AN OVERVIEW
MEASURING INNOVATION PERFORMANCE IN CANADA'S RESOURCE SECTORS

Background paper prepared for the Public Policy Forum, May 2011

1. INTRODUCTION

On October 22, 2010, the Public Policy Forum (PPF) convened *Innovation in Canada's Resource Sectors,* a conference hosted in partnership with Natural Resources Canada. The purpose of the conference was to explore the current state of innovation among Canada's resource sectors, as well as opportunities and strategies to advance current innovation efforts. Panellists and participants, including members of the private sector, academia and federal and provincial governments, represented a variety of sector interests.

Conference participants were asked to focus on actionable solutions to enhance innovative capacity among Canada's resource sectors, and identified three next steps. First, a concerted effort must be made to fully account for the innovative activities of the resource sector using relevant metrics. Second, more needs to be done to build a culture of innovation in the resource sectors. Last, resource industries can and must do a better job at connecting and collaborating with each other in order to share knowledge and best practices.

This paper draws in large measure on an earlier version prepared in support of the 2010 PPF conference. It is important to note that this backgrounder does not attempt to fill an identified gap in available data concerning innovation performance in natural resource industries, nor to fully investigate how or why innovation occurs in the resource sectors. [1]

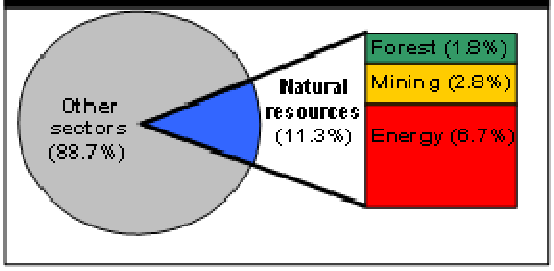
Instead, the paper's principal focus is a review of the performance measures used to describe and gauge innovation, as well as their limitations and alternatives. It begins by providing an overview of the role of resource sectors in Canada's economy, followed by a description of the unique characteristics of innovation in the industry. Last, it discusses trends in selected innovation metrics within the resource sectors.

2. NATURAL RESOURCES IN CANADA

2.1 Role in the Canadian economy

Resources play a key role in Canada's economy. The energy, mining and forest products sectors have served as an engine of economic growth and job creation for generations of Canadians.[2] In 2010, the extraction and processing of natural resources contributed over 11% of Canada's GDP ($140 billion in 2002 constant dollars) and directly employed about 755,000 workers (see Figure 1 and Table 1). [3]

Figure 1: Natural resources' contribution to Canada's GDP, 2010



Source: NRCan, Statistics Canada

Canada is also a leading exporter of natural resources. For example, in 2009 Canada was the world's largest exporter of potash, the second largest exporter of uranium, newsprint, wood pulp and softwood lumber,

Canada

Table 1: Contribution of natural resources to various Canadian economic indicators, 2010	
Contribution to…	**Percent of Total**
Real GDP	11.3%
Direct Employment	5.1%
New Capital Investments	23.5%
Exports	53.1%
Imports	29.1%

Source: NRCan, Statistics Canada

and the third largest exporter of nickel and natural gas. Together, resources accounted for over half the value of Canadian goods exported in 2010. Over 75% of Canada's resource exports are destined for U.S. markets, including 55% of Canada's minerals and metals, 97% of energy and 71% of forest products exports.

Both domestic and foreign investment bring many benefits to the Canadian economy, including helping to improve innovation performance. As highly capital-intensive industries, natural resource sectors also contribute significantly to Canada's investment portfolio. Capital investment in Canadian resource sectors accounted for approximately one-quarter of the national total in 2010, amounting to roughly $80 billion. Importantly, these investments also support significant economic activity in other industries, including construction, equipment manufacturing (i.e., advanced technology), engineering and financial services sectors.

In 2010, foreign direct investment (FDI) among Canadian resource sectors was over $198 billion, accounting for more than 35% of the national total. Direct investment abroad by Canadian resource firms hovers between 20% and 25% of the national total, reaching more than $140 billion in 2009.

2.2 Natural resource sector outlook

Since mid-2009, higher commodity prices, driven largely by strong demand in emerging economies (particularly China) have contributed to a resurgence of growth in Canada's natural resource sector. Overall output and exports of Canada's resource sectors are rising.

While sound fundamentals are expected to continue to support growth in the natural resource sectors over the long term, a few issues are causing uncertainty over the short term. In particular, the demand outlook for all natural resources is clouded by continuing uncertainty about the strength of the US economy and the global economic recovery.

Resource sectors will continue to play an important role in Canada's future prosperity. However, energy, mining and forest products firms are facing new challenges. For one, Canada's non-renewable resource base is increasingly unconventional, placing Canadian producers on the high end of the cost curve. Second, resource firms must find ways to add value to their products to increase revenues. As well, resource firms are under increasing pressure to reduce their social and environmental impacts in order to maintain their social license to operate, respond to consumer demand, address international regulations and sustain or strengthen their reputation.

Furthermore, innovative clean technologies and processes represent a potential source of innovation, improved productivity and resource efficiency. Canada has the potential to be a global leader in "clean-tech" markets

– like clean power generation – and to be an important niche player in some supply chains, such as carbon capture and storage (see textbox).

These drivers point to the need for natural resource sectors to continue to innovate to remain competitive.[4]

3. Innovation in Resources

3.1 Characterizing innovation

In recent years, innovation has been at the forefront of discussions on the future of the Canadian economy. Concerns about economic competitiveness and Canada's relatively low position in international rankings of innovation and productivity have caused many to raise concerns about our ability to compete in the global economy. As a result, many experts stress the need for Canada to intensify the transformation of the Canadian economy into a leader in innovation.[5]

While there is no single definition of innovation, the OECD's *Oslo Manual* – a respected source on the development and interpretation of innovation metrics – provides a generally accepted meaning: "the implementation of a new or significantly improved product (good or service) or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations".[6]

However, simply creating a new product, process or service is not enough. According to Roger Martin, chairman of the Ontario Institute for Competitiveness and Prosperity, innovation must not be confused with invention – the creation of something new –

Clean Technologies – Innovating to build on Canada's competitive advantage

Clean technology has the potential to transform Canadian businesses through the production and use of all resources in more efficient ways. It can contribute to the commercialization of greener products and technologies, improve productivity, meet market expectations of investors and consumers and reduce GHG emissions.

The market for clean technology is sizeable and projected to grow. Innovas, a UK-based think tank, estimated that the global market for low-carbon goods and services was worth CND $6.5 trillion in 2007/08.[1] As well, a US-base source predicts that clean energy technology will be the third-largest industrial sector in the world by 2020, worth roughly US $2 trillion.[2]

Canada has established strengths in specific clean technologies. A well known example is Ballard Power Systems' hydrogen fuel cells, which were used in the world's first fleet of fuel cell buses for the Vancouver 2010 Olympics. Other examples include carbon capture and storage, advanced materials for vehicles and smaller niche technologies like gas turbines and photovoltaic system controllers.

Taking advantage of Canada's established strengths hinges on the ability to turn ideas into new commercial products and services quickly, and adopt the best technologies across the entire economy. This will require new and innovative ways of doing business that maximize local and global value chains for Canadian products and processes.

[1] Innovas, *Low Carbon and Environmental Goods and Services: An Industry Analysis* – 2009.

[2] Roland Berger Strategy Consultants, *Clean Economy, Living Planet: Building Strong Clean Energy Technology Industries – 2009.*

but must also involve a tangible economic or social benefit.

Innovation takes many forms and can occur in any aspect of a business' operation. As a result, organizations and researchers have chosen to categorize innovation in several different ways. For example, in their 2008 study of the national innovation system, the Australia government provides a summary of different types of innovation often cited in the literature.[7]

Radical vs Incremental – Radical innovations lead to fundamental changes in processes or products, while incremental innovations involve adaptations of a core innovation in particular applications.

Process vs Product – Process innovations reduce the costs of producing and delivering a given good or service (a product), while product innovations improve the qualities of existing products or provide new products to be offered to consumers.

Science-led vs Customer-driven – Science-led innovations are an outcome of scientific research both in the public and private sectors, while customer-driven innovation is built upon careful market research and user interaction.

Technological vs Organisational – Technological innovations are generally embodied in equipment used by labour, while organisational innovations involve the organisation and reorganisation of groups of people into effective teams in the production and delivery of goods and services.

3.2 Features of resource sector innovation

The form and characteristics of innovation processes in each sector of the economy are shaped by the different drivers, constraints and opportunities each one faces. The natural resource sectors are made up of industries with widely different characteristics. They do not perform economically as a group; prices for some may soar while others collapse. Nevertheless, it is possible to identify a few commonly shared features that differentiate resource industries from other sectors of the economy:

Commodity production – Many resource-based industries produce products differentiable only on the basis of price and sold on global markets – in other words, they are commodity producers. According to the first 2006 Banff Innovation Summit – a meeting of 35 Western Canadian leaders of industry, government and civil society – resource commodity producers face "volatile and ruthlessly competitive global markets with razor-thin margins and dense value added structures. Few, if any, of the competitive conditions in these markets globally are determined in Canada, even when unique endowments like the oil sands are concerned."[8]

Capital intensity – Resource operations, particularly in the extractive (mining and oil & gas) sectors, entail very large capital investments. Furthermore, in many cases initial investments in technology and structures result in capital that remain in service for several years, even decades, and may be difficult to change once put into place. The scale of resource projects, along with the volatility of commodity markets, makes resource production an inherently risky venture.

Complexity – The production processes of natural resource products are multidimensional and involve numerous activities: exploration, gaining access to resources, resource management, harvesting or extraction, manufacturing, and preventing

and mitigating environmental impacts. Several different actors are implicated, such as upstream suppliers of equipment, service providers and manufacturers. In addition, innovators in the resource sectors draw on developments from disciplines as diverse as medical, space robotics and military fields. For instance, mining companies have adopted medical tomographic imaging technology to provide higher-resolution images of ore.

Together, these factors shape innovation in resource industries in several ways:

- According to the 2006 Banff Innovation Summit, the highly competitive and inherently risky nature of resource sector activity creates "an overall **atmosphere of conservatism** insofar as innovation is concerned", despite the fact that they are accustomed to taking on large levels of risk.[9]
- Given the intense competition they face, resource producers generally **focus on process innovation** to lower costs. [10] For example, a Statistics Canada study found that while 100% of innovative firms in Canadian metal ore mining industries were process innovators, only 46% were product innovators. [11] A challenge for the resource sectors is to increase their focus on developing innovative value-added products that can create wealth and contribute to sustainable development.[12]
- As process innovators, resource firms often **acquire innovative technologies through machinery & equipment purchases** rather than through in-house R&D.[13]
- The complexity of resource production helps to make the innovation process in the resource sectors **highly collaborative**.
- Resource firms often **outsource R&D work** to private organizations or universities. Service companies and equipment suppliers are also a very important source of technological innovation in the resource sectors.[14] According to a 2008 article in the Financial Times, technology development in the oil & gas sector is in the "hands of service companies, which began to overtake the big integrated oil companies in the mid-1990s and are now far ahead in terms of new patents granted."[15]

4. Measuring Innovation Performance

4.1 The challenges of measuring innovation in resource industries

The unique characteristics of innovation processes in the resource sectors make measurement a challenge. According to the 2008 Banff Innovation Summit, the follow-up to the 2006 event, and 2010 PPF innovation conference, metrics used in other sectors may not capture the full range of innovative activities that take place in resource industries. Although there is no standard set of measures of innovation performance, a review of literature reveals five commonly-used indicators.[16]

Three of the standard indicators measure the use of inputs in the innovation process:

1. R&D effort, in terms of expenditures and/or labour force allocations;
2. Quality of the workforce, in terms of various measures of educational attainment, which may include a focus on science and engineering skills; and
3. Investment, by measures such as amount of venture capital and investment in machinery and equipment.

Since it is perhaps the most widely used measure of innovation inputs, R&D

expenditures provide a good example of the limitations of standard metrics in the resource sectors. One 2003 study found that R&D is most relevant with respect to product innovation. In sectors where process innovation is stressed – such as many natural resource commodities – the acquisition of technologies (e.g., through machinery and equipment purchases) is more important.[17] Even when in-house R&D is conducted, not all of the costs of developing technologies are captured by this metric. One 1998 case study of a Swedish forest product firm found that R&D expenditures in official accounts captured only 20% of the full development costs of an innovative new technology. [18]

Two additional indicators measure the outputs or effects of the innovation process:

4. Intellectual property, as tracked by counts of patents, copyrights or trademarks; and
5. Productivity growth, in particular, Multifactor Productivity (MFP), which is used to assess the impact of business practices, technology uptake and results of R&D, as well as synergies across determinants of productivity. According to the 2008 performance report of the federal Science, Technology and Innovation Council, "MFP is probably the best measure that we have on the impact that growth in innovation has on the economy."[19]

The unique nature of resource industries can also make it difficult to measure innovation outputs, such as productivity growth. While some resources are relatively easy to pump, mine or log, others only become economically viable when prices rise high enough to offset their higher extraction costs. Higher prices, when they are associated with the depletion of low-cost resources, encourage the exploitation of resources that yield less output per unit of input, thus lowering measured productivity.[21] As a result, using MFP alone to assess progress on innovation, technology uptake or efficiency in the natural resource sectors can be a misleading measure of innovation performance. [22]

4.2 Recent trends in the resource sectors

Despite acknowledged limitations regarding standard innovation metrics, such measures are often applied to describe innovation performance in the resource sectors. This section takes brief look at recent resource industry trends in some of these metrics.

In 2005, NRCan commissioned the Center for the Study of Living Standards (CSLS) to assess the performance of Canadian resource sectors relative to the all-industry Canadian average and natural resource industries in other OECD countries.

The CSLS found the performance of Canada's resource sectors on innovation indicators to be mixed when compared to other Canadian industries, as well as resource firms in OECD countries (Table 2).

Table 2: CSLS Assessment of innovation in Canada's natural resource sectors (selected measures) , 2005

Measure	CND NR sectors compared to the CND average	CND NR sectors compared to OECD NR sectors
R&D Intensity Level	Currently below average	Below
R&D Intensity Trend[20]	Downward	N/A
R&D Personnel	Average	Average
Educational Attainment	Slightly below	N/A
M&E Capital Intensity	Above	N/A

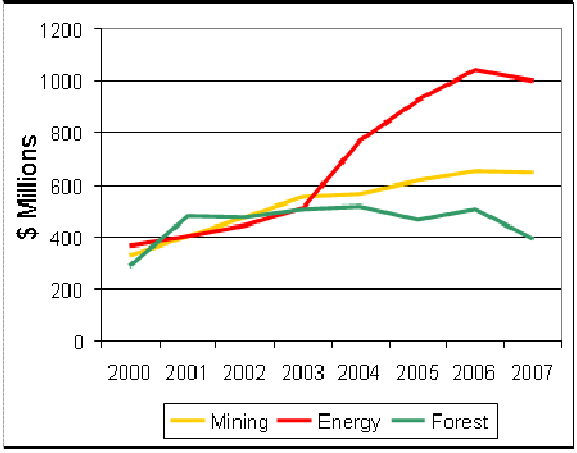
Source: CSLS, Statistics Canada

For example, while the energy, mining and forest sectors outperformed the Canadian average on capital investment, they lagged in R&D investment and educational attainment. Within the OECD, Canadian natural resource sectors ranked as average or below average in terms of their innovation performance.

More recent Statistics Canada data supports the CSLS results, showing that Canada's natural resource sectors have demonstrated mixed results when compared to the national average in the following areas:

R&D Expenditure and Intensity– According to Statistics Canada data, natural resource industries accounted for 13% of intramural R&D expenditures in 2007. All resource sectors increased spending on innovation activities during the past decade (Figure 2).

Figure 2: Total intramural expenditure on R Figure 2: Total intramural expenditure on R&D by



Source: CSWGES, Statistics Canada

Total R&D expenditures in the resource sectors more than doubled (+107%) between 2000 and 2007, increasing by $1.1 billion. In comparison, R&D spending in all other industries increased by only 28% during this period. Growth in R&D spending was driven by the energy and mining sectors, where average annual spending increased by 15% and 10% per year respectively. Average annual growth in the forest products sector was 4%.[23]

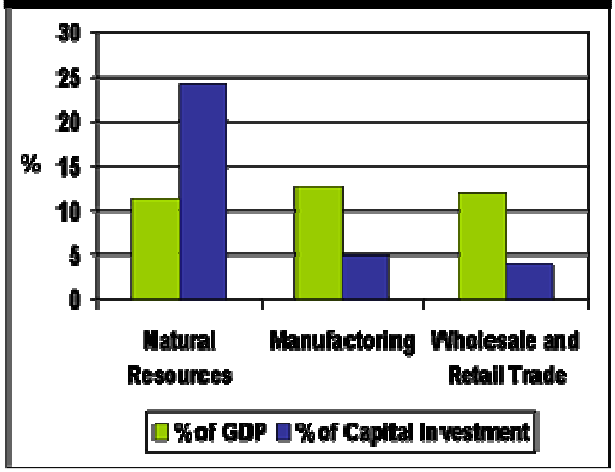
While R&D expenditures have been growing, resource sectors have a mixed record on R&D intensity. This can be measured as the percentage of the workforce engaged in R&D or as R&D expenditures as a percentage of firm revenue. In both instances, resource sectors' performance is mixed compared to the national average (Table 3).

Table 3: Canadian R&D effort, 2007[23]

Sector	Personnel engaged in R&D as a percent of total sectoral employment	R&D expenditure as a percent of firm revenue
Energy		
Oil & gas	1.9%	0.5%
Electric power	1.1%	0.4%
Petroleum and coal products	2.7%	0.3%
Mining and Minerals		
Mining	0.6%	0.7%
Non-metallic mineral products	1.7%	1.0%
Primary metal	2.0%	0.7%
Fabricated metal products	2.2%	1.8%
Forest		
Forestry and logging	0.6%	2.3%
Wood products	0.8%	0.6%
Paper	1.7%	1.4%
Canada, Average	**1.0%**	**1.8%**

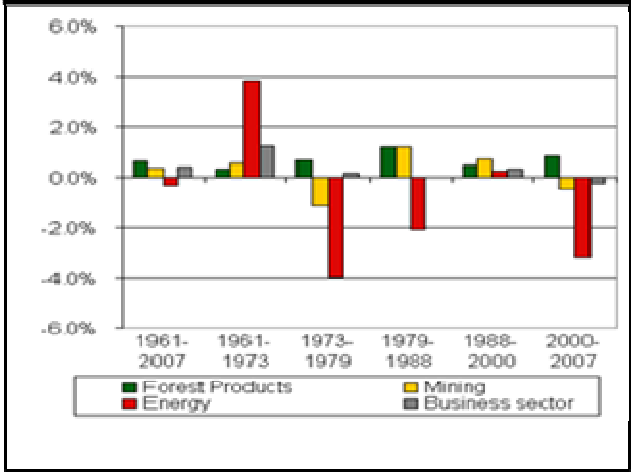
Source: Statistics Canada

Figure 3: Share of GDP and capital investment per sector, 2010



Source: Statistics Canada

Figure 4: Average annual MFP growth rates, 1961-2007



Source: Statistics Canada

Educational Attainment – According to the 2006 Census, 9% of workers in resource sectors had at least a bachelor's degree, compared with 14% of the total workforce. However, 30% of Canada's resource workers (34% in energy and mining, 21% in forest products) had training in engineering or related fields (at either the college or university level), compared to 13% of the total Canadian workforce. On this limited basis, specialized skills in technical design and application are important for resource-oriented firms.

Capital Investment– Capital investment in the resource sectors is higher than the national average and accounted for 24% of total Canadian capital investment in 2010, more than their share of GDP (see Figure 3).

Productivity – Analyses by the Council of the Canadian Academies, Statistics Canada, and the Centre for the Study of Living Standards have shown the critical link between Canadian productivity, economic growth and innovation.[24]

As shown in Figure 4, multifactor productivity in natural resource sectors has lagged that of the rest of the economy in some periods, while at other times has outperformed the Canadian average. Interestingly, most periods of low MFP growth in the energy sector have generally corresponded to periods of rising oil and gas prices. According to the CSLS, resource depletion, as well as a shift to unconventional resources, helps explain this relationship.[25] When these factors are at play, it can be difficult to ascertain the impact of innovation on resource productivity.

For example, bitumen production uses more capital and labour to produce a unit of output than conventional resources. As a result, shifting production towards the oil sands can result in a fall in the ratio of output to inputs – in other words lower productivity – despite the fact that bitumen production entails the use of innovative technologies and processes.

4.3 Looking beyond the standard metrics

One of the main conclusions of the October PPF 2010 Conference was a call for a concerted effort to fully account for innovation activities that are taking place in the resource sectors. This includes looking beyond standard innovation metrics, and using better performance indicators that capture the unique aspects of resource sector innovation.

For instance, investment in exploration, including technology and methods, for new resources can be considered similar to the R&D discovery process in other sectors. However, current approaches to defining and measuring R&D intensity do not consider exploration expenses in the mining and energy sectors.[26]

Buoyed by strong prices, exploration spending in the mining sector reached successive record levels in 2006 ($1.8 billion), 2007 ($2.6 billion) and 2008 ($2.9 billion). The same trend was evident in the oil and gas sector, with expenditures on exploration reaching $10.1 billion in 2006, $7.9 billion in 2007 and $10.7 billion in 2008. While spending on exploration fell during the course of the recent recession, previous investments are expected to bear fruit as the economic recovery progresses.

In addition, a report by the OECD – *Measuring Innovation: A New Perspective* – asserts that standard indicators of innovation may not adequately reflect the full role of innovation in today's economy. Consequently, they should be complemented by measures that reflect the broader context in which innovation occurs. In particular, while innovation to address environmental and social concerns is increasingly critical for business success, environmental and social expenditures are not often used as a measure of innovation.

Results from Statistics Canada's 2005 Survey of Innovation indicated that natural resource sectors expend considerable innovation effort in meeting governmental environmental standards and regulations. For example, Statistics Canada data indicate that in 2008, capital and operating expenditures on environmental protection reached a combined total of $6.5 billion in the mining and minerals, forestry, and energy sectors.[27] As in the case of capital expenditures, some of this amount undoubtedly represents spending on technological innovations and process.

6. Conclusion

This paper began by underscoring the important role that resource-based industries play in the Canadian economy. However, the ability of the energy, mining and forest products sectors to generate jobs, support GDP growth and attract investment will depend on their ability to adopt new and useful processes, products and organizational forms.

The need for greater resource sector innovation is being driven by many different factors. Canada's natural resource industries continue to face intense pressure to improve their cost competitiveness in the face of growing global competition and constrained access to new resources. At the same time, energy, mining and forest product sectors will need to respond to increased expectations for improved environmental and social performance. Innovation will be integral to addressing these challenges.

According to standard measures of innovation performance presented in this paper, Canada's natural resource sectors have a mixed record. However, traditional metrics fail to capture the full range of innovative activities that take place in the

resource sectors. Perhaps more importantly, aggregate analysis may mask important distinctions within the energy, mining and forest products sectors, including both examples of successful innovation and opportunities for progress.

Industry, government, universities, research institutions and civil society all have a role in improving innovation performance in Canada's resource sectors and the economy as a whole. At the federal level, for example, in October 2010 the Government of Canada launched a comprehensive review of federal programs that support business innovation.[28] The six-member Research and Development Review Expert Panel will review existing federal support for business R&D to determine how this support can be enhanced to make sure federal investments are effective at delivering maximum results for Canadians. Provincial and territorial governments have also put into place a number of initiatives unique to their own circumstances. To ensure continuing improvements to innovation in the natural resource sectors, ongoing efforts by all the participants in the innovation system remain essential.

6. BIBLIOGRAPHY

Arsenault, Jean-François and Andrew Sharpe. *An Analysis of the Causes of Weak Labour Productivity Growth in Canada since 2000*. International Productivity Monitor.

Baldwin, John R., Wulong Gu, Amélie Lafrance and Ryan Macdonald. 2009. "Investment in Intangible Assets in Canada: R&D, Innovation, Brand, and Mining,O il and Gas Exploration Expenditures." *The Canadian Productivity Review.* 15-206-X No. 026

Australian Government Department of Innovation, Industry, Science and Research. *Australian Innovation System Report 2010.* 2010.

Center for Innovation Studies. *The Banff Consensus: Integrating the Creative Capacities of Western Canada into the Global Innovation System*. Summary of the first proceedings of the Banff Innovation Summit. 2006.

Center for the Study of Living Standards. *A detailed Analysis of the Canadian Forest Products Sector since 2000.* October 2009.

-- *A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada.* September 2009.

-- *A Detailed Analysis of the Productivity Performance of Mining in Canada.* September 2009.

-- *Indicators of Innovation in Canada's Natural Resource Sectors*. May 2005

Conference Board of Canada. *How Canada Performs: A Report Card on Canada.* March 2010.

-- *Investing in Innovation in the Resource Sectors*. April 2001.

Council of Canadian Academies. *Innovation and Business Strategy: Why Canada Falls Short.* 2009

Crooks, Ed. Oil innovation after years of caution. Financial Times. July 28 2008. Accessed April 6, 2011. http://www.ft.com/cms/s/0/d39b8088-5cc9-11dd-8d38-000077b07658.html#axzz1Ilr5Eya4

Hawkins, Richard, Cooper Langford et al. 2006. *The Banff Consensus : Integrating the Creative Capabilities of Western Canada into the Global Innovation System.* The First Banff Conference on Innovation. September 29- October 1, 2006.

Laestadius, Staffan. 1998. The relevance of science and technology indicators: the case of pulp and paper. *Research Policy* 27. 385-395.

Le, Can D. and Jianmin Tang. 2003. "Innovation Inputs and Innovation Outputs". *Understanding Innovation in Canadian Industry.* Ed. Fred Gault. McGill-Queen's University Press. Pg 231-255

Martin, Roger. *What is innovation, really?* Globe and Mail Report on Business, June 11, 2010.

Natural Resources Canada. *Important Facts on Canada's Natural Resources*. April 2010.

Olewiler Nancy. *Natural Capital, Sustainability and Productivity: An Exploration of the Linkages*. Institute for Research on Public Policy. The review of Economic Performance and Social Progress. 2002

Organization for Economic Cooperation and Development. *Measuring Innovation – A new perspective.* June 2010.

-- Oslo Manual: The measurement of Scientific and Technological Activities, Proposed Guidelines for Collecting and Interpreting Technological Innovation. 3rd Edition. 2005.

Persaud, A.,Uma Kumar and Vino Kumar. 2007. "Innovation and Natural Resources: Myths and Realities about the 'Old' Economy versus the 'New' Economy". *Innovation, Science, Environment: Canadian Policies and Performance 2007-2008*. Montreal: McGill

--. 2003. "Innovation in the Upstream Oil and Gas Sector: A Strategic Sector of the Canadian Economy." *International Handbook on Innovation.* Ed Laura Shavinina. Elsevier Science.

Public Policy Forum. 2010. Conference Report: Innovation in Canada's Resource Sectors.

Rao, Tang & Wang. *What Explains the Canada-U.S. TFP Gap?* Industry Canada. Working Paper Series. 2006.

Science and Technology Innovation Council. *State of the Nation 2008 – Canada's Science, Technology and Innovation System*. 2009

Statistics Canada. *Productivity accounts.* Economic Accounts Tables 383-0021 and 383-0022.

-- *Balance of International Payments.* Economic Accounts. Table 376-0005

-- *Innovation and use of Advanced Technologies in Canada's Mineral Sectors: Metal Ore Mining*. July 2002.

-- *Innovation in the Forest Sector*. June 2002.

-- *Industrial Research and Development: Intentions 2009*. January 2010.

-- *Industrial Research and Development: Intentions 2009*. January 2010.

-- *Environmental Protection Expenditures in the Business Sector - 2008*, 2008

End Notes

[1] Papers by the PPF, the OECD, the Conference Board and the Center for Innovation Studies all point to the fact that traditional innovation metrics fail to capture the full suit of innovation activities in the resource sectors.

[2] In this paper, the natural resource sectors refer to the following industries: energy (including oil & gas extraction; support activities for mining and oil & gas extraction; electric power generation & transport; natural gas distribution; petroleum and coal products manufacturing; pipeline transportation); forest products (including forestry and logging; support activities for forestry; wood product manufacturing; paper manufacturing); and mining (including all mining excluding oil and gas; non-metallic mineral product manufacturing; primary metal manufacturing; fabricated metal manufacturing).

[3] These diagrams provide a 'snapshot' of the current role of natural resources in the Canadian economy. Time series data would reveal a more complete picture of current trends.

[4] Public Policy Forum. *Conference Report: Innovation in Canada's Resource Sectors.* Pg 7.

[5] Organizations that have recently written reports highlighting the importance of innovation to Canada's future prosperity include: TD Economics, The Council of Canadian Academies, The Conference Board, The Institute for Research into Public Policy, The Public Policy Forum and numerous government agencies.

[6] OECD Oslo Manual, 2005

[7] *Australian Innovation System Report 2010.* Chapter 2. Pg 16.

[8] Center for Innovation Studies. The Banff Consensus. 2006. Pg 5.

[9] Idem. It is important to note that in some contexts, competition can be regarded as a spur to innovation. For example, in their 2009 report, the Council of Canadian Academies attributed the Canadian economy's poor innovation performance to a relatively non-competitive domestic market.

[10] A. Persaud, Uma Kumar and Vino Kumar. 2001. Pg 1003.

[11] *Innovation and Use of Advanced Technologies in Canada's Mineral Sectors: Metal Ore Mining* and *Innovation in the Forest Sector*. The figures cited in the text are from the former paper.

[12] The Conference Board. *Investing in Innovation in the Natural Resource Sectors.* 2001. Pg 1.

[13] idem

[14] A. Persaud, Uma Kumar and Vino Kumar. 2003. Pg 89.

[15] Ed Crooks. "Oil innovation after years of caution." *Financial Times.* July 28, 2008.

[16] Sources in this literature review included the OECD Olso Manual, the Center for the Study of Living Standards *Indicators of Innovation in Canada's Natural Resource Sectors*; the Science and Technology Innovation Council *State of the Nation 2008 – Canada's Science, Technology and Innovation System;* the Council of Canadian Academies *Innovation and Business Strategy: Why Canada Falls Short.*; the conference report from the PPF *Innovation in Canada's Resource Sectors* conference.

[17] Can D. Le and Jianmin Tang. "Innovation Inputs and Innovation Outputs". Pg 254.

[18] Staffan Laestadius, "The relevance of science and technology indicators: the case of pulp and paper". Pg 389.

[19] Science and Technology Innovation Council. "2008 Performance Report. Pg 18.

[20] The CSLS measured R&D effort as expenditures per value added.

[21] Center for the Study of Living Standards. *A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada*. Pg 31-32.

[22] As noted, standard measures of innovation listed above suffer from a number of limitations. A more consistent effort to measure innovation using a broader range of methods and metrics – such as innovation surveys – is important to supporting the innovation performance among resource firms.

[23] Average growth rates reported for the energy, mining and forest product sectors are compound annual growth rates.

[24] The Council of Canadian Academies *Innovation and Business Strategy: Why Canada Falls Short*; and The Center for the Study of Living Standards *A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada* and *A Detailed Analysis of the Productivity Performance of Mining in Canada.*

[25] Center for the Study of Living Standards. *A Detailed Analysis of the Productivity Performance of Oil and Gas Extraction in Canada.* Pg 31-32.

[26] Baldwin, John R., Wulong Gu, Amélie Lafrance and Ryan Macdonald. 2009. *Investment in Intangible Assets in Canada.* Pg 19.

[27] This figure was taken from Statistics Canada's 2008 Survey on Environmental Protection Expenditures. It includes expenditures from: Oil and gas; Mining; Electric power generation, transmission and distribution extraction; Wood products; Paper manufacturing; Petroleum and coal products; Non-metallic mineral products and Primary metals. Figures from other resource industries were either too unreliable to

be published or were suppressed to meet the confidentiality requirements of the Statistics Act, and as such were not available.

[28] OECD Science, Technology and Industry Scoreboard 2009 : Canada Highlights. Accessed May 5, 2011. http://www.oecd.org/document/52/0,3746,en_2649_34173_44265268_1_1_1_1,00.html