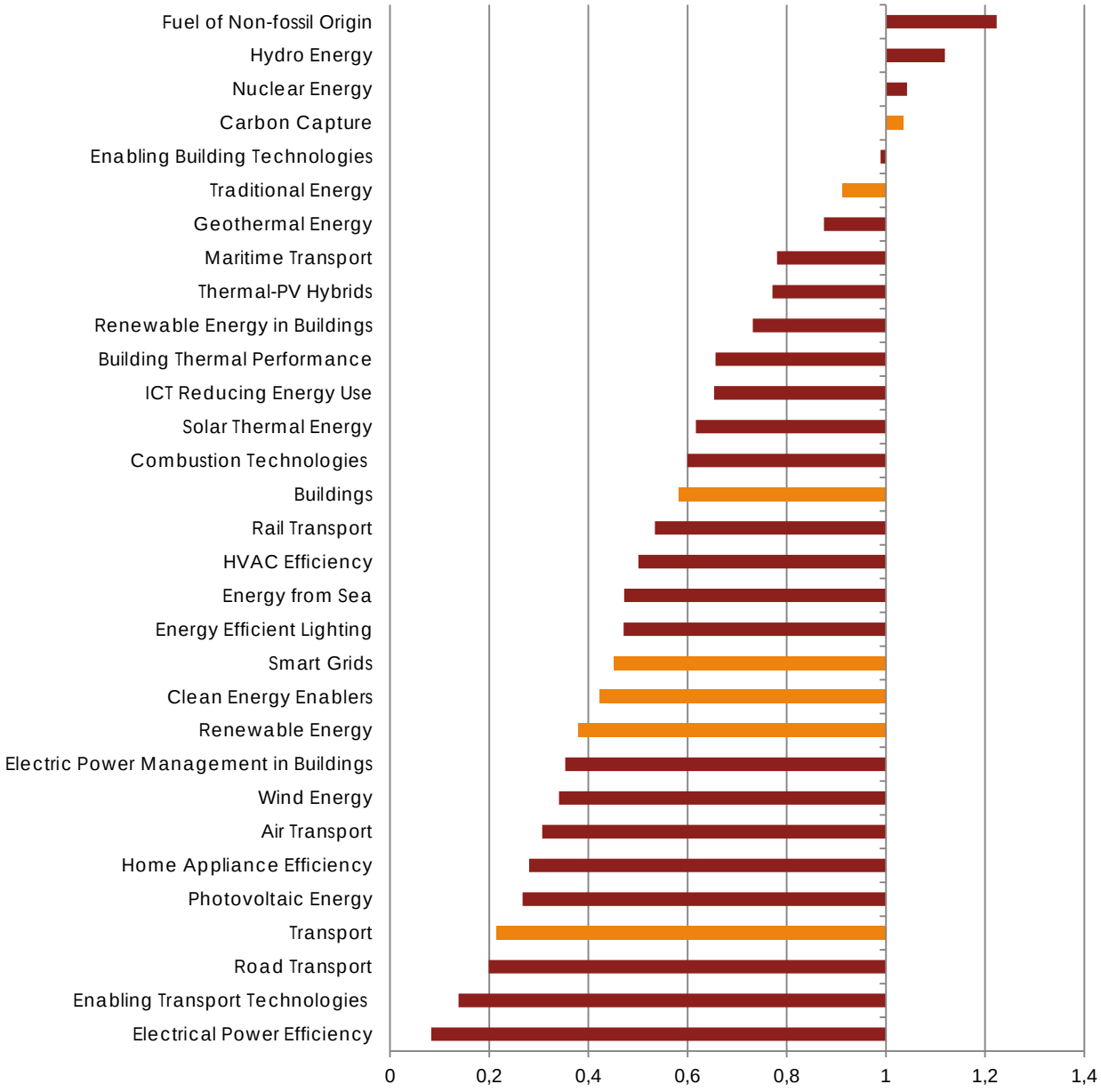
Classification Code	Description
Y02B	**INDEXING SCHEME RELATING TO CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, e.g. INCLUDING HOUSING AND APPLIANCES OR RELATED END-USER APPLICATIONS**
Y02B10	Integration of renewable energy sources in buildings
Y02B20	Energy efficient lighting technologies
Y02B30	Energy efficient heating, ventilation or air conditioning [HVAC]
Y02B40	Technologies aiming at improving the efficiency of home appliances
Y02B50	Energy efficient technologies in elevators, escalators and moving walkways
Y02B60	Information and communication technologies [ICT] aiming at the reduction of own energy use
Y02B70	Technologies for an efficient end-user side electric power management and consumption
Y02B80	Architectural or constructional elements improving the thermal performance of buildings
Y02B90	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
Y02C	**CAPTURE, STORAGE, SEQUESTRATION OR DISPOSAL OF GREENHOUSE GASES [GHG]**
Y02E10	**ENERGY GENERATION THROUGH RENEWABLE ENERGY SOURCES**
Y02E101	Geothermal energy
Y02E102	Hydro energy
Y02E103	Energy from sea
Y02E104	Solar thermal energy
Y02E105	Photovoltaic [PV] energy
Y02E106	Thermal-PV hybrids
Y02E107	Wind energy
Y02E20-50	**TRADITIONAL ENERGY**
Y02E20	Combustion technologies with mitigation potential
Y02E30	Energy generation of nuclear origin
Y02E40	Technologies for an efficient electrical power generation, transmission or distribution
Y02E50	Technologies for the production of fuel of non-fossil origin
Y02E60-70	**CLEAN ENERGY ENABLERS**
Y02E60	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
Y02E70	Other energy conversion or management systems reducing GHG emissions
Y02T	**CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION**
Y02T10	Road transport of goods or passengers
Y02T30	Transportation of goods or passengers via railways
Y02T50	Aeronautics or air transport
Y02T70	Maritime or waterways transport
Y02T90	Enabling technologies or technologies with a potential or indirect contribution to GHG emissions mitigation
Y04S	**SYSTEMS INTEGRATING TECHNOLOGIES RELATED TO POWER NETWORK OPERATION, COMMUNICATION OR INFORMATION TECHNOLOGIES FOR IMPROVING THE ELECTRICAL POWER GENERATION, TRANSMISSION, DISTRIBUTION, MANAGEMENT OR USAGE, i.e. SMART GRIDS**

We combine Y02E20, 30, 40, and 50 and call the category Traditional Energy (Y02E 20-50). We also combine Y02E60 and 70 and call the category Clean Energy Enablers (Y02E 60-70). Y02E10 is a combination of Y02E101, 102, 103, 104, 105, 106 and 107 and we call the category Renewable Energy (Y02E 101-107).

APPENDIX B: Ranking Category and Subgroup Revealed Technological Advantages (RTA) for Canadian Researchers



APPENDIX C: Ranking Category and Subgroup Revealed Technological Advantages (RTA) for Canadian Businesses and Institutions



[i] Canadian Intellectual Property Office, http://www.ic.gc.ca/eic/site/cipointernet-internetopic.nsf/eng/h_wr00025.html
[ii] Discussion Paper of the Working Group on Clean Technology, Innovation and Jobs (2016)
[iii] 2017 Canadian Clean Technology Industry Report, Analytica Advisors. http://analytica-advisors.com/sites/default/files/2017%20Canadian%20Clean%20Technology%20Industry%20Report%20Synopsis%20FINAL.pdf
[iv] Pan-Canadian Framework on Clean Growth and Climate Change: Canada Plan to Address Climate Change and Grow the Economy (2016). https://www.canada.ca/content/dam/themes/environment/documents/weather1/20170125-en.pdf
[v] Discussion Paper of the Working Group on Clean Technology, Innovation and Jobs (2016) http://www.climatechange.gc.ca/Content/6/4/7/64778DD5-E2D9-4930-BE59-D6DB7DB5CBC0/Working%20Group%20on%20Clean%20Technology,%20Innovation%20and%20Jobs%20Final%20Report%20Engl....pdf

[vi] http://www.climatechange.gc.ca/Content/6/4/7/64778DD5-E2D9-4930-BE59-D6DB7DB5CBC0/WG_Report_SPECIFIC_MITIGATION_OPPORTUNITIES_EN_V04.pdf
[vii] http://www.nrcan.gc.ca/energy/resources/mission-innovation/18612
[viii] https://www.canada.ca/en/innovation-science-economic-development/news/2017/04/budget_2017_measurestosupportcleantechnology.html
[ix] https://www.canada.ca/en/environment-climate-change/news/2016/11/canada-submits-century-strategy-clean-growth-economy.html?=undefined&
[x] http://unfccc.int/files/focus/long-term_strategies/application/pdf/canadas_mid-century_long-term_strategy.pdf
[xi] Subclasses Y02 and Y04 are only to be used for tagging documents which are already classified or indexed elsewhere and which relate in a broad sense to specific major technical fields. As the primary purpose of the tagging is to monitor new technological development and to tag cross-sectional technologies that do not fit in a single other section of the IPC, the tagging codes of this section do not in any way replace the classification or indexing codes of the other sections. (https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y.html)
[xii] The Renewable Energy (Y02E10) category is composed of CPC subgroups Y02E101, 102, 103, 104, 105, 106 and 107. Traditional Energy category includes CPC subgroups Y02E20, Y02E30, Y02E40, and Y02E50. CPC subgroups Y02E60 and Y02E70 are combined to form the Clean Energy Enablers category.
[xiii] http://www.ieso.ca/Pages/Ontario%27s-Power-System/Smart-Grid/default.aspx
[xiv] http://www.energy.alberta.ca/CCS/pdfs/FSCCS.pdf
[xv] Environmental Policy and Innovation, Environment and Climate Change Canada (2016)
[xvi] Kleinknecht, Alfred, Van Montfort, Kees and Brouwew, Erik, (2002). "The Non-Trivial Choice Between Innovation Indicators" Economics of Innovation and New Technology 11(2), 109-121.
[xvii] OECD (2010), "Insight into different types of patent families," Statistical Analysis of Science, Technology and Industry Working Paper 2010/2, Paris.
[xviii] Hanel, Petr, (2008). "The Use of Intellectual Property Rights and Innovation by Manufacturing Firms in Canada," Economics of Innovation and New Technology 17(4), 285-309.
[xix] 2014 Survey on Financing and Growth of Small and Medium Enterprises, ISED and Statistics Canada
[xx] Baldwin, John R. and Gellatly, Guy (2006). "Innovation Capabilities: The Knowledge Capital Behind the Survival and Growth of Firms," The Canadian Economy in Transition Research Paper Series, Statistics Canada
[xxi] Dernis, H. and D. Guellec. 2001. Using patent counts for cross-country comparisons of technology output. STI mimeo, Organisation of Economic Co-operation and Development.
[xxii] 2014 Survey on Financing and Growth of Small and Medium Enterprises, ISED and Statistics Canada
[xxiii] http://www.hse.ru/data/2013/04/10/1297571825/09STI2013.pdf
[xxiv] Institut Européen d'Administration des Affaires
[xxv] Quacquarelli Symonds (QC) University Rankings
[xxvi] http://www.hse.ru/data/2013/04/10/1297571825/09STI2013.pdf
[xxvii] http://www.climatechange.gc.ca/Content/6/4/7/64778DD5-E2D9-4930-BE59-D6DB7DB5CBC0/WG_Report_SPECIFIC_MITIGATION_OPPORTUNITIES_EN_V04.pdf
[xxviii] Ibid
[xxix] http://www.theglobeandmail.com/report-on-business/canadas-innovation-gap/article1368640/?page=all
[xxx] http://bcic.ca/wp-content/uploads/2015/12/bcic_csl_0006_westport.pdf
[xxxi] Ibid
[xxxii] http://www.westport.com/news/2014/westport-and-delphi-sign-joint-development-agreement-to-commercialize-natural-gas-injector-tech
[xxxiii] http://www.westport.com/company/merger/
[xxxiv] http://helioscsp.com/magna-announces-new-facility-in-arizona-for-solar-energy/
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