COMMERCIAL ALIGNMENT OF FIRMS AND GOVERNMENT AGENCIES ADVANCING CLIMATE CHANGE TECHNOLOGIES

by

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A thesis submitted to the Faculty of Graduate Studies and Research

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Abstract

This research investigated the commercialization of emerging climate change technologies by building upon an existing framework for explaining the proportion of profits that accrue to firms from the commercialization of a technical innovation. The first stage of the research developed the operational definitions and a method to clarify the relationships between (i) firms' commercialization strategies for advancing climate change technologies, and (ii) government agencies' criteria for investing in the advancement of climate change technology. The second stage applied the definitions and method to examine the commercialization strategy of 16 firms in the Canadian fuel cell industry and investment criteria of two government agencies. Results suggest: (i) there was diversity in firms' commercialization strategies, while there was uniformity in the agencies' investment criteria, and (ii) the commercialization strategies of 12 of the 16 firms were misaligned with the two agencies' investment criteria.

Acknowledgements

I would like to thank advisor and friend Professor Tony Bailetti for his help and encouragement in completing the research. Tony was never without insightful comments, and always, always had the time to meet and discuss. I am particularly indebted to my wife Francine Clement whose encouragement and support was very much appreciated. Finally, I would like to thank my daughter Claire for providing the incentive.

Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

The objectives of this research were:

1) To develop the operational definitions and a method to clarify the relationships between (i) firms' commercialization strategies for advancing climate change technologies and (ii) government agencies' criteria for investing in the advancement of this technology.
2) To apply the definitions and method to the Canadian fuel cell industry.

This research builds on Teece's (1986) conceptual framework for explaining the proportion of profits that accrue to firms from the commercialization of a technical innovation. Research published subsequently to 1986 has built on this framework to make important contributions to the literature on technology commercialization (Gans and Stern, 2000, 2003; Gans, Hsu, and Stern, 2002; Jorde and Teece, 2001; Teece, 1988, 1989, 1997).

This research is relevant because the objectives of government agencies for advancing technology have a bearing on the commercialization strategies of firms. Teece (1986) and Gans and Stern (2003) observed that an industry's commercialization environment should be reflected in a firm's commercialization strategy. This research advances the idea that an agency's investment criteria should be reflected in a firm's commercialization strategy and a firm's commercialization strategy should be reflected in the agency's investment criteria.

Teece (1986) and Gans and Stern (2003) investigated the relationship between a firm's commercialization strategy and the industry's commercialization environment using three concepts: (i) Appropriability Regime, (ii) Complementary Assets, and (iii) Dominant Design Paradigm. The right-hand side of Figure 1 illustrates the relationship between a firm's commercialization strategy and the industry's commercialization environment as conceptualized by Teece, and Gans and Stern.

This thesis examines the relationship between a firm's technology commercialization strategy and the investment criteria of a government agency responsible for funding technology advancement using the three concepts used by Teece (1986) and Gans and Stern (2003). The left-hand side of Figure 1 illustrates the context for this research.

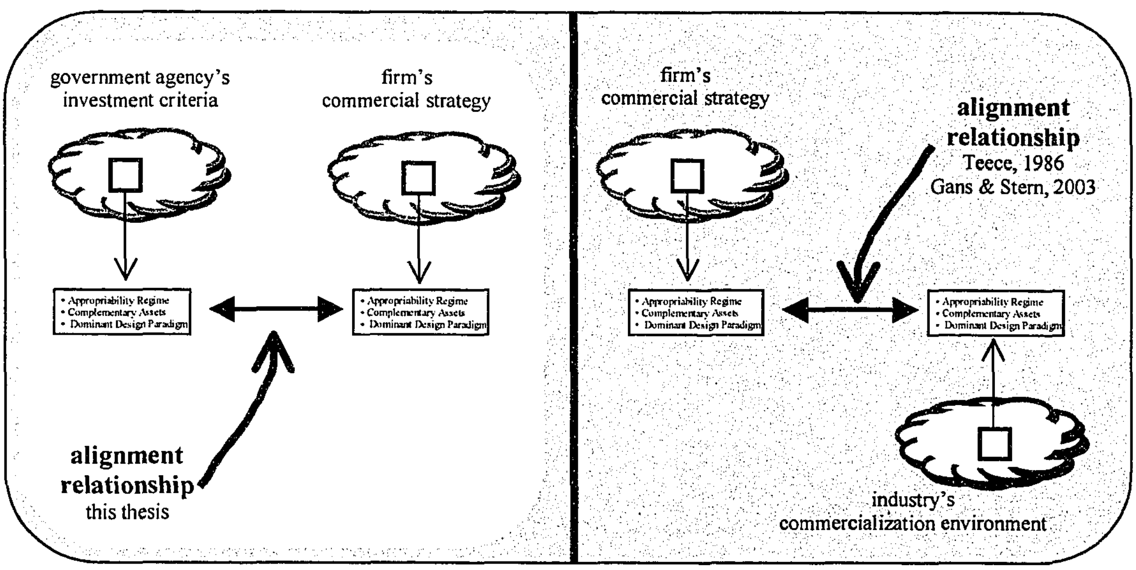

Figure 1: Investigative context

The government agencies considered are supporting the advancement of climate change technologies to reduce Greenhouse Gas (GHG). The objectives of these agencies are particularly pronounced in the context of commitments arising from the Kyoto Protocol (United Nations Environment Program, 2003): Table 1 shows that many of the leading industrial nations have obligations to reduce GHG emissions by approximately 6% below 1990 levels by the Kyoto period of 2008-2012. The Kyoto Protocol acknowledges that these aggressive targets are contingent upon advancement and adoption in technology. The Kyoto Protocol is an international treaty that limits a nation's GHG emissions. It also requires industrialized nations to assist the non-industrialized nations through technological and financial assistance. The Kyoto Protocol was ratified in November of 2004, and will come into force in February 2005 (Framework Convention on Climate Change, 2004).

In 2000, Canada's Kyoto commitment to be achieved by the 2008-2012 Kyoto period was estimated at 19.6% above 1990 levels of GHG emissions (United Nations Environment Network, 2004). To achieve its commitment of 6% below 1990 levels, government agencies are supporting the advancement of an assortment of climate change technologies with targeted investments in specific areas; one notable area is the hydrogen economy. In this thesis, we are specifically interested in Canadian firms and agencies involved in the advancement of fuel cell technologies. As of October 2001, there were 17 Canadian fuel cell producers whose primary market focus was on the production of fuel cells and/or their systems integration (Fuel Cells Canada, 2003; Industry Canada, 2003). Additionally, one can distinguish two government agencies for advancing climate change technologies that are specifically attentive to supporting hydrogen economy initiatives (i.e., fuel cell technologies).

Canadian federal initiatives to advance fuel cell technologies commenced in the mid 1980s with a total contribution as of 2003 estimated to be $183M (Auditor General, 2003). The federal 2003 budget (Department of Finance, 2003) designated a further $100M to specifically advance hydrogen technologies. The federal government has the stated objective for vehicles equipped with fuel cells to contribute 0.1 megatons (Mt) of GHG reductions by 2010 (page 20, Climate Change Action Plan for Canada, 2002). Various government agencies are responsible for ensuring that the commercialization of fuel cell technologies advances at a rate sufficient to deliver on this commitment.

G8 nation	% of world's GHG emissions in 1999	Kyoto commitments (reduction from 1990 levels)
Canada	2.5%	-6%
France	1.8%	-8%
Germany	3.7%	-8%
Italy	2.0%	-8%
Japan	5.0%	-6%
Russia	6.5%	0%
UK	2.5%	-8%
US	24.7%	-7%
Total	48.7%	

Table 1: G8 nations' Kyoto commitments

Partnerships can accelerate commercialization (Barringer and Harrison, 2000; Glaister and Buckley, 1996). Consequently, to accelerate commercialization, a government agency may encourage firms to develop partnerships through the lure of possible investment, and firms may develop partnerships, in part, in an attempt to obtain government agency investment. However, firms risk having their innovation expropriated when entering into partnerships (Teece, 1986; Gans and Stern, 2003).

Intellectual Property Rights (IPR) can be useful to a firm to combat the expropriation of its innovation (Teece, 1986; Gans and Stern, 2003; Giarratana 2004). Further, IPR can give rise to a secondary market - a market of ideas (Gans and Stern, 2003) and is related to a firm's longevity (Giarratana, 2004). Consequently, an agency in an effort to both (i) protect its investments and (ii) encourage national welfare, may encourage firms to develop and protect intellectual property through the lure of their investments. Moreover, firms may pursue activities that produce intellectual property, in part, in an attempt to obtain an agency's investment. However, IPR is not applicable to all industries (Teece, 1986; Giarratana, 2004), and can slow the rate of commercialization (Shapiro, 2001; Teece, 1986).

This thesis makes four contributions. First, it establishes a set of principles that may be used to compare firms' commercialization strategies and government agencies' investment criteria, as well as assess the alignment between firms' commercialization strategies and agencies' investment criteria. Second, it operationalizes Teece's (1986) framework to facilitate examining the relationships between (i) Appropriability Regime, (ii) Complementary Assets, and (iii) Dominant Design. Third, it applies the operationalization to generate insights relevant to the Canadian fuel cell industry. And fourth, it provides an explicit definition of what it means for an agency's commercialization environment to be aligned with a firm's commercialization strategy, and conversely.

This thesis is organized into six chapters: Chapter 1 is the introduction. Chapter 2 provides background material on Teece's (1986) framework. Chapter 3 provides a literature review together with summary observations. Chapter 4 provides the operational definitions and the method required to operationalize Teece's (1986) framework. Chapter 5 applies the operationalization to the fuel cell industry and discusses the results. Chapter 6 presents the thesis' conclusions together with limitations and suggestions for further research.

The appendices provide additional material. Appendix A provides a brief overview of Canada's climate change initiatives. Appendix B describes the Canadian fuel cell industry and the seventeen Canadian fuel cell firms examined. Appendices C and D provide details on how the measurements of the government agencies and the fuel cell firms were derived. Table 2 provides a list of the acronyms used in this thesis.

Acronym	Expansion
AFC	Alkaline Fuel Cell
CIPO	Canadian Intellectual Patent Office
CO2	Carbon Dioxide
DMFC	Direct Methanol Fuel Cells
GHG	Greenhouse Gas
IPC	International Patent Classification
IPR	Intellectual Property Rights
IRAP	Industrial Research Assistance Program
MCFC	Molten Carbonate Fuel Cells
Mt	Megaton
NRC	National Research Council
NRCan	Natural Resources Canada
NSI	National System of Innovation
PAFC	Phosphoric Acid Fuel Cells
PCB	Polychlorinated Biphenyls
PEMFC	Proton Exchange Membrane Fuel Cell
PDA	Personal Digital Assistant
R&D	Research and Development
SDTC	Sustainable Development Technology Canada
SME	Small and Medium Enterprises
SOFC	Solid Oxide Fuel Cell
TEAM	Technology Early Action Measures
TSI	Transnational Systems of Innovations

Table 2: List of acronyms

2 Teece's framework

2.1 Introduction

This chapter provides an overview to certain ideas and concepts introduced by Teece (1986). Section 2.2 introduces central concepts. Section 2.3 discusses the Appropriability Regime. Section 2.4 discusses the Dominant Design Paradigm. Section 2.5 discusses Complementary Assets, and section 2.6 summarizes Teece's framework.

2.2 Concepts

It is not uncommon for firms that first commercialize a technical innovation to profit less from the innovation than other firms. To explain this phenomenon, Teece (1986) developed a framework that could provide answers to such questions as: What determines the share of profits captured by the innovating firm? How may one explain the distribution of profits from a technical innovation? Who are the winners and losers when an innovation is commercialized, and why?

A central concept is the innovation, and it provides a basis in which to understand the role of the three essential participants:

1) Innovator: a firm that is first to market with a given innovation.
2) Supplier: a firm that has requisites that the innovator requires.
3) Imitator/follower: a firm that is subsequent to market with the innovation.

We hasten to add that a fourth participant is identified as the "customer" (may be intuitively understood as all other participants). The "customer" falls outside the themes introduced here.

The role of a supplier is broadly understood as:

1) Providing inputs (e.g., parts, systems, and/or services) to the innovator or imitator/follower.
2) Receiving inputs (e.g., the innovation) from the innovator or imitator/follower.

We note that nothing in Teece's exposition prevents the possibility that a supplier could be an investor (e.g., a VC or a government agency); though this premise is not addressed.

Teece's framework provides explanation for how the profits from an innovation may accrue to the three identified participants. The framework has three building blocks: (i) Appropriability Regime, (ii) Complementary Assets, and (iii) Dominant Design Paradigm. These building blocks (i) provide prescriptive insights on how to approach commercializing a given technical innovation, and (ii) serve to anticipate the participants who may ultimately realize the greatest benefits from the commercialization of a given technical innovation.

The following sections examine each of the building blocks in turn.

2.3 Appropriability Regime

The Appropriability Regime is concerned with identifying and understanding the environmental issues that govern an innovating firm's ability to capture the profits generated from their technical innovation. Environmental issues are reduced to two considerations:

1) The effectiveness of legal mechanisms to protect the innovation from imitators/followers.
2) The extent to which the nature of the technology provides inherent protection from imitators/followers.

Collectively, measurements of these two considerations permit one to distinguish between:

1) A tight Appropriability Regime: an environment in which it is relatively easy to protect the innovation from unauthorized use (e.g., being mimicked by rivals).
2) A weak Appropriability Regime: an environment in which it is exceedingly difficult to protect the innovation from unauthorized use.

The Appropriability Regime has implications on how a firm might approach commercializing some innovation in order to maximize profits. For example, Teece observed that in the pre-paradigmatic stage of an industry with a weak Appropriability Regime it may advantageous (e.g., prudent use of capital) for a firm to pursue an imitator role; letting other firms invest in activities to distill what will eventually become the dominant design.

2.4 Dominant Design Paradigm

The notion of the Dominant Design Paradigm is modeled after the scientific theory that once a dominant paradigm emerges as being "normal" scientific research can proceed. Teece (1986) distinguishes two stages of evolutionary development for a technical innovation: (i) the pre-paradigmatic stage and (ii) the paradigmatic stage.

During the pre-paradigmatic stage the industry can be characterized as having properties that include: (i) fluid product designs; (ii) manufacturing processes that are loosely and adaptively organized; (iii) production that is reliant upon the use of generalized capital; and (iv) competition among firms primarily based upon competing designs. The latter stages of the pre-paradigmatic period is characterized by an assortment of demonstrations and prototypes that are attempting to drive out remaining ambiguity in the design and otherwise distill out the more compelling (winning) customer value propositions.

The paradigmatic stage follows the pre-paradigmatic stage with a transition signaled by (i) the arrival and general acceptance of a particular design, called the Dominant Design, and (ii) competition shifting away from design and towards price.

The paradigmatic stage of an industry has properties that contrast those of the pre-paradigmatic stage, and include: (i) fixed designs appropriate for scalable production; (ii) structured and rigid manufacturing processes; (iii) production based upon the use of specialized capital assets (e.g., purpose built manufacturing equipment).

In sum, certainty over the product design permits competition to shift to more specialized and longer term capital investments such as, e.g., least cost manufacturing and education.

As with the Appropriability Regime, the status of the Dominant Design has implications on how a firm might best approach commercialization. For example, Teece observed that it is critical for a firm to be in a position to take advantage of the Dominant Design as an industry transitions into the paradigmatic stage.

2.5 Complementary Assets

For a technical innovation to generate profits, it must be sold. As Teece (1986) observed, almost without exception, the successful commercialization of a technical innovation has dependencies upon other capabilities, products, and/or services. For example, marketing, competitive manufacturing, after-sales support, and complementary technologies (e.g., fuel storage and refueling apparatus). These things Teece calls Complementary Assets.

Complementary Assets have three important properties: (i) The types of Complementary Assets required, (ii) the source from which the Complementary Assets are obtained, and (iii) the number of Complementary Assets required. Each property is explored in turn in the following paragraphs.

Teece distinguishes three types of Complementary Assets:

1) Generic assets: independent of the innovation. For example, the ability to use an existing parcel delivery service to pickup and deliver the innovation to the customer,

or the ability to use an existing manufacturing facility to produce the product (e.g., a foundry for chip design).

2) Specialized assets: unilateral dependence on the innovation. For example, a purpose-built manufacturing or repair facility dedicated to the innovation.
3) Co-Specialized assets: bi-lateral dependence on the innovation. For example fueling stations, automotive repair facilities, automotive repair training, and automobiles all have mutual dependencies on one another.

Teece distinguishes two sources of Complementary Assets:

1) Internal. For example, the innovating firm in-sources specialized manufacturing plants and manufacturing equipment.
2) External. For example, the firm out-sources marketing efforts and customer service.

Internal versus external sources influence the recipient of profits accruing from an innovation. For example, if the innovating firm out-sources some specialized asset then the innovator can anticipate a loss of revenue commensurable with the risks and costs born by the provider of that specialized asset. Indeed, Teece observed that if the innovator must outsource a requisite complementary asset to a provider having a monopolistic hold then the innovator can anticipate a loss of revenue commensurable with that provider's privileged position.

The number of Complementary Assets required is critical to the complexity that needs to be addressed to bring about a market offer. Self-contained market offers having few dependencies on complementary assets are inherently simpler to commercialize.

Teece (1986) does not explicitly introduce a notion of measurement for complementary assets though there is a prevailing theme of complementary assets having a minor or a major role in commercialization.

2.6 Summary of Teece's framework

In summary, the three building blocks of Teece's framework are as follows: (i) Appropriability Regime which is concerned with the environment's ability to protect the innovation from unauthorized use; (ii) Complementary Assets which is concerned with the type, number, and sourcing of commercialization activities; and (iii) Dominant Design Paradigm which is concerned with the state of a technology's commercialization.

Figure 2 provides a conceptual depiction of Teece's framework. Referencing Figure 2, we observe the following:

- To the left-hand side of the horizontal axis is the central notion, viz., the technical innovation. Here, the technical innovation is intended to represent the words and ideas that are the precursor to any physical realization of the innovation as a market offer.
- To the right-hand side of the horizontal axis is the market offer. Use of "market offer" underscores the importance of complementary assets. For example, the ability to have the innovation repaired.
- To the top of the vertical axis are Teece's three building blocks labeled as "categories".

- To the bottom of the vertical axis are Teece's three participants labeled "winners and losers".
- The horizontal left-to-right arrow is intended to convey the notion of the commercialization process, and represents the sundry activities required to bring an innovation to the market place.
- The vertical top to bottom arrow is intended to convey the notion of the influence that Teece's building blocks have upon the commercialization process; ultimately determining the success and failure of firms.
- The cloud represents commercialization.

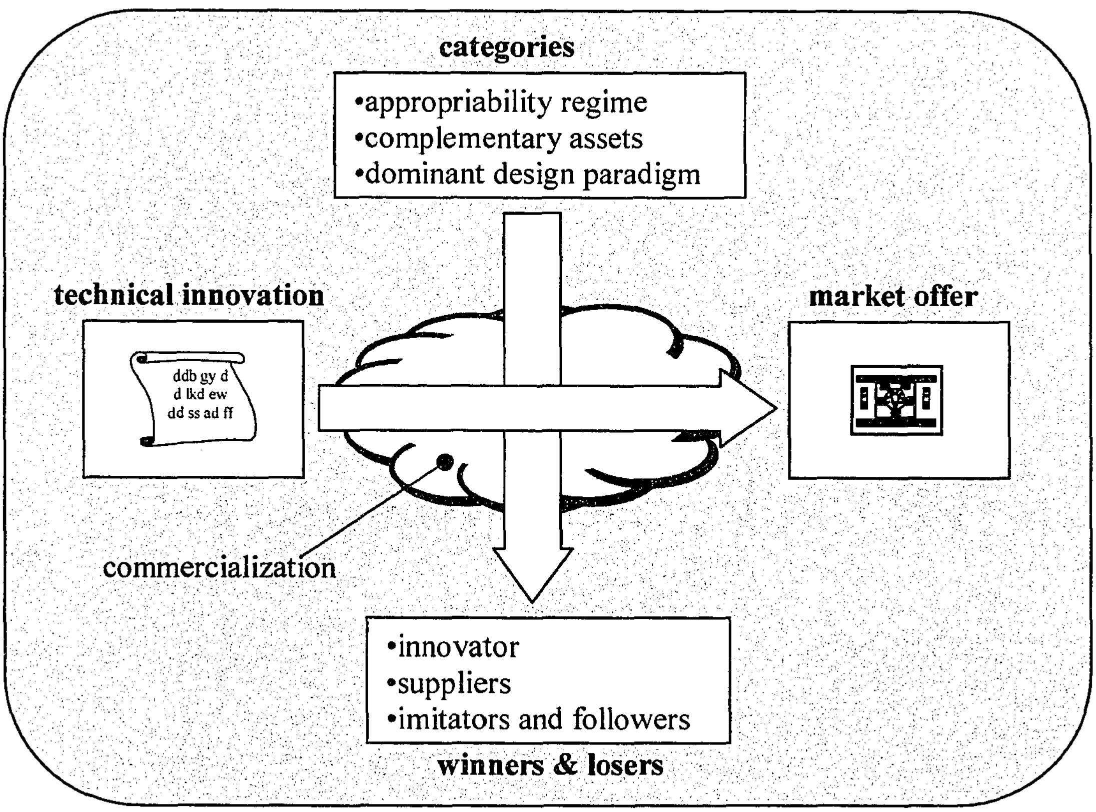

Figure 2: Model of Teece's framework

A dimension that this thesis addresses with respect to this conceptualization surrounds the notion of a nation being a winner or loser. In particular, independent of who wins among the innovator, imitator, or supplier, as long as climate change technology reaches a suitable state of commercialization and adoption, the nation will win with respect to achieving its Kyoto commitments.

3 Literature review

3.1 Introduction

This chapter is organized into three sections: Section 3.2 surrounds National Systems of Innovation and is organized into four streams of inquiry: (i) Evaluation, (ii) Classification, (iii) Policies, and (iv) Adoption. Section 3.3 surrounds emerging technological industries, and it is organized into two streams of inquiry. And section 3.4 provides a summary discussion of the observations obtained from the literature review.

3.2 National Systems of Innovation

A National System of Innovation (NSI) is a nationally sponsored organization (government agency) that is mandated to cultivate technology advancement through incentives (e.g., financial). There are various alternative definitions for NSI, see, for example, Lundvall (1992), Nelson (1993), Edquist (1997), with Chung (2002) introducing the following classification:

- Broad: any government agency that creates, diffuses, and/or exploits innovations.
- Narrow: any organization directly involved in surfacing technological innovations. For example, Research and Development (R&D) departments and universities.

Appling this classification, our usage of NSI (government agency) in this thesis is considered "broad".

The relevant literature on NSIs may be organized into four streams of inquiry:

1) Evaluation: surrounds retrospective evaluation of a NSI in terms of economic benefits.

2) Classification: surrounds positioning a NSI so as to suggest the sort of objectives it may be likely to achieve.
3) Policies: surrounds understanding the implications and complexities of the NSI's directives (i.e., policies).
4) Adoption: surrounds assessing the deployment potential and complexities.

These streams of inquiry are far from independent. For example, in part, the purpose of understanding evaluation is to create better policies which in turn increase adoption. And, in part, the purpose of understanding policies is to better position (i.e., classify) NSIs so their evaluation reflects their objectives.

The following subsections explore a selective sampling of the literature in each stream.

3.2.1 Evaluation

A main objective of studies in the evaluation stream is to provide a retrospective evaluation of government programs in terms of their economic benefits. These studies seek to ensure that governments are held accountable for the public money they dispense. Chung (2002) observes that many of evaluation studies are either too theoretical or too superficial.

Georghiou and Roessner (2000) observed that it is difficult to distinguish between evaluating a program, and evaluating the performance of that program. And Cozzens

(1995) concludes that evaluating program performance may be contentious because it links programs to national goals and milestones.

Porter, et. al. (2001) reviewed 33 nations with respect to technology exports since 1987, and observed that (i) national competitiveness is based on technology and (ii) nations increasingly rely on technology as a means for competitive expansion. Porter provided indicators to measure the relative performance of nations:

- National Orientation, the strength of a nation's commitment for technology based development.
- Socioeconomic Infrastructure, the strength of a nation's education system, mobility of capital, and encouragement of foreign investment.
- Technological Infrastructure, the strength of a nation's scientific and engineering manpower, electronic data processing, relationship of R&D to industrial applications, and the ability to make effective use of technological knowledge.
- Productive Capacity, the strength of a nation to manufacture technology-intensive products.

3.2.2 Classification

Ergas (1987) introduced the classification of technology policy within an evolutionary framework as either mission-oriented or diffusion-oriented. Ergas' classification provides a means for reasoning about the achievements of a NSI based upon a classification of the policies promoted by that NSI.

Cantner and Pyka (2001) advanced the work by Ergas (1987) by proposing the classification scheme shown as Figure 3. Referencing Figure 3, the vertical axis positions programs according to the relative vicinity to market of the technology it is hoping to influence, while the horizontal axis positions programs according to the specificity of the technology it is hoping to address. The "Basic" quadrant of the Cantner and Pyka classification includes programs without commercial expectation or specific achievements (e.g., university research). The "Vision" quadrant includes programs without commercial expectation but having very specific technology advancement objectives (e.g., time travel). The "Diffusion" quadrant refers to programs with commercial expectation but lacking technical specificity (e.g., technology advancements that may find their way into many applications). The "Mission" quadrant includes programs with commercial expectation and technical specificity (e.g., technology advancements specific to reducing the GHG emissions).

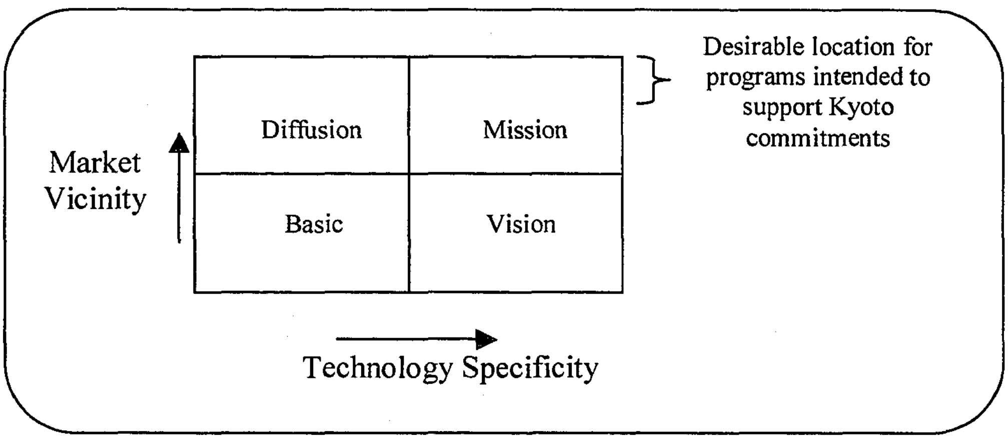

Figure 3: Classification of programs that support research and development

Programs designed to support the achievement of Kyoto commitments are Mission-Oriented in the classification scheme proposed by Cantner and Pyka.

Chiang (1998) refines Mission-Oriented and Diffusion-Oriented policy through an enumeration of policy attributes: (1) objective, (2) government role, (3) policy tools, (4) driving forces, (5) potential contribution (6) innovation pattern, and (7) technology life cycle.

3.2.3 Policies

Within policies it is possible to distinguish three areas: (i) Policy complexity, (ii) Program governance, and (iii) Policy assessment.

3.2.3.1 Policy complexity

Papathanasiou and Anderson (2001) approached the complexity of understanding the implications of policy through the development of a "what if" computational model. The authors were concerned with the development of technologies related to renewable energy and modeled scenarios that explored the costs and benefits of developing technology to reduce energy demands within a certain time frame (e.g., by 50% by 2020).

Grande (2001) explores the complexity resulting from the globalization of companies, markets and technologies, and its effects on a nation's ability influence the creation, distribution, and utilization of technologies. He concludes that programs to direct the advancement of technology are becoming large and complex, and that globalization continues to erode a nation's ability to influence the advancement of technology.

Chiang (1998) discusses the existence of certain inherent national differences that influence policy concerns and emphasis. Of noteworthy interest is the fundamental differences between the US and Japan as it relates to the creation and protection of Intellectual Property. For example, Chiang (1998) observes that the purpose of patents in the U.S. is to protect inventors, whereas in Japan the main purpose of patents is to support industry.

3.2.3.2 Program governance

Kuhlmann and Jakob (2003) examined the consequences of globalization through consideration of program governance. They express concerns about a nation's ability to influence technology policies, and recognized that technology is becoming the basis for international competition. They proposed the replacement of NSIs with Transnational Systems of Innovation (TSI). These TSIs would set the policies for multiple nations. Against the backdrop of the Kyoto protocol, which is not mentioned in the paper, the replacement of NSIs with TSIs seems particularly relevant: TSIs would set the policies for multiple nations and thereby coordinate international efforts to advance the likelihood that nations will collectively and individually meet Kyoto commitments.

3.2.3.3 Policy assessment

The special issue of Technology Analysis & Strategic Management (Jamison and Rohracher 2001) is devoted to exploring the theme of "culture in the development of sustainable technology". Generally, the following view is advanced: that sustainable development necessitates environmentally-oriented policy, and that such policies will result in a general migration towards integrating environmental concerns into all areas of science and technology.

Jamison (2001) observes that the commercialization of research and development is increasingly co-opting the priorities of science and technologies, and by extension governments are placing too much emphasis on furthering economic growth and international competitiveness.

Salter and Martin (2001) concluded that policies should ensure appropriate investments in research, training and education.

3.2.4 Adoption

Technical change is sometimes explained by appealing to Schumpeterian trilogy (Stoneman, 1983): invention, innovation, and diffusion. Adoption is concerned with the diffusion of technology.

Schot (2001), Hahn and Pyung (1999) and Wiser (1998) argue that there are significant hurdles related to the adoption of sustainable/environmental technology.

Schot (2001) brings together a number of recurrent themes, among them that the development process must change to accommodate appropriate environmental concerns. In part, the issue is that in an environmental setting, technology developments have generally been accompanied by negative environmental impacts (e.g., industrial by-products – GHGs, and environmental pollution - PCBs); or consumer fears such as, e.g., that represented by genetically modified foods. Schot concludes that historical precedent creates adoption barriers for new technologies in the environmental sector.

Hahn and Pyung (1999) argue that diffusion policies merit as much attention as technology policies and that technology advancement programs need to be aligned with technology adoption programs.

Wiser (1998) reports on an extensive literature review related to the marketing of renewable energy and the implications on public goods, free-riders, and similar issues.

3.3 Emerging technological industries

An emerging technological industry has characteristics that include: (i) The market being new and uncertain, with a general lack of authoritative information surrounding, e.g., viability and growth prospects. (ii) The technological innovation manifests itself as demonstrations, prototypes, and first generation products that are evolving rapidly in conjunction with improvements in technological know-how. (iii) The firms advancing the technology are struggling with fundamental issues such as, e.g., investments, growth, partnerships, and profitability. And (iv) customers are generally leery and reserved in their approach to, and acceptance of, the innovation. Informally, these and similar characteristics define the industry's commercialization environment, see, for example, Hahn and Pyung (1999) Schot (2001) and Wiser (1998).

The section is organized into two streams of inquiry: (i) consideration of a prior application of Teece's framework, and (ii) inquiries providing breadth to Teece's building blocks.

3.3.1 Prior application

Gans and Stern (2003) explore the relationship between a startup's commercialization strategy and the underlying commercialization environment. Gans and Stern position their inquiry as refinement of Teece's (1986) analysis. This refinement may be summarized as follows: the Dominant Design Paradigm is set to pre-paradigmatic, and the imitators and suppliers are collapsed into a single entity called imitator. Figure 4 diagrammatically summarizes this refinement based upon an assumed familiarity with Chapter 4.

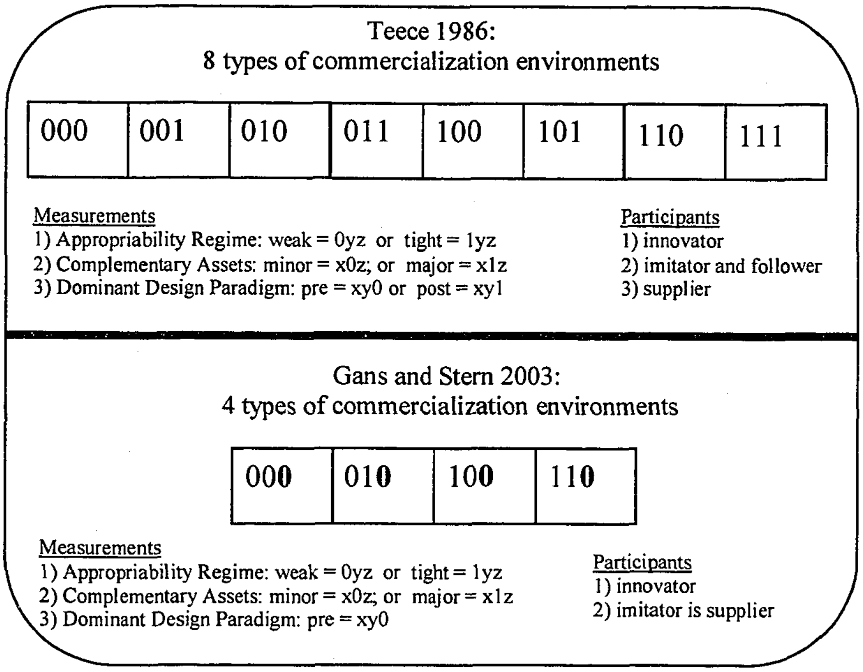

Figure 4: Commercialization environment of Gans and Stern

The focus of the Gans and Stern (2003) inquiry is on the importance (i) Complementary Assets and (ii) the Appropriability Regime. And key contributions include:

- The likelihood that imitators are sourced from the firms controlling the key complementary assets, thus re-enforcing Teece's (1986) observation surrounding cooperative strategies: there is considerable risk that the owners of complementary assets will expropriate the innovation.
- The observation that the emergence of a "market for ideas" can be linked to the inability to expropriate an innovation. And a key indicator that such a market will emerge is the innovator being able to compete credibly with partners.
- The observation that innovator's fall prone to pursuing short term revenue opportunities that may not necessarily coincide with their long term interests. That is,

a firm's commercialization strategy should coincide with the industry's commercialization environment.

- The observation that firms have a greater affinity towards sourcing (cooperative) arrangements when they are protected by IPR.

3.3.2 Inquiries related to Teece's building blocks

The section is structured into three sub-sections that coincide with Teece's three building blocks.

3.3.2.1 Appropriability Regime

Giarratana (2004) provides an empirical study of the emergence of the encryption software industry with attention on three areas: (i) the commercialization environment, (ii) the innovation, and (iii) the innovators. Using the nomenclature of Teece (1986), Giarratana (2004) investigated the role of the Appropriability Regime and Complementary Assets, with particular attention on the former as it was seen as influencing the latter. For example, of the firms Giarratana (2004) examined, 27% had one or more patents, and these firms accounted for 54% of the technological alliances.

Giarratana measured three things: (i) U.S. Patents, (ii) Worldwide Alliances, and (iii) Top Management Team. It is noteworthy that in addition to counting patents, Giarratana (2004) used patent citation to measure the importance of patents.

Giarratana's key observations include:

- Patents are important, however they are not applicable to all industries, and the software industry is one example of an industry where patents offer minimal value. And that the encryption software industry is an exception. Here, we observe that Teece (1986) also observed that there are areas where patents offer limited value.
- Early stage firms pursue activities that promise self-sustaining economics, and such commercial strategies are different from those required for growth. This observation supports the observation by Gans and Sterns (2003) surrounding firms being lured to pursue short term revenue opportunities that may not contribute to the firm's longer term welfare.
- Patent ownership may be related to firm longevity in certain industries. For example, of the firms Giarratana (2004) considered, 200 had gone out of business and of these only 3.5% had patents.

It is also interesting to note that Giarratana's (2004) inquiry has a number of interesting parallels with the Gans and Sterns (2003) inquiry. For example, (i) the Gans and Sterns (2003) notion of a "market for ideas" is paralleled by Giarratana's (2004) notion of a "technology market". And whereas the Gans and Sterns (2003) inquiry is a refinement of Teece (1986), the Giarratana (2004) inquiry is based upon framework by Gartner (1985) which parallel's Teece's (1986) framework. For example, Giarratana (2004) uses the notion of a technology regime which mirrors Teece's (1986) notion of an Appropriability Regime.

Shapiro (2001) observed that a principle value of IPR resides with the threat of litigation and the resulting consequences on both stalling of commercial activities, and wasting precious resources. That is, whereas Barringer and Harrison (2000) and Glaister and Buckley (1996) suggest commercialization may be accelerated through teaming agreements, Shapiro suggests commercialization may be decelerated through IPR. Teece (1986) supports Shapiro view of IPR in that Teece suggests that in a tight Appropriability Regime when the innovator is protected by IPR, the innovator is afforded the luxury of time to internally develop Complementary Assets rather than outsource them.

Pruett et. al. (2003) introduces low and high appropriability to capture the notion of a firm's ability to capture the economic rents generated by its activities. A low appropriability situation is undesirable and can be corrected by the firm acquiring patents. This use of appropriability may be contrasted with Teece's (1986) notion of an Appropriability Regime that reflect the realities of the industry's commercialization environment, and that firms need to accommodate this reality in their commercial strategies.

Pruett et al. (2003) also introduce a notion of externalities that has parallels with the notion of modular and integral innovations discussed in sub-section 3.3.2.3 below.

3.3.2.2 Dominant Design Paradigm

Christensen (Christensen, 1997; Anthony et. al., 2002; Christensen et. al., 2002) distinguishes two types of technological innovation:

1) Sustaining technologies: "improve the performance of established products, along dimensions of performance that mainstream customers in major markets have historically valued" (page xv, Christensen, 1997).
2) Disruptive technologies: "technology or business model that an incumbent is unable to mount an effective competitive response against resulting in a loss of significant market share and dramatic changes in the competitive landscape of a market or industry" (page 12, Anthony et. al., 2002).

We observe that the commercialization trajectories for these two types of innovations are fundamentally different: sustaining technologies retain the incumbents whereas the disruptive technologies unseat the incumbents.

Figure 5 illustrates the traditional reference model for disruptive technologies. Referencing Figure 5, according to the model for disruptive technology, incumbents are understood as being on a product development trajectory that provides product improvements that overshoot the requirements of all but the most demanding customers. Meanwhile, the disruptive product is on a development trajectory that is initially below interest from even the least demanding of the core market. However, it nevertheless offers sufficient values as to generate revenue from certain niche customers. This revenue funds product improvements that eventually attract mainstream customers.

Figure 5 shows that a disruptive technology starts out as a disruptive idea, which (i) is developed into a niche revenue generating opportunity; which then (ii) provides necessary funding to improve the technology; and which finally (iii) permits the technology to invade mainstream market serviced by incumbents - with the incumbents trapped in an existing business model that prevents them from responding to the threat. These steps provide a litmus test (Anthony et. al., 2002) that may be applied to distinguish a disruptive technology from a sustaining technology: i) *Is there a new growth opportunity to fund initial development?* ii) *Can it sufficiently improve so as to invade the existing market?* And iii) *Does it have characteristic making it impossible for the incumbent to respond?*

Christensen (1997), unlike Teece (1986) who is interested in explaining which of the participants (i.e., innovator, imitator, or supplier) involved in the commercialization of an innovation will accrue the greatest remuneration, is interested in explaining the phenomena of how the commercialization of an innovation can result in incumbents being replaced.

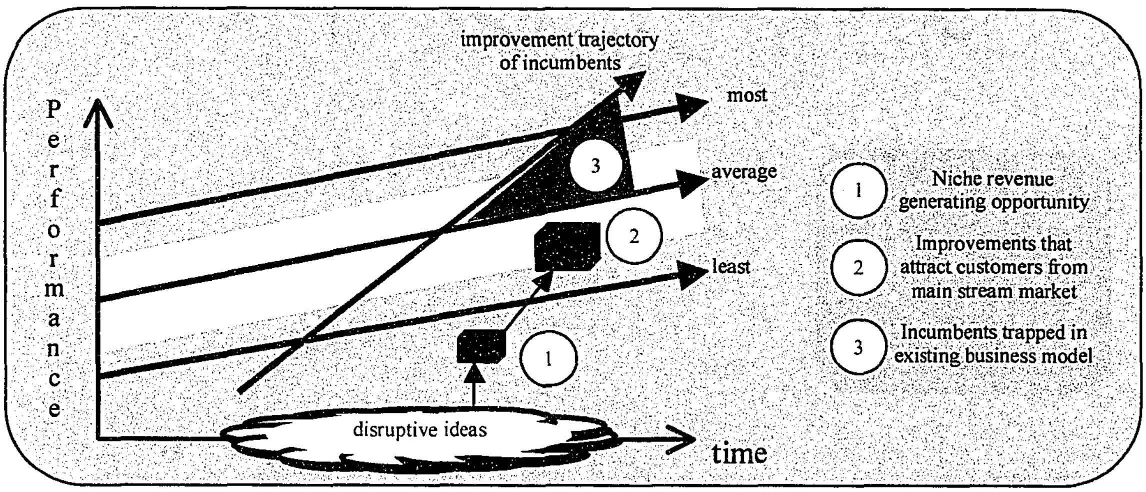

Figure 5: Reference model of disruptive technology invading an existing market

Goldenberg et. al. (2001) introduces a prescriptive framework for evaluating the marketplace success of an innovation in its early stages of development. The framework is based upon (i) categorizing the innovation as belonging to one of five product templates, and (ii) categorizing the idea for the innovation as belonging to one of three classifications. Particularly relevant is the empirical analysis: an examination of patents from which products were derived, and a determination of the subsequent success and failure of the resulting products in the marketplace. And thus this framework is applicable to evaluating the commercial potential of products underpinned by patents.

3.3.2.3 Complementary Assets

Teece (1986) considered a weak or tight Appropriability Regime as criterion for making in-sourcing and out-sourcing decisions. When a tight Appropriability Regime exists the innovator has both (i) the luxury of time to (develop) in-source the capability, and (ii) the flexibility provided by property rights to out-source the capability. Other models that may be used make sourcing decisions include: (i) Retain Intellectual Property; (ii) Cost of Transactions; (iii) Mission-Critical versus Supporting Processes; (iv) Make versus Buy (or Skate to the Money). Each of these alternatives is briefly considered in the following paragraphs.

The "Retain Intellectual Property" model, illustrated in Figure 6, recognizes the importance of intellectual property (IP), see, for example, Brull (2002), Cheung (2000), Donnelly (2002), Halket (2002), Kolker (2001), and Tuck (1997). This model is based upon the observation that among the sundry activities associated with commercialization, typically only a few have the potential to derive IP. And the IP derived from these few activities represent the ability: (i) to raise equity and protect investment, (ii) to create a sustainable competitive advantage, (iii) to generate revenue. In sum, this model posits retaining IP as a decision criterion for sourcing decisions.

The "Cost of Transactions" model, illustrated in Figure 6, reduces sourcing decisions to economic considerations (Coase,1930). Coase (1930) conceptualizes business activities as having a "transaction cost" that accounts for the interactions among groups to perform an activity. This "transaction cost" will either favor in-sourcing or out-sourcing. In sum, this model posits transaction costs as a decision criterion for sourcing decisions.

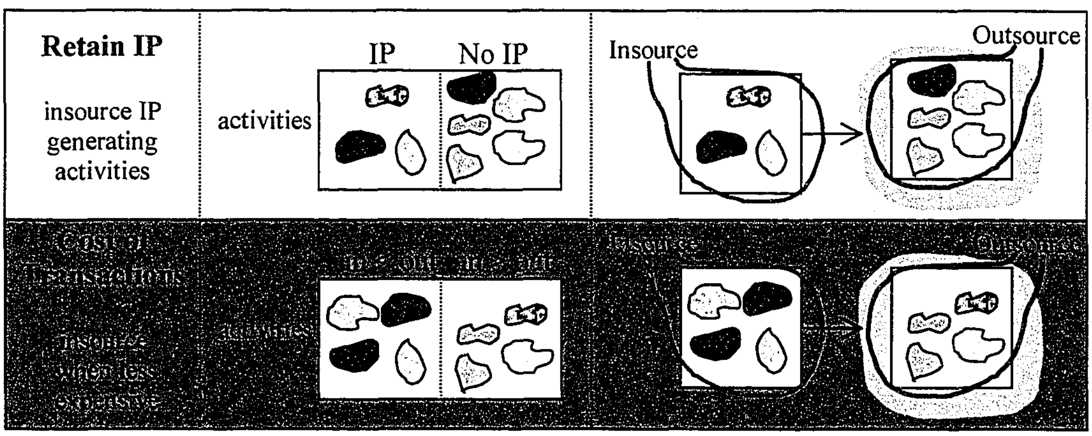

Figure 6: Models: (i) Retain IP and (ii) Cost of Transactions

The "Mission-Critical versus Supporting" model, illustrated in Figure 7, proposes that sourcing decisions be made according to their potential for increasing shareholder value (Moore, 2002).

The "make versus buy" (Fine, 1998) and the "skate to the money" (Anthony et. al., 1998) model, referenced in Figure 7, is based upon two related observations: The first is that product development comprises two types of activities: (i) integral activities, that are inherently complex and have unpredictable interdependencies, and (ii) modular activities, that are easier to understand and have interdependencies that easier to manage by specialist firms. And the second is that it is extremely challenging to outsource "pieces" of integral activities and therefore they are an important source of competitive advantage.

Fine (1998) also observes that outsourcing is a means for accelerating commercialization.

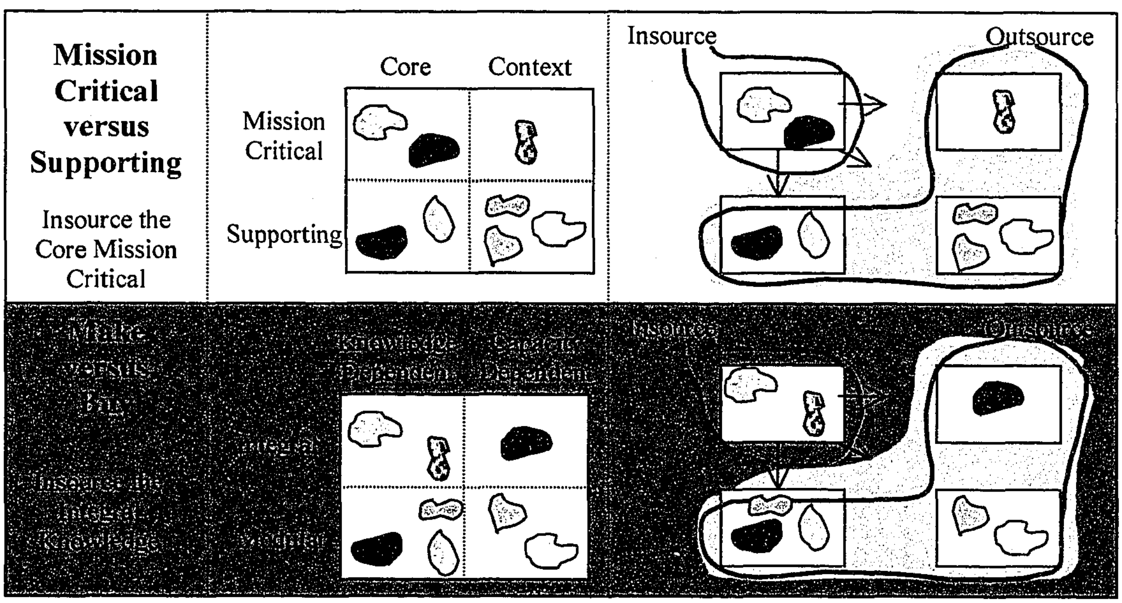

Figure 7: Models: (i) Mission Critical vs. Supporting and (ii) Make vs. Buy

3.4 Lessons learned from literature review

The lessons learned from the literature review are as follows:

Incorporate government investment into commercialization frameworks

There are various frameworks that examine aspects of the commercialization strategies of firms. For example, Teece (1986), Gans and Stern (2003), Shapiro (2001), Giarratana (2004), and Moore (2002). However, none of these incorporate the case in which government agencies are making significant investments to advance technology in support of an international agreement.

Develop tools for comparing agency's investment criteria and firm's commercialization strategy

There are frameworks that examine aspects of the commercialization objectives of government agencies. For example, Jamison (2001), Kuhlmann and Jakob (2003), Grande (2001), and Chiang (1998). Also there are frameworks that examine aspects of the commercialization strategies of firms. For example, Teece (1986), Gans and Stern (2003), Shapiro (2001), Giarratana (2004), and Moore (2002). However, none of these provide an algorithmic operationalization for assessing the alignment of an agency's investment criteria with that of a firm's commercialization strategy, that may also be used to compare investment criteria between agencies and commercialization strategies between firms.

Use Teece's building blocks to examine relationships between industry participants

Prior empirical studies of firms in emerging industries have employed Appropriability Regime and Complementary Assets. In particular, Giarratana (2004) examined the emergence of the encryption software industry, while Gans and Stern (2003) sampled an assortment of industries including software and pharmaceutical. In these studies, and in Teece (1986) generally, the central relationship examined is between the firm and the underlying commercialization environment. These studies do not consider the situation where Appropriability Regime and Complementary Assets are used to examine relationships between different types of industry participants. And in particular, they are not applied to examine the relationship between investors and firms.

Examine the influence of government agencies' investment criteria on firms

A general finding of Gans and Stern (2003) is that startup firms will adjust their commercialization strategies to avail themselves of revenue generating opportunities. However, Gans and Stern did not consider the situation where the revenue generating opportunity is represented by government agency funding. That is, the alignment of a firm's commercialization strategy with that of a government agency's investment criteria has not been examined.

An additional value to investigating the alignment of a firm's commercialization strategy with that of a government agency's investment criteria surrounds the accountability of government agencies. In particular, it has been observed that government agencies are particularly attentive to ensuring there are metrics associated with sponsorship. For example, see Chung (2002), Cozzens (1995) Georghiou and Roessner (2000), Porter, et. al. (2001), and Salter and Martin (2001). The need for such metrics suggests that the investment criteria of government agencies may incorporate evaluation related metrics, and that these, in turn, may be apparent is the commercialization strategy of firms receiving sponsorship. For example, it is conceivable that for certain industries the sponsorship of programs producing IPR may have more to do with agency evaluation than sound business practice.

Examine the type of technology being advanced

Christensen (Christensen, 1997; Anthony et. al., 2002; Christensen et. al., 2002) provides a categorization of two types of technological innovation: (i) sustaining and (ii) disruptive. The pivotal distinction between the two is that incumbents are normally unable to respond to threats from disruptive technologies. However, this distinction has not been applied to government investment criteria. For example, when a government agency provides investment to an incumbent, is it generally investing in the advancement of sustaining or disruptive technologies? By extension, if a government agency has a stated preference for investing in certain types of projects (e.g., consortiums that are themselves contributing significant funds) does this suggest a preference for advancing one type of technology over another?

Introduce commercialization based metrics for government agencies

There are various prescriptive methods based upon theory for examining government agencies. For example: (i) the analysis of the attributes of policies (Chiang, 1998); (ii) The analysis of data such as, e.g., GNP, GNP/capita (Porter, et al. 2001); (iii) The analysis of a program's market vicinity (Cantner and Pyka, 2001). However, these methods are lacking metrics that take into account an agencies investment criteria and a firm's commercialization strategy.

4 Operationalization of Teece's framework

4.1 Introduction

The purpose of operationalizing Teece's framework is to examine the relationship between (i) the commercialization strategies of the firms advancing technical innovation and (ii) the investment criteria of the government agencies applicable to that industry. Additionally, the intent is to subsequently apply the operationalization to consider a specific emerging industry, namely, the fuel cell industry. This purposefulness provides us with overarching guidance to determine what is useful to operationalize. In particular, we limit our operationalization as follows: (i) Appropriability Regime: examination of patents; (ii) Dominant Design Paradigm: announcements related to technology trials, demonstrations, general availability, and similar events; (iii) Complementary Assets: announcements related to cooperative agreements, teaming agreements, and similar events.

In particular, we wish to emphasis that:

- The measurement, major Complementary Assets, refers to the existence of one or more teaming agreement announcements, while the measure, minor Complementary Assets, refers to having found no evidence to support a measurement of major Complementary Assets. This measurement reflects the reality that government agencies are attentive to cooperative agreements.

- The measurement, Dominant Design Paradigm, refers to the state of a firm's technology with respect to being pre-commercial or commercial. More specifically, measurements are based upon a firms' participation in demonstrations and trials, and indicates their technology is in close proximity to commercial technology (Teece, 1986). This measurement confirms the state of the firm's technology relative to the general state of fuel cell technology being pre-dominant design. In particular, Industry Canada (Industry Canada, 2003) predicts that the general availability of stationary and portable fuel cells will commence in the period 2006-2008; and the general availability of fuel cells in the transportation sector will commence in the period 2008-2012. This measurement reflects the reality that government agencies are attentive to pre-commercial technology.
- The measurement, Appropriability Regime, refers to a firm's ownership of patents together with the inherent intellectual protection provided by the firm's technology. Government agencies are attentive to IPR.

The remainder of this chapter is structured as follows: Section 4.2 provides a frame of reference for the operationalization. Section 4.3 discusses the scale used to measure categories. Section 4.4 introduces the measurement methodology. Section 4.5 presents the features of the categories that are measured and the basis for assigning of values to the variables. And section 4.6 concludes with an example comparison of a measurement of an agency's investment criteria with four measurements of a firm's commercialization strategy.

4.2 Frame of reference

Figure 8 provides the framework used to operationalize Teece's framework. Referencing Figure 8 we observe that there are two areas of concern: (1) firms and (2) government agencies. For each area a specific attribute has been identified: (i) the firm's commercialization strategy and (ii) the agency's investment criteria. Teece's three building blocks are used to categorize the two attributes. The use of a common categorization enables comparison of the different attributes belonging to the different areas.

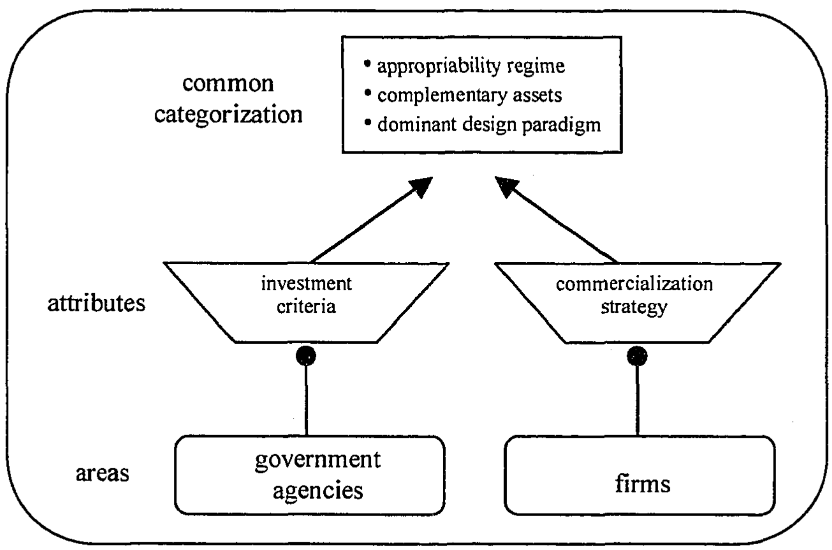

Figure 8: Operationalization of firms and agencies

The operationalization of the framework requires:

1) A scale for measuring the three categories.

2) A methodology for measuring the three categories.

3) An assignment of values to categories by identification of the measured features.

Each of these is considered in turn in the following sections.

4.3 Scale for measuring the three categories

Teece (1986) explicitly introduce measures for (i) the Appropriability Regime – weak or tight and (ii) Dominant Design Paradigm – pre-paradigmatic or paradigmatic, and implicitly introduced a measure for complementary assets based upon their role – we have elected to use the terms "minor" or "major". As illustrated in Figure 9, as a simplification these continuum measurements are transitioned into categorical measurements.

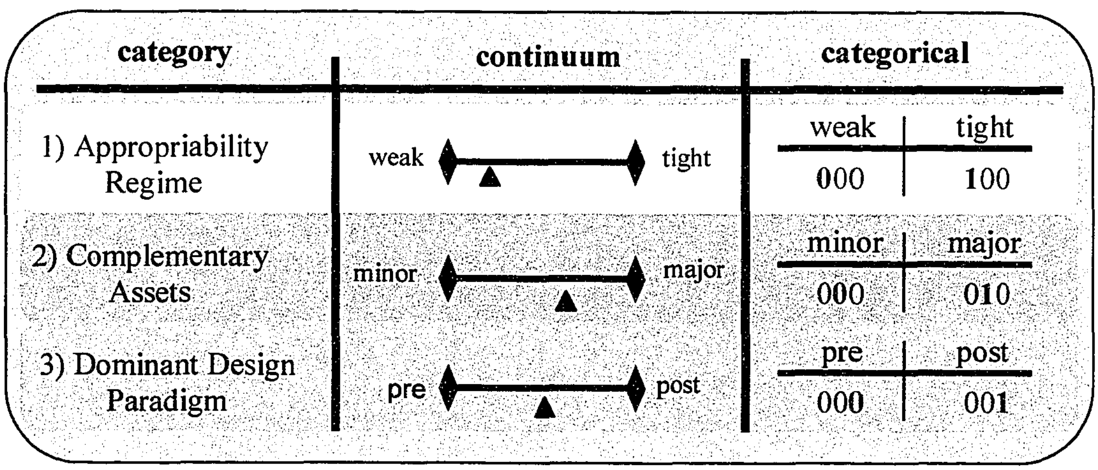

Figure 9: Categorical measurements

Referencing Figure 9 we observe that the three categories are given categorical values of either a 0 or a 1. However, we also observe there is a positional component that provides for combining the three measurements into an overall measurement. Specifically, a combined measurement for a given attribute has the syntactic form "xyz", where (i) "x" denotes the categorical measurement for Appropriability Regime, (ii) "y" denotes the categorical measurement for Complementary Assets, and (iii) "z" denotes the categorical measurement for Dominant Design Paradigm. The rationale for this syntactic form is to make overt where agreement exists when comparing the measurements of attributes.

4.4 Methodology for measuring

The methodology for obtaining measurements may be algorithmically expressed as follows:

- Let attribute ∈ {investmentCriteria, commercialStrategy};
- Let s := sample(attribute); % e.g., a specific fuel cell firm
- Let x := appropriabilityRegime(s); % measurement is **0**yz or **1**yz
- Let y := complementaryAssets(s); % measurement is x**0**z or x**1**z
- Let z := dominantDesignParadigm(s); % measurement is xy**0** or xy**1**
- Let measurement(s) := x + y + z; % measurement for "s" of the form "xyz"

As illustrated in Figure 10, the measurement of a given instantiation of an attribute will have one of 8 possible values.

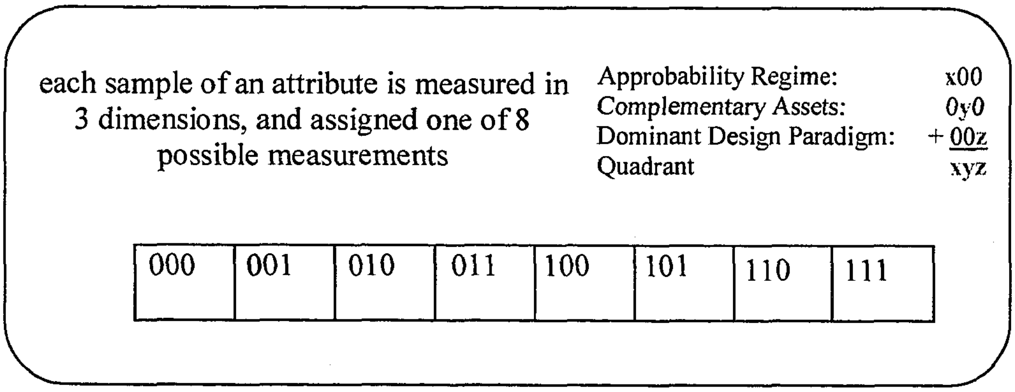

Figure 10: Possible attribute values

4.5 Assignment of values to categories

Table 3 summarizes the variables of the three categories measured by the operationalization. Referencing Table 3 we note that we use AR to denote Appropriability Regime; use CA to denote Complementary Assets; and use DD to denote Dominant Design Paradigm:

Area; Attribute	Variable	Value
agency; Investment Criteria	IP	If (stated preference for IP) Then (AR = 1yz) Else (AR = 0yz)
	Partnerships, alliances, etc	If (stated preference for partnerships) Then (CA = x1z) Else (CA = x0z)
	commercial state of the technology	If (stated preference for pre-commercial technology) Then (DD = xy0) Else (DD = xy1)
firm; Commercialization Strategy	number of patents filed in the industry and/or a categorization of the product	If (Num > 0) Then (AR = 1yz) Else If (product) Then (AR = 0yz) Else If (process) Then (AR = 1yz) Else If (tacit) Then (AR = 1yz) Else If (codified) Then (AR = 0yz)
	Number of alliances, partnerships, etc., in support of commercialization	If (Num > 0) Then (CA = x1z) Else (CA = x0z)
	state of technology announcements	If (trials or demonstrations or pre-trial or pre-demonstration) Then (DD = xy0) Else If (product Generally Available) Then (DD = xy1)

Table 3: Summary of measurements

The assignment of values in Table 3 takes into account domain knowledge related to the intended application. For example, Table 3 equates Complementary Assets internal to the firm with the firm not having Complementary Assets. The rationale for not measuring Complementary Assets internal to the firm is because the investment criteria of the agencies sampled are attentive to Complementary Assets external to the firm. A more substantive operationalization would measure both internal and external Complementary Assets and would extend comparisons to discriminate accordingly.

4.6 Comparison

The framework and methodology allows for the comparison between government agencies' investment criteria and firms' commercialization strategies. Table 4 below considers an example comparison. Referencing Table 4 we observe that the first column has assigned the measurement "110" to an agency. This value "110" represents a tight Appropriability Regime, major Complementary Assets, and a pre-Dominant Design Paradigm. The second column represents four of the possible eight values that may be assigned to a firm. These four values agree on value for the Dominant Design Paradigm, and with the agency's value.

Table 4 also details the expectation that value alignment and misalignment represents. For example, for the situation where the firm and the agency are fully aligned we would anticipate: (i) that the firm would be eligible for the agency's funding, and (ii) that the agency would be supportive of the firm's commercial activities. Whereas for a firm that is misaligned, we would expect the lure of obtaining the agency's money may result in the firm pursuing activities that result in alignment.

agency AR/CA/DD	firm AR/CA/DD	Expectation of firm behavior
110	000	misaligned • choose to reinvent itself for alignment • choose to forgo agency investments
	010	misaligned • shift of activities to those leading to IP • mining of existing strengths and developments for IP
	100	misaligned • leverage security of existing IP to pursue cooperative strategies • pursue opportunities that involve cooperative agreements that meet agency's requirements
	110	agency reinforces firm • expansion of those activities that are eligible for agency funding

Table 4: Firm behavior based upon alignment with agency

5 Application

5.1 Introduction

The areas and attributes to be examined are as follows:

- Canadian government agencies supporting the fuel cell industry; Investment Criteria.
- Canadian fuel cell firms; Commercialization Strategy.

The remainder of this chapter is structured as follows: Section 5.2 provides a brief sketch of how certain measurements were taken. Section 5.3 reports on our investigation of the Canadian government agencies. Section 5.4 reports on our investigation of the Canadian fuel cell firms. Section 5.5 summarizes the results. And section 5.6 discusses the validity of the results based upon consideration of agency funded programs.

5.2 Walkthrough example

In this section we sketch how the measurements for a government agency and a firm are obtained. Details are provided in appendix C and appendix D, respectively.

5.2.1 Sketch of SDTC's measurements

For the government agency, the Sustainable Development Technology Canada (SDTC), we wish to obtain three categorical measurements: (1) weak or tight Appropriability Regime, (ii) minor or major Complementary Assets, and (iii) pre or post Dominant

Design Paradigm. To obtain these measurements we reviewed the material available on the SDTC's web site (SDTC, 2004) for stated preferences for the characteristics of projects in which it invests.

For Appropriability Regime we sought statements that indicated the importance of intellectual property for obtaining investment. An example of one of the statements we found is as follows:

> *"To qualify for funding, a technology must show strong market relevance, and should generate incremental intellectual property to reduce uncertainties throughout the project".*

Based upon this and other similar statements we assigned the value of "tight" (i.e., 100) to SDTC's Appropriability Regime.

For Complementary Assets we sought statements that indicated the importance of teaming agreements for obtaining investment. An example of one of the statements we found is as follows:

> *"Completed SOIs are screened and evaluated by SDTC as well as external experts to ensure adherence to selection criteria (Gate 1) that include capabilities in technology, marketing, and business (partnerships and funding). Each of these topics is essential to project assessment."*

Based upon this and other similar statements we assigned the value of "major" (i.e., 010) to SDTC's Complementary Assets.

For Dominant Design Paradigm we sought statements that indicated the importance of the commercial state of the technology for obtaining investment. An example of one of the statements we found is as follows:

> *"Eligible projects must focus on the development and demonstration of new technologies that address climate change and clean air issues"*

Based upon this and other similar statements we assigned the value of "pre" (i.e., 000) to SDTC's Dominant Design Paradigm.

Table 5 summarizes these measurements together with the overall measurement that was assigned to SDTC's investment criteria. Referencing Table 5 we observe that each of the three individual values have been added to obtain an overall value for SDTC's investment criteria; with digit positioning providing visibility of the individual values.

Categories	**SDTC**
Appropriability Regime (x00)	100
Complementary Assets (0y0)	010
Dominant Design Paradigm (00z)	000
Investment Criteria (xyz)	**110**

Table 5: Sketch of SDTC's measurements

5.2.2 Sketch of a firm's measurements

For the fuel cell firm, Hydrogenics Corporation, we wish to obtain three categorical measurements: (1) weak or tight Appropriability Regime, (ii) minor or major Complementary Assets, and (iii) pre or post Dominant Design Paradigm. To obtain these measurements we reviewed the material available on the Canadian Intellectual Patent

Office (CIPO) web site (Canadian Intellectual Property Office, 2004) and on the LexisNexis web site (LexisNexis, 2004).

For Appropriability Regime we used the firm's name (viz. Hydrogenics Corporation) to determine the number of Canadian patents filed by this firm related to fuel cell technology using the International Patent Classification (IPC) "H01M 8" (World Intellectual Property Organization, 2004). We determined that Hydrogenics had filed fifteen patents in this category. Based upon this measurement we assigned the value of "tight" (i.e., 100) to Hydrogenics' Appropriability Regime.

For Complementary Assets we sought announcements that indicated Hydrogenics' involvement in teaming agreements. An example of one of the statements we found is as follows:

> *"Under the five-year agreement announced Wednesday, Toronto-based Hydrogenics will collaborate with the American farm and heavy equipment giant on fuel cell development and engineering"*

Based upon this and other similar statements we assigned the value of "major" (i.e., 010) to Hydrogenics' Complementary Assets.

For Dominant Design Paradigm we sought announcements that indicated the commercial state of Hydrogenics' technology. An example of one of the statements we found is as follows:

"a designer and manufacturer of hydrogen and fuel cell systems, announced two additions to its HyPM(R) product line at this week's 2004 Fuel Cell Seminar in San Antonio, Texas. The two additions are the HyPM 7 (kW) unit and the HyPM 65 (kW) unit, both with which the Company will strategically access additional early market opportunities that exhibit long-term potential, specifically in light mobility and backup power applications.

Last year, at the same event, the Company launched the newly commercialized design of its HyPM 10 fuel cell power module. To date, 26 units of the HyPM 10 have been shipped to a diversity of early-adopting markets, from light mobility to backup and auxiliary power."

Based upon this and other similar statements we assigned the value of "pre" (i.e., 000) to Hydrogenics' Dominant Design Paradigm.

Table 6 summarizes these measurements together with the overall measurement that was assigned to Hydrogenics' commercial strategy. Referencing Table 6 we observe that each of the three individual values have been added to obtain an overall value Hydrogenics' commercial strategy; with digit positioning providing visibility of the individual values.

Categories	**Hydrogenics**
Appropriability Regime (x00)	100
Complementary Assets (0y0)	010
Dominant Design Paradigm (00z)	000
Commercialization Strategy (xyz)	**110**

Table 6: Sketch of Hydrogenics' measurements

5.3 Canadian agencies

The two Canadian agencies investigated were:

1) Technology Early Action Measures (TEAM) (TEAM, 2004). TEAM is a second-tier agency that provides supplemental investments to complement other federal agencies' investments in climate change technologies.
2) Sustainable Development Technology Canada (SDTC) (SDTC, 2004). The SDTC is Canada's principal agency dedicated to advancing climate change technologies.

The measurements are summarized in Table 7, with details provided in Appendix C. Referencing Table 7, we observe there are no discernable differences in the investment criteria: both have a preference for projects (i) producing IP; (ii) having an assortment of partnerships; and (iii) developing pre-commercial technology.

Government Agency	Appropriability Regime (x00)	Complementary Assets (0y0)	Dominant Design Paradigm (00z)	**Investment Criteria (xyz)**
SDTC	100	010	000	**110**
TEAM	100	010	000	**110**

Table 7: Summary of measurements for the government agencies

5.4 Canadian fuel cell firms

The Fuel Cell Canada (2003) report identified 17 firms as "companies in Canada whose primary market focus is fuel cell production and/or systems integration". Table 8 summarizes the measurements obtained for these firms. The details surrounding these measurements are provided in Appendix D. Referencing Table 8, we observe the following:

- Of the seventeen (17) Canadian fuel cell firms we were able to find indications of ongoing and/or prior business activities for sixteen (16) of the firms. In particular, we elected to omit the firm called, PEM Technologies, from our analysis.
- The values assigned to the Commercialization Strategies of these firms are apportioned as follows:
  - Four (4) firms received the value: 110. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a tight Appropriability Regime, (ii) require major Complementary Assets, and (iii) is pre-Dominant Design Paradigm.
  - One (1) firm received the value: 100. This value indicates that the Commercialization Strategy of this firm embodies criteria that are appropriate for industries with commercialization environments that (i) have a tight Appropriability Regime, (ii) require minor Complementary Assets, and (iii) is pre-Dominant Design Paradigm.
  - Five (5) firms received the value: 010. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a weak Appropriability Regime, (ii) require major Complementary Assets, and (iii) is pre-Dominant Design Paradigm.

- One (1) firm received the value: 001. This value indicates that the Commercialization Strategy of this firm embodies criteria that are appropriate for industries with commercialization environments that (i) have a weak Appropriability Regime, (ii) require minor Complementary Assets, and (iii) is post-Dominant Design Paradigm.
- Five (5) firms received the value: 000. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a weak Appropriability Regime, (ii) require minor Complementary Assets, and (iii) is pre-Dominant Design Paradigm.

Firm	Appropria-bility Regime (x00)	Complement-ary Assets (0y0)	Dominant Design Paradigm (00z)	**Commercialization Strategy (xyz)**
Aluminum-Power Inc	000	010	000	**010**
Angstrom Power Inc	000	000	000	**000**
Astris Energi Inc	000	010	000	**010**
Ballard Power Systems Inc	100	010	000	**110**
Cellex Power Products Inc	000	000	000	**000**
DuPont Canada Inc	000	000	000	**000**
Energy Visions Inc	000	000	000	**000**
Fuel Cell Technologies Inc	000	010	000	**010**
FuelCell Energy Ltd	100	010	000	**110**
GreenVOLT Power	000	000	001	**001**
Hydrogenics Corporation	100	010	000	**110**
Kinectrics Inc	000	010	000	**010**
MagPower Systems Inc	000	000	000	**000**
Palcan Fuel Cells	000	010	000	**010**
PEM Technologies	n/a	n/a	n/a	**n/a**
PowerDisc Development Corporation	100	000	000	**100**
Siemens Canada Limited	100	010	000	**110**

Table 8: Summary of measurement results for the fuel cell firms

5.5 Discussion of measurements

The results for the two agencies and the sixteen firms are summarized in Figure 11. Referencing Figure 11, we observe that, while there is uniformity between the government agencies, there is considerable diversity between the firms.

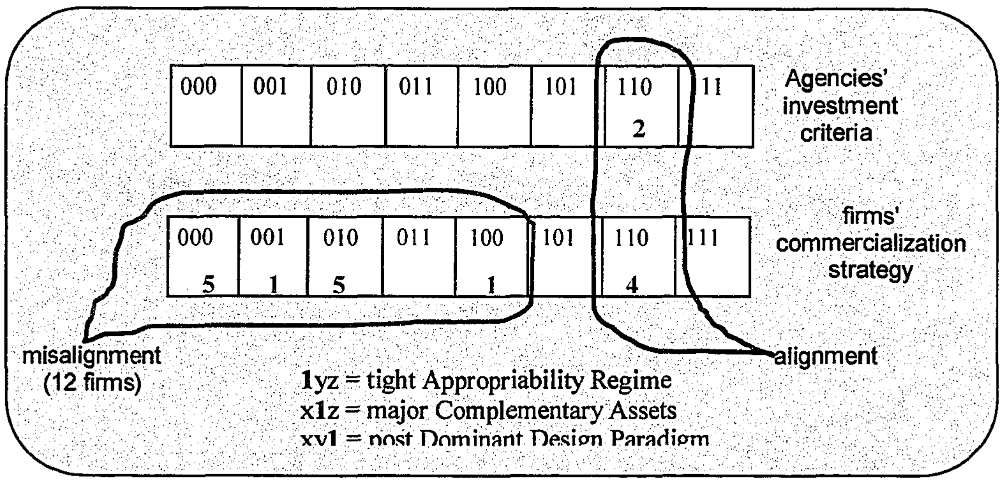

Figure 11: Comparison of measurements

Figure 11 indicates there is alignment between four of the firms and the two agencies. Further investigation of this alignment reveals the following:

- Two of the firms are (i) Ballard Power Systems Inc. and (ii) Hydrogenics Corporation. Both Ballard and Hydrogenics are recognized world leaders in the development of Proton Exchange Membrane Fuel Cell (PEMFC) technology (PriceWaterhouseCoopers, 2000). Further, Ballard is partially owned by both Ford and DaimlerChrysler, while Hydrogenics is partially owned by General Motors. More specifically, of the 16 firms analyzed, these were the only two having intimate ties with the transportation sector (via., automakers Ford, DaimlerChrysler, and General

Motors). And thus the alignment of these firms with the two agencies bodes well for the Canadian government's objective to have motor vehicles equipped with fuel cells contribute 0.1 Mt of GHG reductions by 2010.

- A third firm is Siemens Canada (i.e., Siemens Westinghouse). Siemens is a large multinational and a world leader in Solid Oxide Fuel Cell (SOFC) technologies (PriceWaterhouseCoopers, 2000). Siemens also has teaming agreements with two of the fuel cell firms not aligned with the agencies: Fuel Cell Technologies and Kinectrics.
- The remaining firm is FuelCell Energy Ltd. FuelCell Energy recently acquired Global Thermoelectric. Prior to the acquisition FuelCell Energy was a recognized world leader in Molten Carbonate Fuel Cells (MCFC) technologies while Global Thermoelectric was a recognized world leader in SOFC technologies (PriceWaterhouseCoopers, 2000). And thus the acquisition has created a formidable powerhouse for commercializing two fuel cell technologies: MCFC and SOFC.

Generally, however, Figure 11 indicates that the majority of Canada's fuel cell firms (12 of the 16 considered) have commercialization strategies that are misaligned with the investment criteria of the two agencies.

5.6 Discussion of funded programs

In this section we briefly consider the projects funded by TEAM and the SDTC that have benefited one or more of the 17 fuel cell firms. We begin by considering SDTC:

As of the fall 2004, the SDTC had invested $72M in thirty-seven (37) projects (SDTC Project Descriptions, 2004). For two of these projects, fuel cell firms have been beneficiaries. In particular, referencing Table 9, we observe that the two firms that have benefited are Cellex Power Products Inc. and Hydrogenics Corporation. We also observe that both projects have similar objectives: to demonstrate fuel cell powered forklifts.

Our measurements indicate Hydrogenics' commercialization strategy (110) is aligned SDTC's investment criteria (110), however Cellex's commercialization strategy (000) is misaligned. That Cellex received funding from the SDTC while apparently not meeting either of SDTC's investment criteria, IPR and cooperative agreements, is puzzling. Referencing Table 9, the following is noteworthy regarding the Cellex project's partners: Fuel Cells Canada is a non-profit, national industry association, while Arpac Storage Systems Corporation is a manufacturer and distributor of an assortment of material handling equipment that includes distributing Nissan's fork lifts and Crown's lift trucks.

Using Christensen's (1997) classification, we observe that the technologies being advanced by the two SDTC sponsored projects are sustaining.

SDTC sponsored firm	project partners	description	Commercialization Strategy (xyz)
Cellex Power Products Inc	1) Fuel Cells Canada 2) Arpac Storage Systems Corporation	demonstration of a fuel cell powered lift trucks (i.e., forklifts)	000
Hydrogenics Corporation	1) Deere and Company Inc. 2) Federal Express Canada Ltd. 3) General Motors of Canada Ltd. 4) NACCO Materials Handling Group Inc. 5) Canadian Transportation Fuel Cell Alliance	develop, demonstrate, and commercialize fuel cell powered forklifts	110

Table 9: Summary of firms that have received SDTC funding

As of the end of phase 2 in 2003, TEAM had invested \$93.5M in 98 projects, that complemented an additional \$97M of funds from other federal sources (TEAM Projects, 2004). For four (4) of these projects, fuel cell firms were beneficiaries. In particular, referencing Table 10, we observe that the four (4) firms that benefited are:

- Kinectrics with Siemens Canada (a.k.a. Siemens Westinghouse) have benefited from two funded projects;
- Hydrogenics Corporation benefited from one project
- Global Thermoelectric (now Fuel Cell Energy) benefited from one project.

Referencing Table 10, we observe that only Kinectrics is not aligned with TEAM's investment criteria (110). It is noteworthy that Kinectrics was formerly a division of Ontario Power Generation, and that Ontario Power Generation is partner in both the projects involving Kinectrics. It is also noteworthy that in these projects, Kinectrics is also partnering with Siemens, and Siemens is aligned with TEAM.

Using Christensen's (1997) classification, we observe that three (3) of the TEAM funded projects may be considered as advancing sustaining technology; while the remaining project is a research activity.

TEAM sponsored firm	project partners	description	Commercialization Strategy (xyz)
Kinectrics Inc	1) TEAM 2) NRCan's Industrial Energy R&D 3) Siemens-Westinghouse 4) Ontario Power Generation	demonstrate the feasibility of SOFC cogeneration and build the world's largest solid oxide fuel cell generator	010
Hydrogenics Corporation	1) Canadian National Exhibition	demonstration of a fuel-cell stationary power generator at the Canadian National Exhibition	110
Global Thermoelectric (now FuelCell Energy Ltd)	1) TEAM through the National Research Council's (NRC) Industrial Research Assistance Program (IRAP) 2) NRC's Institute for Chemical Process and Environment Technology	investigate R&D issues applicable to next-generation solid oxide fuel-cell components	110
Siemens Canada (a.k.a. Siemens-Westinghouse)		Refer to Kinectrics	110

Table 10: Summary of firms that have received TEAM funding

In summary, the agencies have funded six programs in which five fuel cell firms have benefited. Three of these firms are aligned with the agencies. The involvement of a fourth firm may be understood as “pull through” from the project’s partnerships, while the remaining project is seemingly an anomaly. Classification of the technology being advanced in these six projects indicates that five are sustaining technology; while the remaining is a research activity.

6 Conclusions, limitations, and suggestions for future research

This chapter is structured as follows: Section 6.1 provides the conclusions drawn from the two objectives. Section 6.2 discusses the limitations of this research, and section 6.3 suggests avenues for further research.

6.1 Conclusions

The motivation for this thesis was to investigate the commercialization of emerging climate change technologies. This investigation had two objectives:

1) To develop the operational definitions and a method to clarify the relationships between (i) firms' commercialization strategies for advancing climate change technologies and (ii) government agencies' criteria for investing in the advancement of this technology.
2) To apply the definitions and method to the Canadian fuel cell industry.

Section 6.1.1 contains the conclusions for objective one, while section 6.1.2 contains the conclusions for objective two and summarizes the results.

6.1.1 Objective one conclusions

Teece's (1986) framework can be detailed to provide useful insights about the relationships between innovating firms' commercialization strategies and government agencies' investment criteria.

Operational definitions can be developed for the three theoretical concepts in Teece's framework (Teece, 1986). Moreover, for the companies and government agencies involved in the advancement of emerging climate change technologies, the dimensions of these operational definitions can be measured.

The commercialization strategy of a firm advancing climate change technology can be represented and easily compared with the commercialization strategies of other firms advancing climate change technology. Similarly, a government agency's investment criteria for funding the advancement of climate change technologies can be easily represented and compared with other agencies' criteria. The representation used in this thesis makes it possible to assess the alignment of the investment criteria of government agencies responsible for advancing climate change technologies with the commercialization strategies of firms advancing climate change technologies.

6.1.2 Objective two conclusions

From the investigation of the 16 Canadian fuel cell firms and the two government agencies responsible for advancing fuel cell technology, four conclusions can be made.

The investment criteria of the two government agencies are aligned

The investment criteria of the two government agencies can be represented as 110. Both agencies prefer to support a firm (i) whose innovation is, or can be protected by, intellectual property rights, (ii) cooperates with other firms in the use of the complementary assets required to commercialize their technology, and (iii) is developing pre-commercial technology.

Four firms had commercial strategies aligned with the investment criteria of the two government agencies

The commercialization strategy of the four firms can be represented as 110. These four firms have intellectual property, execute cooperative commercialization strategies, and are involved in demonstrations and trials.

Twelve firms had commercialization strategies that were not aligned with the investment criteria of the two government agencies

The commercialization strategies of the 12 firms not aligned with the investment criteria of government agencies can be represented as 100 (one firm), 010 (five firms), 001 (one firm), and 000 (five firms).

Clarity as to which companies are eligible for funding

Consideration of the projects funded by these agencies suggests that alignment provides a concise explanation of the agency's funding practices for the firms considered, together with an intellectual apparatus that contributes to investigating related issues. For example, is it generally the case that a recipient of an agency's funding will have a commercialization strategy that is aligned with the investment criteria of that government agency?

6.2 Limitations

The measurement, major Complementary Assets, refers to the existence of one or more teaming agreement announcements, while the measure, minor Complementary Assets, refers to having found no evidence to support a measurement of major Complementary Assets. A more complete treatment would consider the number, types, source, and importance of the complementary assets required to commercialize a given innovation.

The measurement, Dominant Design Paradigm, refers to the state of a firm's technology with respect to being pre-commercial or commercial. A more complete treatment would consider the distinction of pre-commercial technology and pre-dominant design in a non-emerging industry setting.

The measurement, Appropriability Regime, refers to a firm's ownership of patents together with the inherent intellectual protection provided by the firm's technology. A more complete treatment would consider a firm's technology in greater detail. Issues which were not considered in this research include a firm's ability to assert the rights granted by patent ownership, as well as the utility of patents in the international markets being targeted.

6.3 Future research

In addition to addressing the limitations in section 6.2, suggestions for further research include:

1) Consider other industries, and other industry participants: This study considered (i) the fuel cell industry, (ii) investors that were government agencies with a stated interest in advancing hydrogen technologies, and (iii) firms whose primary market focus was on the production of fuel cells and/or their systems integration. Other industries that may be interesting to consider include, for example, semiconductor and telecom, while other participants that may be interesting to consider include, for example, private sector capital providers.
2) Classify the technologies: This study sampled and superficially classified the technologies being sponsored by the agencies as sustaining – rather than disruptive. A fuller treatment would classify the types of technologies being advanced by firms, and compare such a classification with the types of technologies the government agencies are supporting.

3) Investigate the industry sectors: The diversity in the commercialization strategies of the fuel cell firms suggests that the firms may be pursuing different industry sectors, and that their commercial strategies may be entirely appropriate for these sectors. For example, IPR and cooperative agreements are unnecessary. By extension, any misalignment of these commercialization strategies with an agency's investment criteria amounts to those agencies not supporting the development of that industry sector. A fuller treatment might discriminate different industry sectors, and examine the commercialization requirements and potential for these industry sectors.

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Appendix A: Canadian climate change initiatives

The United Nations Environment Program (2003) reports that in 1990 Canada's total GHG emissions expressed in carbon dioxide (CO2) equivalents was 607.19 Mt. And that for 2010, Canada's Kyoto commitment of 6% less than 1990 levels equates to a total GHG emissions of 570.76 Mt (i.e., a reduction of 36.43 Mt). It is noteworthy that for 2000, it also reports that Canada's total emissions were 726.25 Mt – representing an increase of 19.6% over 1990 levels, and projects that Canada's 2010 emissions will be 769.7 Mt – representing an increase of 27% over 1990 levels.

A Canadian authority for Canada's Kyoto commitment is the Government of Canada's Climate Change Plan for Canada (2002). This document equates Canada's Kyoto commitment of 6% less than 1990 levels to a reduction of 240 Mt of GHG over the projected "business-as-usual" 2010 emission levels. To relate this 240 Mt to recent emissions, Table 11 details Canada's emissions by sector for 2001 (Office of Energy Efficiency, 2004). Referencing Table 11, we observe the following: (i) 240Mt equates to approximately 50% of Canada's total GHG emissions of 473Mt in 2001; (ii) electricity is the energy source producing the most GHG; and (iii) transportation is the energy use sector producing the most GHG. In particular, we observed that 34% of Canada's GHG emissions can be sourced to the transportation sector, and that this sector is being targeted by many of the fuel cell firms. That is, fuel cell technology is being developed to replace combustion engine technology.

Canadian	**2001 (Mt)**	**2001 (%)**
total GHG emissions (Mt)	473.3 Mt	100%
by energy use sector		
Residential	74.2	15.7
Commercial/Institutional	61.7	13.0
Industrial	158.9	33.6
Total Transportation	163	34.4
Agriculture	15.5	3.3
by energy source		
Electricity	116.1	24.5
Natural Gas	97.9	20.7
Motor Gasoline	96.2	20.3
Oil	98.9	20.9
Aviation Gasoline	0.3	0.1
Aviation Turbo Fuel	15.1	3.2
Still Gas and Petroleum Coke	25.1	5.3
LPG and Gas Plant NGL	6.7	1.4
Wood Waste and Pulping Liquor	0.0	0.0
Other	15.3	3.2
Residential Wood	1.8	0.4

Table 11: Canada's 2001 GHG emissions

The Climate change Plan for Canada (2002) details a three step approach to achieving Canada's Kyoto commitment. Step 1 equates to when Canada initially signed the Kyoto Protocol in 1998. Step 1 launched an assortment of initiatives that are expected to deliver 80Mt of reductions by 2010. Step 2 equates to when Canada ratified the Kyoto Protocol in 2002. Step 2 details an assortment of initiatives that are expected to deliver a further 100Mt of reductions. Step 3 presently consists of an assortment of suggested actions for achieving the remaining 60Mt of reduction. It is noteworthy that step 1 included the stated objective of delivering 0.1 Mt of GHG reductions through vehicles equipped with fuel cells. And that this equates to just 0.06% of the GHG emissions attributable to the transportation sector.

To relate the above steps to financial commitments, between 1998 and 2002 the Canadian government committed $1.6B to step 1 climate change initiatives. As illustrated in Figure 12, in 2003 the Canadian government allocated $2B to step 2 climate change initiatives with $500M allocated to advance five key technologies: (i) Cleaner Fossil Fuels, (ii) Advanced End-Use Efficiency Technology, (iii) Decentralized Energy Production, (iv) Biofuels, and (v) the Hydrogen Economy. And, suggestive of its importance, we observe in Figure 12 that $120M of this $500M was dedicated to the Hydrogen Economy.

In 2004 the Canadian government allocated additional funds to climate change initiates. For example, the federal government announced that one half of the proceeds from the sale of their stake (18.6%) in Petro-Canada would be applied to the development of climate change technologies.

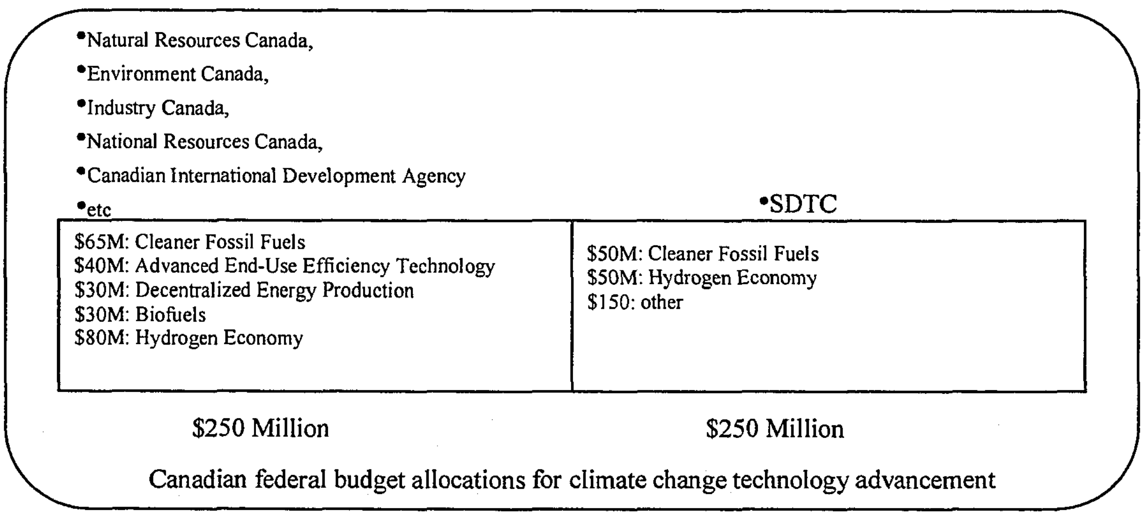

Figure 12: Technology advancement budget for 2003

In sum, climate change technologies in support of Kyoto commitments may be characterized as being mission critical with high market vicinity (Cantner and Pkya, 2001). Further to this, the Canadian fuel cell industry – the key technology of a hydrogen economy, is seen as an excellent example owing to how the hydrogen economy has been singled out in the 2003 federal budget to receive at least $120M in investment; and how prior to 2003, and commencing in the mid 1980s, fuel cell technology has been the recipient of $183M of agency investments (Auditor General, 2003).

Appendix B: Canadian fuel cell industry

B.1 Introduction

This appendix provides a brief overview of the Canadian fuel cell industry. Section B.2 discusses the industry, while section B.3 provides a very brief synopsis of each of the seventeen (17) fuel cell firms

B.2 Overview of the Canadian fuel cell industry

We begin this section with by briefly considering the global leaders involved in the international fuel cell industry. Table 12 lists the top firms whose primary goal is fuel cell production, systems integration, or fueling infrastructure (PriceWaterhouseCoopers, 2002). Of the 21 firms identified in Table 12, we observe that eight are U.S. based while five are Canadian based. We also observe that six nations presently comprise the global leaders, and that the dominant technology is PEMFC. It is generally acknowledged that PEMFC and SOFC have the broadest range of commercial applications.

Num	Sub-Num	Firm	Country	FC type
1	1	Ballard Power Systems Inc	Canada	PEMFC
2	2	Hydrogenics Corp	Canada	PEMFC
3	3	General Motors	USA	PEMFC
4	4	UTC Fuel Cells	USA	PEMFC
5	5	Plug Power Inc	USA	PEMFC
6	6	H Power Corp	USA	PEMFC
7	7	Teledyne	USA	PEMFC
8	8	Toshiba	Japan	PEMFC
9	9	Toyota	Japan	PEMFC
10	10	Honda	Japan	PEMFC
11	1	Global Thermoelectric	Canada	SOFC
12	2	Fuel Cell Technologies Canada	Canada	SOFC
13	3	Siemens Westinghouse	Germany	SOFC
14	4	Sulzer Hexis	Switzerland	SOFC
15	5	Rolls-Royce (UK)	UK	SOFC
16	1	UTC/ONSI/Toshiba	US-Japan partnership	PAFC
17	1	MTU Friedrichschafen	Germany	MCFC
18	2	FuelCell Energy	USA	MCFC
19	1	Astris Energi	Canada	AFC
20	1	Energy Ventures	USA	DMFC
21	2	Motorola Labs	USA	DMFC

Table 12: Global leaders in fuel cell technology

Fuel cell technology is categorized into one of the three application segments:

1) Stationary market: Large power units for residential, industrial, and urban settings. For example, products to replace technology for residential heating and electricity production.

2) Portable market: Small power units for flexible electricity storage and generation. For example, products to replace technology for portable electric generation. This market also contains products to produce smaller amounts of electricity. For example, products to replace the batteries currently used to power consumer electronics such as cell phones, (Personal Digital Assistant) PDAs, hearing aids, cameras, etc.
3) Mobile (Transportation) market: Power units for use in the transportation sector. For example, products contributing to the replacement of the internal combustion engine used in motor vehicles.

A key observation from the forgoing discussion on the three application segments is that the systems derived from fuel cells may be characterized as replacement technology.

The fuel cell industry is expected to achieve a compound average annual growth rate of 75% during the period 2003-2013. With the global market for fuel cells expected to be $46B by 2011 (PriceWaterhouseCoopers, 2002). This $46B is proportioned into the three application segments as follows: (i) Stationary market: $17.9B, (ii) Portable market: $17.6B, and (iii) Transportation market: $10.3B. It is projected that the worldwide market for the fuel cell industry will exceed $2.6 trillion by 2021 (PriceWaterhouseCoopers, 2002).

Table 13 identifies the 17 Canadian fuel cell producers whose primary market focus is on the production of fuel cells and/or their systems integration (Fuel Cells Canada, 2003; Industry Canada, 2003). Referencing Table 13 we observe that nine of the firms are public while the remaining eight are private. The most recent firm to be incorporated was Angstrom in 2001.

num	FCC designated Canadian fuel cell firms	incorporation date	private/public
1	Aluminum-Power Inc	?	private
2	Angstrom Power Inc	2001	private
3	Astris Energi Inc	1983	public
4	Ballard Power Systems Inc	1989	public
5	Cellex Power Products Inc	1998	private
6	DuPont Canada Inc	1877	public
7	Energy Visions Inc	1996	public
8	Fuel Cell Technologies Inc	1994	public
9	FuelCell Energy Ltd (Global Thermoelectric)	1969	public
10	GreenVOLT Power	2000	private
11	Hydrogenics Corporation	1995	public
12	Kinectrics Inc	1912	private
13	MagPower Systems Inc	1999	private
14	Palcan Fuel Cells	1998	public
15	PEM Technologies	n/a	n/a
16	PowerDisc Development Corporation	2000	private
17	Siemens Canada Limited	1966	public

Table 13: Canada's publicly traded fuel cell producers

The Fuel Cells Canada's report (Fuel Cells Canada, 2003) indicates that the majority of the 17 firms identified in Table 13 are Small and Medium Enterprises (SME), and of the larger firms, most had fewer than 500 employees engaged in activities related to fuel cell and/or their systems integration. Ballard Power Systems was the noted exception: the majority of Ballard's estimated 1100 employees were engaged in fuel cell related activities.

The Fuel Cells Canada's report (Fuel Cells Canada, 2003) also indicates that many of the firms identified in Table 13 have strategic alliances and partnerships with both domestic and foreign firms. And that many of these alliances and partnerships are with firms in industries that are, or will be, users of fuel cell technology. The explanation for the alliances and partnerships included: (i) to acquire various skills (e.g., technical, manufacturing, and marketing) and (ii) to acquire the financial resources necessary to commercialize fuel cell products and/or systems.

Figure 13 illustrates Fuel Cells Canada's (Fuel Cells Canada, 2003) classification of the participants in Canada's fuel cell industry. Referencing Figure 13 we observe there are four types of participants: (i) fuel cell producers, (ii) major suppliers, (iii) fueling infrastructure; (iv) service providers.

	producers	suppliers	fueling infrastructure	service providers
number of firms	**17**	**25**	**17**	**47**

Figure 13: Participants in Canada's fuel cell industry

The Fuel Cells Canada's report (Fuel Cells Canada, 2003) and the PriceWaterhouseCoopers' report (PriceWaterhouseCoopers, 2002) identify five regions in Canada that are, or have the potential to become, fuel cell clusters. Referencing Table 14 , we observe these regions are: (i) Vancouver, (ii) Calgary, (iii) Toronto, (iv) Kingston, and (v) Montreal. Table 14 also indicates the predominant fuel cell technology being developed as well as the number of firms of each type present in that region.

	Vancouver	**Calgary**	**Toronto**	**Kingston**	**Montreal**
Technology focus	PEMFC	SOFC	PEMFC	PEMFC & SOFC	
producers	5	1	2	2	0
suppliers	6	1	6	1	0
fueling infrastructure	6	1	2	0	4
service providers	6	0	0	0	0
Government institutions	5	1	0	0	2
Universities and colleges	4	1	2	1	0
Government test facilities	2	0	0	1	0
Government R&D	2	1	0	0	1

Table 14: Fuel cell cluster regions in Canada

Vancouver is presently Canada's only fuel cell cluster, with a concentration of fuel cell expertise that is reported to be among the largest in the world (Fuel Cells Canada, 2003). Vancouver was the center of Canada's earliest corporate fuel cell activities: Ballard Power Systems.

The Canadian fuel cell industry is primarily focused on PEMFC and SOFC, with PEMFC being the more prevalent:

- PEMFC is the leading contender worldwide for mobile (transportation) applications. The fuel cell operates at a relatively low temperature (~80C), entailing a relatively short period of time is required to reach operating temperate, and the ability to use an inexpensive containment housing. It is relatively small, but requires pure hydrogen as the input fuel. A specific type of PEMFC is the Direct Methanol Fuel Cell (DMFC). The DMFC takes as input unreformed methanol and from it produces hydrogen. The DMFC is applicable to the portable market (e.g., lawn mowers and portable power generators). PEMFC is also being demonstrated in various stationary applications (e.g., power supply in industrial settings).

- SOFC is primarily appropriate for stationary applications where one can take advantage of the heat generated: the SOFC operates at a very high temperature (600C to 1000C). The heat generated by the SOFC can be reclaimed for heating and steam generation, and this reclamation permits claims that SOFC delivers 90% efficiency. An important property of the SOFC is its ability to take as direct input a variety of fuels such as natural gas, gasoline, and propane.

B.3 Profile of the Canadian fuel cell producers

This section provides a brief synopsis of the seventeen (17) firms identified by Fuel Cells Canada (Fuel Cells Canada, 2003). Our investigations failed to find recent information on PEM Technologies Inc., and it was therefore excluded from our analysis. While a second firm, Global Thermoelectric, has been recently acquired and renamed FuelCell Energy. The remainder of this section presents a synopsis of each of the firms in alphabetic order.

Aluminum-Power Inc.

Aluminum-Power Inc (www.aluminum-power.com) is a private company developing an aluminum air fuel cell for use in portable electronics and automotive applications. Aluminum-Power Inc is the majority shareholder of Trimol Group Inc. which has exclusive licensing rights to Aluminum-Power's technology. The firm Eontech Group Inc. is the parent company of Aluminum-Power Inc. See: http://www.eontechgroup.com/ and http://www.trimolgroup.com.

Angstrom Power Inc.

Angstrom Power Inc. (www.angstrompower.com) is a private company founded in late 2001, and based in Vancouver B.C. Angstrom is commercializing micro-structured fuel cell technology developed at the University of Victoria. Initial target applications include battery replacement and portable power. Angstrom closed its first round of financing for US $2.85 million in April 2002.

Astris Energi Inc.

Astris Energi Inc. (www.astrisfuelcell.com) was founded in 1983 and trades on NASDAQ with Stock Symbol ASRNF. Astris is based in Mississauga, Ontario and is developing alkaline fuel cell (AFC) technology. This technology is addressing the three main energy markets (i) stationary, (ii) portable and (iii) transportation. In 1986 Astris Energi Inc. acquired the assets of the University of Toronto's Institute for Hydrogen Systems, including all of its alkaline fuel cell (AFC) intellectual property.

Astris has an affiliate in the Czech Republic that is responsible for developing its new fuel cell during 2003, with pilot production in 2004. Astris went public in 1995 through a reverse takeover of a Canadian company. Recently (Sept 2004) Alternate Energy Corporation (www.cleanwatts.com, NASDAQ ARGY) acquired a 10% equity stake in Astris.

Ballard Power Systems Inc

Ballard Power Systems Inc (www.ballard.com) was founded in 1989 and trades on NASDAQ with Stock Symbol BLDP and on the TSX with Stock Symbol BLD. Ballard is headquartered in Burnaby, British Columbia and is developing PEMFC technology to address the three main energy markets (i) stationary, (ii) portable and (iii) transportation. The automakers Ford and DaimlerChrysler own 19% and 17% of Ballard, respectively.

Cellex Power Products Inc.

Cellex Power Products Inc. (www.cellexpower.com) was founded in 1998 and is a private company. Cellex is headquartered in Vancouver, British Columbia and is developing fuel cell technology to replace the lead acid batteries and charger systems used by industrial vehicles (e.g., the lift trucks used by distributors).

Dupont Canada

Dupont Canada (www.ca.dupont.com) has Canadian business origins that may be dated back to 1877. Dupont trades on the NYSE with stock symbol DD. Dupont is a diversified science company, headquartered in Mississauga, Ontario. As of April 12, 2004 Dupont is formally named E. I. du Pont Canada Company.

DuPont Fuel Cells (www.fuelcells.dupont.com) is a developer and supplier of fuel cell membrane and stack components for the PEMFC industry. These development activities are based in Kingston, Ontario.

Energy Visions Inc.

Energy Visions Inc. (www.energyvi.com) was founded in 1996 and trades on the NASDAQ with stock symbol EGYV, and was recently de-listed on the TSX with stock symbol EVI.S. Energy Visions Inc was incorporated in the State of Delaware, and owns 100% of its operating subsidiary Energy Ventures Inc. Energy Ventures Inc. is a Canadian corporation with headquarters in Richmond Hill, Ontario and with fuel cell development based in Calgary, Alberta.

As of August 12, 2004, Energy Visions Inc. was undergoing corporate restructuring: The intent is to change the name of Energy Ventures Inc. to Energy Visions Canada Inc. with shareholders in Energy Visions Inc. receiving equity in this successor company. Energy Visions Canada Inc. will trade solely on the TSX.

Energy Visions Inc. is developing direct methanol fuel cells (DMFCs), and more recently (though an acquisition in 2003) developing single use and rechargeable batteries. EVI is collaborating with the Alberta Research Council to build commercial prototypes of its DMFC.

Fuel Cell Technologies Corporation

Fuel Cell Technologies (www.fct.ca) was founded in 1994 and trades on the TSX with stock symbol FCT.V. FCT is headquartered in Kingston, Ontario, and is developing a solid oxide fuel cell (SOFC) to address small scale stationary applications including, residences and remote sites.

FCT went public through a reverse take-over in 2000. FCT can date its origins to 1981 when Alcan International Limited initiated a program to develop both saline and alkaline fuel cells. In 1989 this program resulted in the creation of Alupower Canada Ltd. In 1994 Alcan closed Alupower Canada Ltd. Shortly thereafter former employees with certain assets secured from Alcan, reopened the firm as Fuel Cell Technologies Corporation.

FuelCell Energy Inc.

FuelCell Energy Inc. (www.fce.com) was founded in 1969 and trades on the NASDAQ with stock symbol FCEL. FuelCell is headquartered Danbury, Connecticut and has a Canadian subsidiary in Calgary Alberta. Prior to November 2003, this subsidiary was one of two divisions of a Canadian company called Global Thermoelectric (TSE: GLE).

In November 2003, FuelCell Energy Inc. acquired Global Thermoelectric, and extracted the Solid Oxide Fuel Cells (SOFCs) development division to form the Canadian subsidiary. The other division of Global Thermoelectric (remote power) was resold and taken private in June 2004. The annual report indicates the motivation for FuelCell acquiring Global Thermoelectric was the winning of a U.S. government contract to develop and supply SOFCs.

Prior to acquiring Global Thermoelectric, FuelCell's had been developing carbonate fuel cell power plants for distributed power generation. Subsequent to the acquisition, it is now also developing SOFC for residential cogeneration, automotive and small-scale commercial applications. Global Thermoelectric had been developing SOFC since 1997.

GreenVOLT Inc.

GreenVOLT Inc. (www.greenvolt.com), is headquartered in Orillia, Ontario, and is developing alkaline fuel cells (AFC) addressing stationary and mobile applications. GreenVOLT Inc. was taken public through a reverse takeover in June 2000. This public firm was renamed GreenVOLT Power Corporation (OTCBB: GVLT) having GreenVOLT Inc. as a 100% owned subsidiary. In August 2002 GreenVOLT Power Corporation was sold to Satellite Holdings Ltd, and Satellite Holdings Ltd renamed the public firm Satellite Enterprises Corp. As a condition of sale, ownership of the subsidiary GreenVOLT Inc. remained with the previous owner of GreenVOLT Power Corporation and the firm reverted to a private Ontario company.

Hydrogenics Corporation

Hydrogenics Corporation (www.hydrogenics.com) was founded in 1995 and trades on the TSX with stock symbol HYG, and on the NASDAQ with stock symbol HYGS. Hydrogenics is headquartered in Mississauga, Ontario, and is a developer PEMFC addressing portable, stationary and mobile/transportation applications. Hydrogenics is a member of the GM alliance of fuel cell commercialization companies, with GM owning 28% of Hydrogenics as of Oct 16th, 2001.

Kinectrics Inc.

Kinectrics Inc. (www.kinectrics.com) is headquartered in Etobicoke, Ontario, and was formerly a division of Ontario Hydro called Ontario Hydro Technologies. Kinectrics is now an independent company providing science and engineering services to the energy sector related to generation (hydro, fossil, nuclear), transmission, distribution, and environmental and industrial services.

Kinectrics is participating in the fuel cell industry in three areas: (i) construction and operation of a prototype 250 kW SOFC CHP plant, made by Siemens Westinghouse (commenced operations in early 2003), (ii) providing testing facilities for solid oxide fuel cell components and stacks (since 1993), and (iii) providing services to Fuel Cell Technologies Corporation in support of the development of a residential SOFC utilizing Siemens Westinghouse's fuel cell stack technology (since May 2000).

MagPower Systems Inc.

MagPower Systems Inc. (www.magpowersystems.com) was founded in 1999 and is headquartered in Delta, British Columbia. MagPower is developing magnesium-air fuel cells to address the portable, stationary, and mobile/transportation sector. In 2001 the firm established two divisions to pursue specific commercialization activities: (i) the Hydrogen Inhibitor Division and (ii) the Magnesium-Air Power Cells Division. The Company emphasizes the importance of their intellectual property.

Palcan Fuel Cells Ltd.

Palcan Fuel Cells Ltd. (www.palcan.com) was founded in 1998 and trades on the TSX with stock symbol PC. Palcan is headquartered in Burnaby, British Columbia, and is developing PEMFC and hydrogen storage products to address the portable and mobile/transportation sectors. On February 12, 2002, Palcan became publicly traded through a reverse takeover.

PEM Technologies Inc.

No recent information on PEM Technologies Inc could be found. Sources indicate PEM Technologies is developing high performance (pure hydrogen and oxygen) small to medium PEMFC addressing selective portable, stationary, and mobile applications. PEM Technologies is headquartered in Richmond, British Columbia.

PowerDisc Development Corporation Ltd.

PowerDisc Development Corporation Ltd. (www.powerdisc.ca) is headquartered in Chilliwack, British Columbia, and was founded in 2000. PowerDisc is developing an integrated hybrid engine using PEMFC together with an electric motor controller technology. This engine addresses the mobile/transportation sectors. Reportedly, PowerDisc is working closely with the National Research Council of Canada under the National Fuel Cell Program.

Siemens Canada Limited

Siemens Canada Limited (www.siemens.com) was founded in 1966 with Siemens AG the parent company trading on the NYSE with stock symbol SI. Siemens Canada is headquartered in Hamilton, Ontario, and is a wholly owned subsidiary of Siemens AG, based in Munich, Germany.

Siemens Westinghouse (www.siemenswestinghouse.com) (formerly Westinghouse) is based in the US and has been conducting research and development on fuel cells since the late 50s. Siemens is presently considered a world leader in SOFC technology. Both Fuel Cells Technology Inc. and Kinectrics utilize its technology.

Appendix C: Government agency measurements

C.1 Introduction

This appendix details the measurements for the investment criteria of the two Canadian government agencies considered. The summary of these measurements are presented in the Table 15. Referencing Table 15 we observe the two agencies considered were:

1) Technology Early Action Measures (TEAM) (TEAM, 2004). The TEAM is a second-tier government agency that provides supplemental investments to complement other federal agencies' investments in climate change technologies.
2) Sustainable Development Technology Canada (SDTC) (SDTC, 2004). The SDTC is first-tier agency dedicated to advancing climate change technologies.

Referencing Table 15 we observe that the value assigned to the Investment Criteria for both agencies is the same, namely, 110. This value indicates that both SDTC's and TEAM's investment criteria embodies criteria that is appropriate for industry's with commercialization environments that (i) have a <u>tight</u> Appropriability Regime, (ii) require <u>major</u> Complementary Assets, and (iii) is <u>pre</u>-Dominant Design Paradigm.

Government Agency	Appropriability Regime (x00)	Complementary Assets (0y0)	Dominant Design Paradigm (00z)	**Investment Criteria (xyz)**
SDTC	100	010	000	**110**
TEAM	100	010	000	**110**

Table 15: Summary of measurements for the agencies

The remainder of this appendix is structured as follows: Section C.1 and section C.2 provide brief overviews of the SDTC and TEAM, respectively. Within each of these sections, there are three subsections that detail the measurements for (i) Appropriability Regime, (ii) Complementary Assets, and (iii) Dominant Design Paradigm, respectively.

C.2 SDTC

Sustainable Development Technology Canada (SDTC, 2004) is a not-for-profit foundation established by the Canadian government in 2001 with $100M and a mandate of 5 years. The SDTC is accountable to the Government of Canada through the department of Natural Resources. The SDTC's stated mission: "to act as the primary catalyst in building a sustainable development technology infrastructure in Canada".

The 2003 budget complemented SDTC's initial $100 million with an additional $250M; with $50M specifically designated for advancing the hydrogen economy.

The SDTC funds projects in amounts ranging from $500K to $3M, with the funding being a non-repayable contribution. As of the fall 2004, the SDTC had allocated $72M to 37 projects (average $1.9M/project).

C.2.1 Appropriability Regime

The methodology comprised reviewing the SDTC web site (viz., www.sdtc.ca) for stated requirements for Intellectual Property. The results are presented in the Table 16, and may be summarized as follows: prior ownership of IP is not a prerequisite for project funding, however for a project to qualify for funding it must demonstrate the promise for securing IP that is relevant to the commercialization. Informally, only projects generating IP are eligible for SDTC funding. As a consequence, we concluded that SDTC's investment criteria are appropriate for commercialization environments with tight Appropriability Regimes.

SDTC's tight Appropriability Regime (100)	
reference	**statement**
http://www.sdtc.ca/en/funding/index.htm	SDTC supports clean-technology projects through these critical stages—without taking an equity stake , without requiring ownership of intellectual property or any repayment of funds
http://www.sdtc.ca/en/funding/advice/index.htm	To qualify for funding, a technology must show strong market relevance, and should generate incremental intellectual property to reduce uncertainties throughout the project;
http://www.sdtc.ca/en/funding/advice/eligible_projects.htm	Applicants should demonstrate that: [omitted text] the new technology and related intellectual property may be rapidly diffused throughout all relevant sectors

Table 16: Measurements for SDTC's Appropriability Regime

C.2.2 Complementary Assets

The methodology comprised reviewing the SDTC web site for stated requirements for teaming agreements that support the commercialization of the innovation. Our results are presented in the following Table 17, and may be summarized as follows: a qualifying project must demonstrate that it possesses a breadth of complementary assets. As a consequence we concluded that SDTC's investment criteria are appropriate for commercialization environments requiring major Complementary Assets.

SDTC's major Complementary Assets (010)	
reference	**statement**
http://www.sdtc.ca/en/funding/process.htm	Completed SOIs are screened and evaluated by SDTC as well as external experts to ensure adherence to selection criteria (Gate 1) that include capabilities in technology, marketing, and business (partnerships and funding). Each of these topics is essential to project assessment.
http://www.sdtc.ca/en/funding/advice/index.htm	SDTC believes that for clean-technologies to be successful in the marketplace, effective, goal-oriented partnerships must be established early on. For that reason, we maintain a national database of organizations active in the clean-technology market, and use that resource to help link entrepreneurs with complementary technologies and potential consortium members.

Table 17: Measurements for SDTC's Complementary Assets

C.2.3 Dominant Design

The methodology comprised reviewing the SDTC web site for stated requirements regarding the state of the innovation's commercialization. Our results are presented in Table 18, and may be summarized as follows: a qualifying project must demonstrate innovation that is on the threshold of commercialization. As a consequence we concluded that SDTC's investment criteria are appropriate for commercialization environments with a pre Dominant Design Paradigm.

SDTC's pre-Dominant Design Paradigm (000)	
reference	**statement**
http://www.sdtc.ca/en/funding/advice/eligible_projects.htm	Eligible projects must focus on the development and demonstration of new technologies that address climate change and clean air issues
http://www.sdtc.ca/en/about/index.htm	There are many links in the innovation chain between R&D and commercialization. Two of the most critical—but traditionally undersupported—are development and demonstration. These are the critical stages at which technologies exit the laboratory and prove themselves in full-scale, real-world test situations. SDTC bridges the gap in the innovation chain by fast-tracking groundbreaking clean technologies through development and demonstration, in preparation for commercialization.

Table 18: Measurements for SDTC's Dominant Design Paradigm

C.3 TEAM

The Technology Early Action Measures (TEAM) (TEAM, 2004) is a funding agency that receives its direction from three federal organizations: (i) Natural Resources Canada, (ii) Environment Canada, and (iii) Industry Canada. TEAM supports projects where the technology under development will reduce GHG emissions at the national and/or international level while promoting sustainable economic and social growth.

TEAM commenced funding initiatives in 1998, and is presently into its third phase of funding, 2004-2008. TEAM provides investments that supplement other federal sources. To be eligible for TEAM funding, the project must be both approved and recommended to TEAM by a federal government agency for advancing technology. If TEAM approves the program, the program may receive up to 75% in additional funding as that being contributed by the other agencies. There are repayment options associated with TEAM investments.

Table 19 lists the 30 agencies identified by TEAM that may recommend projects to TEAM; TEAM notes their may be other agencies. Referencing Table 19, we observe that these agencies represent a diverse range of interests that include agriculture, international development, and transportation as well such readily recognizable agencies as NRC's IRAP. However, they all support the advancement of technology.

government organization	agencies
Agriculture and Agri-Food Canada	1. Canadian Adaptation and Rural Development 2. Energy Co-Generation Program 3. Agricultural Adaptation Council
Regional Development Agencies	4. Atlantic Canada Opportunities Agency – Business Development Program 5. Western Economic Diversification Canada – Technology Investment Loan Funds 6. Canada Economic Development for Québec Regions – IDEA-SME 7. Federal Economic Development Initiative for Northern Ontario
Canadian International Development Agency	8. CIDA
Canada Mortgage and Housing Corporation	9. External Research Program
Environment Canada	10. Environmental Technology Advancement Directorate 11. Oil, Gas, and Energy Branch 12. Environment Canada Regional
Industry Canada	13. Technology Partnerships Canada 14. Energy and Marine Branch 15. Environmental Affairs 16. Sustainable Cities Initiative
National Research Council	17. Industrial Research Assistance Program

Natural Resources Canada	18. Industry Energy Research and Development Program 19. Buildings Energy Technology Advancement Plan 20. Transportation Energy Technologies Program 21. Renewable Energy Technologies Program 22. Community Energy Systems Program 23. Advanced Combustion Technology Program 24. Programs of the CANMET Energy Technology Centre – Devon 25. Programs of the CANMET Energy Technology Centre – Varennes 26. Advanced Separation Technologies 27. National Centre for Upgrading Technology 28. Processing and Environmental Catalysis Program 29. Program of Energy Research and Development
Transport Canada	30. Transport Canada's Technology Development Centre

Table 19: Agencies that may recommend projects to TEAM

C.3.1 Appropriability Regime

The review of the TEAM web site (http://www.climatechange.gc.ca/english/team_2004/) for stated requirements for Intellectual Property proved unsuccessful. However, we obtained a copy of TEAM's business plan (TEAM Business Plan, 2004) and it contains guidelines to be used for evaluating projects. Our findings are provided in Table 20, and indicates intellectual property is a consideration used to evaluate projects. From this we concluded that TEAM's investment criteria are appropriate for commercialization environments with a tight Appropriability Regime.

TEAM's tight Appropriability Regime (100)	
evaluation criteria	**guideline**
Page 61, a guideline related to evaluating the commercialization potential of the submission	For commercial potential, uniqueness of the technology is important, hence consideration must also be given to the protection of intellectual property. Data from the proof of concept demonstration is likely to be included in the patent application.
Page 49, in a section related to the submission providing a detailed business plan and areas to be attentive too to ensure they are addressed	Business plan or technology roll out plan should be in sufficient detail and cover the time period to 2012 and including: [omitted text] Intellectual Property Rights?

Table 20: Measurements for TEAM's Appropriability Regime

C.3.2 Complementary Assets

The methodology comprised reviewing the TEAM web site for stated requirements for partnerships that support commercialization of the innovation. Our results are presented in the following Table 17, and may be summarized as follows: a qualifying project must demonstrate that it has significant financial commitments from a broad array of private and public sectors. Here, we have assumed that financial commitments presume partnership and/or teaming arrangements. As a consequence, we concluded that TEAM's investment criteria is criteria is appropriate for commercialization environments requiring <u>major</u> Complementary Assets.

TEAM's major Complementary Assets (010)	
reference	**statement**
http://www.climatechange.gc.ca/english/publications/team_199801/how.asp	TEAM invests in projects that involve a significant financial commitment from many parties, ranging from the business community to the provinces and municipalities, thus promoting national research and development in the private and academic sectors. All proposals are evaluated through an interdepartmental review process.

Table 21: Measurements for TEAM's Complementary Assets

C.3.3 Dominant Design

The methodology comprised reviewing the TEAM web site for stated requirements regarding the state of the innovation's commercialization. Our results are presented in Table 22, and may be summarized as follows: a qualifying project must demonstrate their innovation is in the latter stages of development and/or the initial stages of demonstration. As a consequence, we concluded that TEAM's investment criteria are appropriate for commercialization environments with a pre Dominant Design Paradigm.

TEAM's pre-Dominant Design Paradigm (000)	
reference	**statement**
http://www.climatechange.gc.ca/english/team_2004/about/	TEAM supports late-stage development projects and first-time demonstration projects designed to reduce GHG emissions nationally and internationally, at the same time sustaining economic and social development.
http://www.climatechange.gc.ca/english/team_2004/approach.asp	Most companies that develop new technologies find that much needed funding and technical assistance is scarce when preparing to bring a new technology to market following the end of research and development (R&D) activities. Without such funding and assistance, a valuable, innovative technology may never become a business reality. TEAM acts as an important strategic partner during this period, helping to create a platform for ongoing success.

Table 22: Measurements for TEAM's Dominant Design Paradigm

Appendix D: Fuel cell firm measurements

D.1 Introduction

This appendix details the measurements for the commercialization strategies of the 17 Canadian fuel cell firms. The summary of these measurements are presented in the Table 23. Referencing Table 23 we observe the following:

- Of the 17 Canadian fuel cell firms we were able to find indications of ongoing and/or prior business activities for 16 of the firms. In particular, we elected to omit the firm PEM Technologies for reasons that included: (i) their published web site (www.pem.ca) is not active. (ii) The search of the LexisNexis database (and various other sources) did not reveal any business news for this firm. And (iii) the Canadian patent database did not record any patents filed under that name.
- Siemens Canada received exceptional treatment based upon the following: (i) the CIPO database (Canadian Intellectual Property Office, 2004) indicated there have been no patents filed by Siemens Canada related to fuel cells. And (ii) there was exactly one news item in the LexisNexis database referencing Siemens Canada. As a consequence, we choose to measure the U.S. affiliate, Siemens Westinghouse. Siemens Westinghouse is a world leader in fuel cell technology. Further, Siemens Westinghouse has teaming agreements with two of the 17 fuel cells firms: Fuel Cell Technologies and Kinectrics.
- The values assigned to the Commercialization Strategies of these firms may be summarized as follows:

- Four firms received the value: 110. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a <u>tight</u> Appropriability Regime, (ii) require <u>major</u> Complementary Assets, and (iii) is <u>pre</u>-Dominant Design Paradigm.
- One firm received the value: 100. This value indicates that the Commercialization Strategy of this firm embodies criteria that are appropriate for industries with commercialization environments that (i) have a <u>tight</u> Appropriability Regime, (ii) require <u>minor</u> Complementary Assets, and (iii) is <u>pre</u>-Dominant Design Paradigm.
- Five firms received the value: 010. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a <u>weak</u> Appropriability Regime, (ii) require <u>major</u> Complementary Assets, and (iii) is <u>pre</u>-Dominant Design Paradigm.
- One firm received the value: 001. This value indicates that the Commercialization Strategy of this firm embodies criteria that are appropriate for industries with commercialization environments that (i) have a <u>weak</u> Appropriability Regime, (ii) require <u>minor</u> Complementary Assets, and (iii) is <u>post</u>-Dominant Design Paradigm.
- Five firms received the value: 000. This value indicates that the Commercialization Strategies of these firms embodies criteria that are appropriate for industries with commercialization environments that (i) have a <u>weak</u>

Appropriability Regime, (ii) require <u>minor</u> Complementary Assets, and (iii) is <u>pre</u>-Dominant Design Paradigm.

Firm	Appropriability Regime (x00)	Complementary Assets (0y0)	Dominant Design Paradigm (00z)	**Investment Criteria (xyz)**
Aluminum-Power Inc	000	010	000	**010**
Angstrom Power Inc	000	000	000	**000**
Astris Energi Inc	000	010	000	**010**
Ballard Power Systems Inc	100	010	000	**110**
Cellex Power Products Inc	000	000	000	**000**
DuPont Canada Inc	000	000	000	**000**
Energy Visions Inc	000	000	000	**000**
Fuel Cell Technologies Inc	000	010	000	**010**
FuelCell Energy Ltd	100	010	000	**110**
GreenVOLT Power	000	000	001	**001**
Hydrogenics Corporation	100	010	000	**110**
Kinectrics Inc	000	010	000	**010**
MagPower Systems Inc	000	000	000	**000**
Palcan Fuel Cells	000	010	000	**010**
PEM Technologies	n/a	n/a	n/a	**n/a**
PowerDisc Development Corporation	100	000	000	**100**
Siemens Canada Limited	100	010	000	**110**

Table 23: Summary of measurements for the fuel cell firms

The remainder of this appendix is structured as follows: Section D.2 provides a brief overview to the two databases used to collect measurements; Section D.3 through to section D.5 reports the results of our measurements.

D.2 Databases

To collect data, two on-line databases were used: (i) Canadian Intellectual Patent Office (CIPO) database (Canadian Intellectual Property Office, 2004) database and the LexisNexis Business News database (LexisNexis, 2004).

The CIPO is maintained by the Federal Government, and it provides a searchable repository for all patents currently filed in Canada. This database was used to obtain measurements for the firms related to the Appropriability Regime. In particular, we used the advanced search option to filter patents based upon the following criteria:

- Date: for patents filed and patents issued, the range selected: Jan 1st, 1920 through to Oct 8th, 2004.
- International Patent Classification: for patent classification we used the World Intellectual Property Organization's International Patent Classification (IPC) for fuel cells: "H01M 8/*" (World Intellectual Property Organization, 2004).
- Owner: for the patent owner we chose the firm's name.

The LexisNexis database may be accessed through the Carleton University Library which maintains a mirror site. This database was used to obtain measurements for firms related to Complementary Assets and Dominant Design Paradigm. In particular, we filtered news items based upon the following criteria:

- Information related to "Business News";
- Selected search criteria "Business & Finance";
- Selected search criteria "All available dates"
- Selected search filtering "Full Text", and limited articles to those containing occurrences of the firm's name and the string "fuel cells".

The results for the LexisNexis database search are detailed in Table 24. Referencing Table 24, we observe that news articles were found for fifteen (15) of the seventeen (17) firms. In the case of:

- PowerDisc Development Corporation, for which no news article were found, what we did is went to their Web Site (www.powerdisc.ca) to obtain statements that indicated the existence of partnerships and the state of their technology.
- For the remaining fifteen (15) firms the articles were inspected for announcements related to the existence of partnerships and the state of their technology.

Firm	Search Strings	Period	Number of announcements
Aluminum-Power Inc	Aluminum-Power & Fuel Cells	May 2002 to July 10, 2002	36
Angstrom Power Inc	Angstrom Power & Fuel Cells	Apr 15, 2003 to May 1, 2001	6
Astris Energi Inc	Astris Energi & Fuel Cells	Nov 8, 2004 to Mar 31, 1995	186
Ballard Power Systems Inc	Ballard Power & Fuel Cells	Nov 12, 2004 to Nov 19, 1990	> 1000
Cellex Power Products Inc	Cellex Power & Fuel Cells	Nov 1, 2004 to Oct 2, 2001	24
DuPont Canada Inc	DuPont Canada & Fuel Cells	Aug 7, 2003 to Dec 21, 1998	19
Energy Visions Inc	Energy Visions & Fuel Cells	Apr 20, 2004 to Nov 24, 1997	65
Fuel Cell Technologies Inc	Fuel Cell Technologies & Fuel Cells & FCT	Nov 12, 2004 to Nov 23, 1998	280
FuelCell Energy Ltd	Global Thermoelectric & Fuel Cells	Oct 21, 2004 to Aug 25, 1997	311
GreenVOLT Power	GreenVOLT & Fuel Cells	May 19, 2004 to Aug 28, 2000	33
Hydrogenics Corporation	Hydrogenics & Fuel Cells	Nov 12, 2004 to Feb 16, 1999	515
Kinectrics Inc	Kinectrics & Fuel Cells	Apr 15, 2003 to Aug 29, 2000	10
MagPower Systems Inc	MagPower Systems & Fuel Cells	May 22, 2003 to Jan 25, 1999	2
Palcan Fuel Cells	Palcan Fuel Cells & Fuel Cells	Oct 18, 2004 to Jun, 2001	66
PEM Technologies	n/a	n/a	n/a
PowerDisc Development Corporation	PowerDisc & Fuel Cells	none	none
Siemens Canada Limited	Siemens Westinghouse & Fuel Cells	Nov 12, 2004 to May 17, 1994	200

Table 24: LexisNexis announcements related to the firms

D.3 Appropriability Regime

This section reports on our investigation into Appropriability Regime. As discussed in section 2.3, Teece (1986) reduced Appropriability Regime to two environmental issues that protect an innovation from imitators and followers: (i) the nature of the technology and (ii) the effectiveness of legal mechanisms. The treatment in this thesis limits the measurement of Appropriability Regime to the number of patents filed by the firms: "tight" means one or more filed patents while "weak" means no filed patents.

This section has two subsections. Section D.3.1 provides measurements for the nature of the technology, while section D.3.2 provides measurements for the number of patents. We hasten to add that while measurements for the nature of the technology are not incorporated into the values assigned to Appropriability Regime, we have included the analysis because it provides insights into the type of technology being advanced by the firms.

D.3.1 Nature of the technology

This subsection reports on the extent to which the fuel cell technology being advanced by the firms has certain inherent intellectual property protection. For example, as Teece (1986) observed, trade secrets can be an entirely effective means for protecting some innovations, while patents are notoriously ineffective at protecting others.

Measurements are based upon classifying the nature of the technology each firm is initially commercializing as belonging to one of the four types introduced by Teece (1986): (i) product, (ii) process, (iii) tacit knowledge, and (iv) codified knowledge.

Specific methodology

- Review the firm Web Sites and/or LexisNexis announcements, and isolate the initial market offer(s) being targeted. Then decide as to the proximity of the market offer to one of the four nature of technology types.

The results are presented in the Table 25 below. Referencing Table 25, we observe the following: in all cases the firms are targeting the creation of physical products that are components of a new type of market offer for an existing and/or established market. For example, (i) the commodity market for small scale portable generators (e.g., as used by cottagers), (ii) the commodity market for automotive vehicles, or (iii) the niche market for large scale cogeneration power plants. In short, the firms are all developing products which have an inherent exposure of being disassembled and copied. Indeed, the requirement for co-specialized assets related to after-market repair and maintenance, would require codifying the workings of many of these products.

In sum, generally we observe that the nature of the technology being advanced by these firms corresponds to a <u>weak</u> Appropriability Regime.

firms	nature of the technology type	initial market offer	nature of the technology Appropriability Regime (x00)
Aluminum-Power Inc	product	portable electronics and automotive applications	000
Angstrom Power Inc	product	conversion systems for batteries and portable power (e.g., electricity generators)	000
Astris Energi Inc.	product	conversion systems for small engines (e.g., power generators, golf carts, electric vehicles, forklifts, and boats	000
Ballard Power Systems Inc.	product	materials and components for OEM and system integrators; conversion systems for engines used in the transportation sector; conversion systems for the stationary and portable power generation markets	000
Cellex Power Products Inc	product	conversion systems for industrial lead acid batteries and charger systems used in industrial vehicles (e.g., forklifts)	000
DuPont Canada Inc	product	materials and components for OEM and system integrators	000
Energy Visions Inc	product	small scale (1-40kW) conversion systems for the stationary and transportation markets	000
Fuel Cell Technologies Inc	product	small and large scale conversion systems for the stationary power unit markets (industrial, remote, and residential)	000
FuelCell Energy Ltd	product	large scale (250kW, 1MW, and 3MW) conversion systems for stationary power cogeneration market (large industrial and commercial facilities, institutions, municipalities, and utilities)	000
GreenVOLT Power	product	small scale conversion systems for the portable power generator	000

Hydrogenics Corporation/Inc	product	material and components for OEMs and system integrators; compete conversion systems for specific end-use markets	000
Kinectrics Inc	product	large scale conversion systems for the stationary power unit markets	000
MagPower Systems Inc	product	conversion systems for lead acid battery	000
Palcan Fuel Cells	product	materials and components for OEM and system integrators; small scale (100 W to 5kW) conversion systems	000
PEM Technologies	n/a	n/a	n/a
PowerDisc Development Corporation/Corp	product	component (fuel cell stacks) for OEM and system integrators	000
Siemens Canada Limited	product	material and components for OEMs and system integrators; large (250 kW) conversion systems for the stationary cogeneration (electricity and heat) market (large industrial, commercial facilities, and institutions)	000

Table 25: Description of fuel cell firm's market offers

D.3.2 Patents

This subsection reports on the extent to which the firms are applying legal mechanisms (viz., patents) to protect their technology from imitators and followers.

Measurements are based upon counting the number of Canadian patents that have been filed and/or issued to the firms.

The results are presented in the Table 26 below. As of October 8th, and referencing Table 26, we observe the following: There were 1789 patents related to fuel cells filed, and of these, 498 had been issued. The 17 firms accounted for 152 (8%) of all filed patents and 27 (5%) of all issued patents. Only five of the 17 firms are contributing patents in the area of technology designated by the IPC (World Intellectual Property Organization, 2004) as fuel cell related. Of these five firms, a disproportionate number of the patents are owned by Ballard Power Systems: 71% of patent filings and 93% of patents issued.

In sum, we observe that the majority of firms are not employing Canadian legal mechanisms (patents) to protect intellectual property arising from the fuel cell technology they are advancing; indicating a <u>weak</u> Appropriability Regime.

	patents filed		patents issued		
firm	all	H01M 8	all	H01M 8	**patent based Appropriability Regime (x00)**
Aluminum-Power Inc	6	0	0	0	000
Angstrom Power Inc	0	0	0	0	000
Astris Energi Inc	0	0	0	0	000
Ballard Power Systems Inc	142	108	34	25	**100**
Cellex Power Products Inc	0	0	0	0	000
DuPont Canada Inc	18	0	0	0	000
Energy Visions Inc	0	0	0	0	000
Fuel Cell Technologies Inc	0	0	0	0	000
FuelCell Energy Ltd	17	14	0	0	**100**
GreenVOLT Power	0	0	0	0	000
Hydrogenics Corporation	23	15	2	1	**100**
Kinectrics Inc	24	0	16	0	000
MagPower Systems Inc	2	0	0	0	000
Palcan Fuel Cells	0	0	0	0	000
PEM Technologies	0	0	0	0	n/a
PowerDisc Development Corporation	3	3	1	1	**100**
Siemens Canada Limited	52	12	1	0	**100**
Firm's total	287	152	54	27	
Firm's total as % of all patents total		8%		5%	
CDN Patents Total		1789		498	

Table 26: Number of patents owned by the Canadian fuel cell firms

D.4 Complementary Assets

This section reports on our investigation into Complementary Assets. As discussed in section 2.5, Teece (1986) discussed Complementary Assets in terms of their number, type and source, where this latter refers to in-sourced or out-sourced. The treatment in this thesis limits measurements of Complementary Assets to out-sourcing activities related to the existence of teaming agreements: "major" means the existence of teaming agreements and "minor" means the existence of teaming agreements is not supported.

Measurements are based upon reviewing public announcements found in the LexisNexis database for statements that indicate firms are participating in teaming agreements. In particular, we sought out the most recent announcements, and used particular keywords and phrases to help discriminate:

- Major Complementary Assets: cooperation agreement, joint development agreement, joint research and development agreement, memorandum of understanding, alliance agreement, technology acquisition agreement, joint venture, cooperation, cooperative, association with, collaboration with, agreement, partner, teamed, partnership, Consortium, acquisition, manufacturing.
- Minor Complementary Assets: this is the default value, and indicates "major" is not supported by the measurements. There are several possibilities that may apply to the firms assigned to this value, including:
    1. The firm's commercialization activities warrant a measurement of "major" but our research failed to find this evidence.

2. The firm is developing their Complementary Assets internal to the firm. Such internally developed Complementary Assets are not considered in our treatment; a fuller treatment would measure internal Complementary Assets and then assign a value of either major or minor.
3. The firm's commercialization activities are not sufficiently advanced as to be pursuing the development of complementary assets.

In general, Complementary Assets represent a snapshot representing the firm's current state.

The results are presented in Table 27. Referencing Table 27, we observe that: 12 firms are assigned a value of major Complementary Assets, while four firms are assigned a value of minor Complementary Assets. Referencing Table 27, we also draw the reader's attention to the incorporation dates for the four firms assigned a value of minor Complementary Assets. These four firms are private, and have relatively recent incorporation dates - possibly indicating that these firms may not have progressed to the point for entertaining teaming agreements.

firm	incorporation date	Complementary Assets (0y0)
Aluminum-Power Inc	private	**010**
Angstrom Power Inc	2001/private	000
Astris Energi Inc.	1983/public	**010**
Ballard Power Systems Inc.	1989/public	**010**
Cellex Power Products Inc	1998/private	**010**
DuPont Canada Inc	1877/public	**010**
Energy Visions Inc	1996/public	**010**
Fuel Cell Technologies Inc	1994/public	**010**
FuelCell Energy Ltd	1969/public	**010**
GreenVOLT Power	2000/private	000
Hydrogenics Corporation	1995/public	**010**
Kinectrics Inc	1912/private	**010**
MagPower Systems Inc	1999/private	000
Palcan Fuel Cells	1998/public	**010**
PEM Technologies	n/a	n/a
PowerDisc Development Corporation	2000/private	000
Siemens Canada Limited	1966/public	**010**

Table 27: Summary of measurements for firm's Complementary Assets

The remainder of this section enumerates in the alphabetic order of the firm's names text extracted from announcements that support of the measurements in Table 27.

Aluminum-Power Inc: Major Complementary Assets (010)	
Source	**Text**
Global News Wire, Service Environment News Service, April 30, 2001	Trimol Group, Inc. (OTC:BB: TMOL) announced today that it has completed the assignment of a Cooperation Agreement with SAGEM SA, a leading European manufacturer of sophisticated electronic systems and equipment, to jointly develop an aluminum-air fuel cell application for SAGEM portable electronics focusing on commercial as well as military applications.
Business Wire, July 9, 2001	Trimol Group, Inc. (OTC-BB: TMOL) (the "Company") announced today that it has entered a Cooperation Agreement with Hitachi Maxell Ltd. ("Hitachi Maxell") one of the world's leading battery manufacturers, to work in cooperation on an aluminum-air fuel cell power source for portable consumer electronics.
Canada NewsWire, July 18, 2001	Trimol Group, Inc. (OTC-BB: TMOL) (the "Company") is pleased to announce its association with Jerry Goodis. A legend in the advertising industry, Mr. Goodis is widely recognized as Canada's foremost marketer whose skills and creativity have had a significant and lasting effect on the Canadian advertising industry. [omitted text] An acclaimed international speaker, award winning marketer, legendary adman and dynamic and successful businessman, Mr. Goodis has agreed to work with Trimol Group to help shape the development of its corporate marketing strategy for its aluminum-air fuel cell technology. Mr. Goodis will also be working with Aluminum-Power, Inc. (the majority shareholder of Trimol Group), and has accepted the position of Executive Vice President of International Marketing for Aluminum-Power's parent company Eontech Group, Inc., a technology based company.
Business Wire, June 19, 2001	Trimol Group, Inc. (OTC-BB: TMOL) (the "Company") announced today that in collaboration with Aluminum Power Inc., ("Aluminum Power") it has opened an International Fuel Cell Research and Development Center for the continued development of its aluminum-air fuel cell technology, which the Company licensed from Aluminum Power for use in portable consumer electronics.
Business Wire, January 12, 2001	Trimol Group, Inc. (OTC-BB:TMOL) (the "Company") announced today that it has entered into a Technology Acquisition Agreement with Aluminum-Power, Inc., a privately held company headquartered in Toronto, Canada.

Angstrom Power: Minor Complementary Assets (000)	
Source	**Text**
	A total of six (6) announcements were found, and among these there were no teaming announcements.

Astris Energi Inc: Major Complementary Assets (010)	
Source	**Text**
Canadian Corporate Newswire, October 19, 2004	Astris Energi Inc. (OTC Bulletin Board - ASRNF), the world's leading alkaline fuel cell (AFC) technology company, announced today that it has signed a Cooperation Agreement with Italy's Electronic Machining s.r.l. (El.Ma.). [deleted text] Under the terms of the new Agreement, Astris will licence the use of its AFC technology and market its products and consulting services to El.Ma. with the objective of quickly expanding El.Ma.'s AFC technical readiness and establishing it as a hydrogen/fuel cell center of expertise in Italy and Europe. All goods and services provided by Astris will be purchased by El.Ma. at market competitive prices. El.Ma. will apply its research and manufacturing expertise to the further commercialization and production development of Astris' alkaline fuel cell technology. Any intellectual property resulting from the execution of the Agreement will be owned exclusively by Astris Energi. Together Astris and El.Ma. will cooperatively develop an AFC sales and marketing plan targeted to the Italian market, with El.Ma. serving as a key Astris representative in Europe.
Business Wire, August 12, 2004	Alliance to Expedite the Deployment of an Economical Hydrogen Power Solution Alternate Energy Corporation (OTCBB:ARGY) announced today that it has participated in a private placement in Astris Energi Inc. of Mississauga, Ontario (OTCBB:ASRNF), a world leader in alkaline fuel cell (AFC) technology. Under the terms of the agreement, AEC will benefit by being guaranteed the first POWERSTACK(TM) MC250 Astris fuel cells 'off the line', to be installed in a 2.4 kW Model E8 affordable AFC generator. Upon delivery of the alkaline fuel cell generator, the unit will then be interfaced to operate using AEC's hydrogen production technology. This completed 'powerpack' will be used as a combined demonstration unit, to jointly and independently, attract and secure commercial, utility and government customers interested in renewable on-site energy.
Business Wire, April 2, 2003	Astris Energi Inc. (OTCBB:ASRNF) announced today that its joint venture partner, CareAction, Inc. of Montreal, Quebec, has acquired the multi-million-dollar fuel cell laboratory and

	production facility in Montreal, which was formerly owned and operated by HPower Corporation of Englewood, NJ. Inc. Most of its experienced technical and operations personnel have become available as well. The facility will be operated by the joint venture -- Astris Transportation Systems, Inc. (ATSI) -- and is expected to be the first volume manufacturer of alkaline fuel cells in the world. According to F. Lynnwood Farr, president and CEO of both ATSI and CareAction, securing this attractive, fully-equipped plant will greatly advance the venture's fuel cell production schedule. Initial output of the plant will be concentrated on alkaline fuel cell power plants for small vehjcles, the first of which will be the ZENN (Zero Emission, No Noise) mini-car scheduled to roll out before the end of this year.
Business Wire, December 12,2002	Astris Energi Inc. (OTCBB:ASRNF), the world's leading developers of alkaline fuel cell technology, announced today the signing of a Memorandum of Agreement with CareAction, Inc., based in the Montreal suburb of Laval, Quebec, under which Astris will license its technology and CareAction will provide financing and management for a $15,000,000 technology and consumer product development program, centered on the transportation sector.
Business Wire, September 15, 2000	Astris Energi Inc. (OTCBB:ASRF) developers for over 17 years of the most advanced alkaline fuel cell (AFC) technology, Friday announced that it is inviting large companies interested in participating in the burgeoning fuel cell industry to become either partners or licensees in the commercialization of this reservoir of experience.

Ballard Power Systems: Major Complementary Assets (010)	
Source	**Text**
Environment News Service, June 19, 2000	Two of the world's largest automakers have teamed up with two of the most advanced fuel cell developers in a partnership that will bring fuel cell powered cars to market within four years. Modine Manufacturing Company and XCELLSIS have signed an exclusive cooperation agreement that focuses on Modine's development and manufacturing of components for fuel cell engines in buses, cars, and trucks. XCELLSIS is a joint venture of DaimlerChrysler, Ballard Power Systems, and Ford Motor Co. to develop, manufacture, and commercialize fuel cell engines to supply equipment manufacturers.
Canadian Corporate Newswire,	UCAR Graph-Tech, Inc. produces expandable and flexible graphite sheets. Flexible graphite is used for gaskets and other sealing applications for internal combustion engines. In

May 29, 2000	1999, UCAR Graph-Tech Inc. and Ballard Power Systems signed an exclusive cooperation agreement for the development of flexible graphite gas distribution plates as well as an exclusive long-term supply contract.
Business Wire, July 8, 2004	Memorandum of Understanding Provides for Realignment of Alliance Responsibilities to Ensure Long-Term Commitment to Advance Fuel Cell Technology and Commercialize Fuel Cell Vehicles In February, Ballard Power Systems (NASDAQ:BLDP) (TSX:BLD) announced it was exploring strategic alternatives with DaimlerChrysler AG and Ford Motor Company to improve their Vehicular Fuel Cell Alliance to, among other things: - Optimize the roles of the partners - Advance development plans for the next generation fuel cell engine and - Provide Ballard with improved financial and operational flexibility. As a result of those discussions, the partners have entered into a comprehensive non-binding Memorandum of Understanding ("MOU") that outlines several initiatives, including further defining the roles and responsibilities of their Alliance and further establishing program funding requirements to ensure that the Alliance continues to build on its leadership.
Japan Economic Newswire, October 23, 2003	The president of Ballard Power Systems Inc. said Thursday the world's largest fuel-cell maker will strengthen tie-ups with Honda Motor Co. and other major Japanese automakers to develop fuel-cell vehicles. 'We expect our collaboration with Honda to grow,' Dennis Campbell told Kyodo News when asked about future relations with Honda, which has developed its own fuel-cell technologies. Canada-based Ballard has an 85% market share of fuel cells in the world, supplying its products to 10 out of the world's 15 top automakers, including Honda, Nissan Motor Co., Mitsubishi Motors Corp., and Volkswagen AG. Campbell indicated that Toyota Motor Corp., which is moving ahead of other Japanese companies in fuel-cell development, will also be a potential Ballard client.
Business Wire, June 8, 2003	Ballard Power Systems (TSX: BLD; NASDAQ: BLDP) fuel cell power trains will power a fleet of five Ford Focus fuel cell vehicles, in Vancouver, in a three year field trial program to begin early in 2004. This demonstration is a collaboration between Fuel Cells Canada, Ford Motor Company and the Provincial and Federal Governments.

	"Ballard is proud to support the launch of Ford's customer demonstration fleet here in Vancouver, which marks Canada's first fuel cell car demonstration program," said Dennis Campbell, Ballard's President and Chief Executive Officer. "These five cars are the first of up to 100 Ford fuel cell vehicles, powered by Ballard(TM), that will be placed in service through 2005. With this demonstration program, the Government of Canada is helping Canadians remain at the forefront of the fuel cell industry and furthering the commercialization of fuel cell vehicles."

Cellex Power: Major Complementary Assets (010)	
Source	**Text**
Business Wire, September 20, 2004	Forklift trucks will soon be the latest vehicles powered by clean and efficient hydrogen energy, thanks to an agreement between BOC (NYSE: BOX), one of the world's largest industrial gases companies, and Cellex Power(TM) Products Inc., the leader in fuel cell power solutions for industrial vehicles. BOC and Cellex are working together to develop complete hydrogen supply solutions to power forklift trucks used in large distribution warehouses in North America. Cellex will supply the hydrogen power units that go into the trucks; BOC will provide the indoor hydrogen refueling facilities.

Dupont Canada: Major Complementary Assets (010)	
Source	**Text**
Canada NewsWire, February 22, 2002	Technology Partnerships Canada Invests $19 Million in DuPont Canada's Fuel Cell Research [omitted text] DuPont Canada Inc. and Technology Partnerships Canada (TPC) today announced a four-year program to develop key components for the emerging fuel cell industry. [omitted text] "This business and government partnership through DuPont Canada is an important part of DuPont's global effort to advance fuel cell technology and expand our offering beyond Nafion(R) membranes into fuel cell components, and highlights the closely integrated network of DuPont business and technical resources focused on this important growth opportunity," said David L. Peet, global business director for DuPont Fuel Cells.

Energy Visions: Major Complementary Assets (010)	
Source	**Text**
Business Wire, May 12, 2003	Superior MicroPowders (SMP, www.smp1.com), an advanced fuel cell materials supplier, and Energy Visions Inc. (EVI, OTCBB: EGYV, TSXV: EVI.S, www.energyvi.com), a developer of fuel cells and rechargeable batteries, announced today that they have signed a strategic alliance agreement for the non-exclusive supply of fuel cell electrocatalysts and services by SMP to EVI. Superior MicroPowders, a manufacturer of advanced fuel cell materials including its commercial Dynalyst(TM) series PEM, alkaline, phosphoric acid, direct methanol and metal-air electrocatalysts, has signed a strategic alliance agreement with Energy Visions Inc. related to the supply of SMP electrocatalysts and services for EVI's flowing electrolyte direct methanol fuel cell (FEDMFC) products. While the terms of the agreement were not disclosed, supply of electrocatalyst, technical support and next-generation electrocatalyst development were all addressed under the agreement.
Business Wire, August 7, 2002	Energy Visions Inc. (TSX:EVI.S) (OTC Bulletin Board:EGYV) ("EVI" or "Company") announced today that the joint development program, initiated more than a year ago, between EVI and the Alberta Research Council Inc. ("ARC") is being restructured to change the immediate focus to completing the first stage research. The intention of the EVI Direct Methanol Fuel Cell ("DMFC") program is to resolve the obstacles of fueling infrastructure and high cost that are restricting other systems. The use of Methanol directly rather than Hydrogen can resolve the first issue. The Hybrid system which the Company has announced, using EVI's proprietary Nickel Zinc batteries and DMFC, can potentially reduce the cost of power systems by 80% as compared to current Hydrogen fuel cell systems. Work in the past year has resulted in a redesign of the basic fuel cell and the Company has chosen to complete the research on this new design and to prototype the complete electric Hybrid system. This focus will result in a deferral of Cdn. $500K of funds scheduled to be paid by ARC for engineering. Those funds become available for engineering of the re-designed system following joint approval of the prototype by EVI and ARC. EVI and the Institute for Chemical Process and Environmental Technologies ("ICPET") of the National Research Council of Canada have agreed to terminate the original joint development agreement on Lithium batteries

	and are anticipating the establishment of a new collaborative agreement where ICPET would become involved with EVI's Fuel Cell and Hybrid development. The Industrial Research Assistance Program ("IRAP") of the NRC has approved a Cdn. $125K grant to support work on the EVI DMFC system.

Fuel Cell Technologies: Major Complementary Assets (010)	
Source	**Text**
Canada NewsWire, November 12, 2004	Fuel Cell Technologies Ltd. (FCT) and Siemens Westinghouse Power Corporation (SWPC) have signed a Memorandum of Understanding (MOU) regarding the global supply, sales and distribution of solid oxide fuel cell systems. Under the terms of the MOU, FCT and Siemens will establish strategic regional marketing relationships that can ultimately cover all parts of the globe. The MOU between the companies will allow for further expansion of introductory markets and positions the companies to form selected global business alliances that can be beneficial to the deployment of solid oxide fuel cell systems for a variety of residential, remote power and selected niche distributed generation markets.
Canada NewsWire, May 19, 2004	FCT's collaboration with NRC-IFCI also includes investigative work on the use of methanol in the 5 kW SOFC system. This takes advantage of the SOFC's ability to utilize a wide range of fuels. FCT's 5 kW fuel cell can operate on any one of several readily available fuels, such as natural gas and propane as well as biogas and methanol which can be manufactured from a wide range of sources including renewables. The collaboration with NRC-IFCI also includes Methanex, the world's largest methanol producer. "This collaboration utilizes a trained team of fuel cell researchers at NRC-IFCI to support FCT in advancing its technology, leading to earlier commercialization", says Dave Ghosh, Director of Science and Technology at NRC- IFCI, "Through this joint collaboration between NRC, FCT and Methanex, we are helping FCT expand its market for SOFCs to remote applications where there is no natural gas grid and helping Methanex find a significant market for methanol. This is a "win-win" project for all partners. The remote unit can run on methanol which is a clean, high quality fuel, producing both power and heat. "We look forward to continuing our collaboration with Fuel Cell Technologies and with NRC to demonstrate the wide range of benefits of methanol as a fuel for SOFC systems," says Mark Grist, manager, Market Development for Methanex. "Methanol's

	high purity, ease of reforming and ease of distribution make it an ideal fuel for this type of application."
Canada NewsWire, May 7, 2004	Fuel Cell Technologies (FCT) is pleased to announce that its second Joint Development Agreement (JDA) with Siemens Westinghouse Power Corporation (SWPC) previously announced in July 2003 has been updated and extended to include supply of the (SWPC) standard tubular generator component subsystems for the manufacture of FCT's second generation 5 kW product throughout 2004 and into 2005
Canada NewsWire, March 18, 2004	FCT is pleased to announce that the 5 kW SOFC undergoing tests in Alaska in collaboration with University of Alaska (UAF) and Fairbanks Natural Gas continues to perform very satisfactorily.
Canada NewsWire, July 17, 2003	Fuel Cell Technologies Ltd. has completed the installation of its pilot VOC reformer and SOFC system at the Ford Motor Company's Dearborn Assembly Plant (DAP) in Michigan. This hardware forms part of Ford's 'Fumes-to-Fuel' System that Ford announced on July 17, 2003. The collaboration between FCT and Ford has resulted in an industrial application of solid oxide fuel cell (SOFC) technology that transforms a waste into useful energy. The pilot system consumes emissions from Ford's vehicle paint shop and turns them into electrical energy and heat for the facility. The process begins with the collection of airborne paint solvent (volatile organic compounds, or VOCs) and their concentration into a rich mixture. The concentrated paint solvent is then fed into a reformer system that breaks the paint solvent down into hydrogen rich gas. The reformer was developed and built by FCT specifically for this application in partnership with Ford. The resulting hydrogen rich gas is then fed into FCT's 5 kilowatt (kW) SOFC unit where electrochemical reactions convert the fuel into useable electricity and heat for use in the facility. The DAP Paint Shop pilot project is a proof-of- concept integrated system. It will be operated to assess SOFC operation using this unique fuel source. In addition, it will showcase advanced pollution abatement technology being developed and advanced by Ford. Larger industrial systems are planned for the future. "The Ford and FCT engineers have worked well together on this first collaboration. This industrial application shows the product's adaptability and usefulness controlling and reducing emissions," commented Dr. John Stannard, President and CEO of FCT. "We welcome Ford's commitment to the environment and its willingness to support innovative initiatives."

Fuel Cell Energy: Major Complementary Assets (010)	
Source	**Text**
Canada NewsWire, November 5, 2003	Enbridge Inc. (NYSE: ENB; TSX: ENB), a leader in energy transportation and distribution in North America and internationally, and FuelCell Energy, Inc. (Nasdaq: FCEL), a leading manufacturer of stationary fuel cell power plants for distributed generation, announced today that they have finalized an agreement whereby Enbridge will be a distributor of FuelCell Energy's Direct FuelCell(R) (DFC(R)) products in Canada
RWE Australian Business News, May 22, 2002	Advanced Energy Systems Ltd has entered an agreement with Global Thermoelectric Inc to develop power electronics and control technologies for the fuel cell industry. AES and Global will design, manufacture and distribute power electronics, control products and technologies developed for Global's markets and sell the products to the fuel cell market. Global will invest in AES and grant it a preferred manufacturing status contingent on meeting price, volume and performance requirements
Canada NewsWire, February 20, 2002	Superior Propane Inc. ("Superior") is pleased to announce that it has signed a Memorandum of Understanding ("MOU") with Global Thermoelectric Inc. ("Global") and Enbridge Inc. ("Enbridge") to distribute propane fuelled solid-oxide-fuel cell ("SOFC") products in Canada
Canada NewsWire, January 29, 2002	Global Thermoelectric Inc. ("Global" or the "Company"), a leading developer of solid oxide fuel cell ("SOFC") products, today announced that it has signed a Memorandum of Understanding ("MOU") with the Bonneville Power Administration ("Bonneville") of Portland, Oregon to establish a strategic relationship for the purpose of developing, evaluating and distributing Global's SOFC products.
Canada NewsWire, October 25, 2001	Global's recent signing of Memoranda of Understanding ("MOU") with two U.S.. energy distributors have brought the Company a significant step forward on the path to commercialization of its SOFC technology. These MOU's are the product of Global's strategy which places a high priority on the Company developing relationships with well-positioned North American energy partners who will support market-based product development. This will ensure that Global's appliances are customer-driven solutions which can represent a best-fit for various consumer and commercial markets. To date, Global has a partnership in place with Enbridge Inc. ("Enbridge") for Canadian distribution of

	residential SOFC products and is developing similar partnerships with Suburban Propane L.P. ("Suburban") of Whippany, N.J., and Citizens Gas & Coke Utility ("Citizens") of Indianapolis, Indiana.

GreenVOLT Power: Minor Complementary Assets (000)	
Source	**Text**
	A total of thirty-three (33) announcements were found, and among these there were no teaming announcements; through there was one (1) OEM agreement.
Business Wire, May 31, 2001	**Greenvolt Power** Corp (OTCBB:GVLT), a development stage company specializing in alternative energy sources, announced an alliance with AOL Technology, an OEM/reseller of Greenvolt products.

Hydrogenics Corporation: Major Complementary Assets (010)	
Source	**Text**
Canadian Press Newswire, July 28, 2004	Fuel cell developer Hydrogenics has signed a deal with John Deere to research and develop hydrogen-fuelled commercial vehicles, a market the company feels will be earlier to adopt the environmentally friendly technology than the auto industry. Under the five-year agreement announced Wednesday, Toronto-based Hydrogenics will collaborate with the American farm and heavy equipment giant on fuel cell development and engineering.
Canada NewsWire, February 25, 2004	Maxwell Technologies, Inc. (Nasdaq: MXWL) announced today that it has entered into a strategic alliance with Hydrogenics Corporation (Nasdaq: HYGS; TSX: HYG) to collaborate on integrating Maxwell's BOOSTCAP(R) ultracapacitors into Hydrogenics' fuel cell power systems to optimize system performance, cost and longevity
Canada NewsWire, October 23, 2003	Hydrogenics Corporation (TSE: HYG and Nasdaq: HYGS), a designer and manufacturer of hydrogen fuel cell systems, announced today that it is partnering with IdaTech, the fuel cell subsidiary of IDACORP, Inc. (NYSE: IDA), to develop a 50-kilowatt fuel cell system that can serve as an independent energy source for large facilities such as hotels, hospitals and office buildings. [omitted text] "We are very pleased to be working in this new partnership with an organization like IdaTech, a company that is recognized as a leader in fuel processing technology and system integration," commented Pierre Rivard, President and CEO of Hydrogenics.
Canada	GM's remarkable achievements also are based on

NewsWire, October 17, 2001	partnerships and alliances with leading companies in the fuel cell industry and in the energy sector. At the same time, GM is ready to share its expertise and education with its partners in the automotive industry as well as with companies in other sectors. The latest members of GM's ever-expanding global team of partners announced today in Tokyo are Suzuki Motor Corporation and Hydrogenics, who join strategic and cooperation partners Quantum Technologies, General Hydrogen, Giner Electrochemical Systems, Toyota Motor Corporation, Exxon-Mobil and others
Canadian Business and Current Affairs, November, 2001	Hydrogenics Corp. announced a partnership with General Motors Corp. thatwill see the world's largest automaker take a 24 per cent stake in the Toronto-based fuel cell developer. The alliance will include shared intellectual property rights and joint efforts in fuel cell product development, engineering, prototyping, testing, branding and marketing strategies. GM will receive 11.3 million shares of Hydrogenics common stock, about 24 per cent of the company's outstanding shares. Hydrogenics will also issue GM warrants to acquire an additional 2.4 million common shares, upping the stake to 28 per cent.

Kinectrics Inc: Major Complementary Assets (010)	
Source	**Text**
Canada NewsWire, March 4, 2003	In 2000 OPG, a commercial company wholly owned by the Province of Ontario, partnered with the Government of Canada, the U.S. Department of Energy, Siemens Westinghouse Power Corporation, and Kinectrics Inc. to develop the world's largest atmospheric solid oxide combined heat and power fuel cell system. Government of Canada funding for the prototype was provided through the Climate Change Action Fund/Technology Early Action Measures, Natural Resources Canada, and the National Research Council.
Canada NewsWire, November 16, 2000	Fuel Cell Technologies Ltd., a wholly owned subsidiary of Fuel Cell Technologies Corporation (FCT), and Kinectrics Inc. announce that they have signed a Joint Research and Development Agreement (JRDA). The JRDA expands the relationship between FCT and Kinectrics that was announced on May 9, 2000. Kinectrics Inc. was formerly known as Ontario Power Technologies

MagPower Systems Inc: Minor Complementary Assets (000)	
Source	Text
	A total of two (2) announcements were found, and among these there were no teaming announcements

Palcan Fuel Cells: Major Complementary Assets (010)	
Source	**Text**
Canadian Press Newswire, July 16, 2003	Palcan Fuel Cells has struck a joint marketing agreement with Nagase & Co. Ltd. to sell the Canadian company's fuel cell technology in Japan. Palcan said Wednesday the deal will give the Vancouver company a "beachhead" in Japan _ a potentially huge market for alternative energy technology. Nagase, founded in Kyoto in 1832, has 100 subsidiary companies in Japan and overseas and annual sales of $4.2 billion US.
PR Newswire, April 17, 2002	Palcan Fuel Cells Ltd. ("Palcan") is pleased to announce that it has signed a memorandum of understanding with Celco Profil S.R.L. ("Celco") of Vigonovo, Italy to jointly develop fuel cell power systems for the European scooter, electric vehicle and portable power industries. Palcan and Celco, a leading supplier and manufacturer of electrical control products and components to European equipment manufacturers, will jointly develop hybrid fuel cell-battery power systems for applications with peak power demands of up to 10 kW.
Business Wire, December 3, 2003	Palcan Fuel Cells Ltd. (TSX Venture:PC) today announced that it has signed a joint venture agreement with Shanghai Mingliang Plastic Co. Ltd., a private manufacturing company based in the Shanghai Pundong economic region. The joint venture is to establish a commercial manufacturing facility in Shanghai using Palcan's proprietary technology, to produce PEM fuel cell stacks for the global fuel cell marketplace. Palcan will have full managerial control of the facility, which is expected to be operational within six months. Palcan will hold a 49% share while its joint venture partner; Shanghai Mingliang Plastic Co. Ltd. will hold a 51% share in the JV. Palcan obtains its 49% share through a combination of (a) the assignment of its manufacturing technology on a non-exclusive basis representing a 30% shareholding, and (b) for a cash investment of US$450,000 for the remaining 19%, the timing of which is at Palcan's election. Palcan will appoint two of the five directors on the JV board.

PEM Technologies: undetermined	
Source	**Text**
	No (0) announcements were found.

PowerDisc Development Corporation: Minor Complementary Assets (000)	
Source	**Text**
	No (0) announcements were found.

Siemens Canada Limited: Major Complementary Assets (010)	
Source	**Text**
Canada NewsWire, November 12, 2004	Fuel Cell Technologies Ltd. (FCT) and Siemens Westinghouse Power Corporation (SWPC) have signed a Memorandum of Understanding (MOU) regarding the global supply, sales and distribution of solid oxide fuel cell systems. Under the terms of the MOU, FCT and Siemens will establish strategic regional marketing relationships that can ultimately cover all parts of the globe. The MOU between the companies will allow for further expansion of introductory markets and positions the companies to form selected global business alliances that can be beneficial to the deployment of solid oxide fuel cell systems for a variety of residential, remote power and selected niche distributed generation markets. The relationship also positions FCT to focus on products in the range of 4 - 75 kW, while utilizing Siemens Westinghouse generator components and subsystems.
Business Wire, June 5, 2002	SatCon Technology Corporation(R) (Nasdaq NM: SATC), a leader in critical powering solutions, announced today that it has shipped a next generation StarSine(TM) 250-kilowatt power conversion system (PCS) to Siemens Westinghouse for use with Siemens' Solid Oxide Fuel Cell (SOFC), which is being developed under a cooperative agreement between Siemens Westinghouse and the U.S. Department of Energy and which is aimed at the stationary distributed power generation market. SatCon shipped its first unit to Siemens last fall and was given another order for an additional two units, the first of which shipped on Monday; the second is scheduled for shipment over the next quarter.
Business Wire, August 3, 2001	The 100 kW system was developed and manufactured by Siemens Westinghouse under a cooperative agreement with the U.S. Department of Energy (DOE) through its National Energy Technology Laboratory.
Business	The Siemens Westinghouse Power Corporation (SWPC)

Wire, December 6, 2000	today announced that it has entered into a Consortium Agreement with four key European Utilities to provide the first MW scale Hybrid Plant to be demonstrated as a pre-commercial plant for the European market. The system will be based on the tubular solid oxide fuel cell (SOFC) technology. The project will be funded under the Framework Five Program of the European Commission and also as part of the DOE Cooperative Development Agreement that Siemens Westinghouse has with the US Department of Energy (DOE). This program will be the largest demonstration in Europe of the Siemens Westinghouse Tubular Solid Oxide Fuel Cell Technology
Power Engineering International, September 1999	Shell Hydrogen and Siemens Westinghouse have signed a cooperative agreement for the development and marketing of low-emission advanced fuel cell technology, to the power market. The deal involves solid oxide fuel cell (SOFC) technology developed by Siemens Westinghouse and the US Department of Energy. The companies will market units that will use Siemens Westinghouse's SOFC technology coupled with carbon dioxide (CO2) sequestration technology being developed by Shell. The companies believe that electricity will be generated that nearly eliminates the release of harmful emissions, including greenhouse gases. Shell intends to use the new technology to produce electricity for its own oil and gas production operations. The CO2 produced from the units will be injected into depleted oil and gas reservoirs where it will remain permanently 'sequestered'. Shell Hydrogen is a unit of Royal Dutch/Shell, and was set up in 1999 to pursue opportunities in the fuel cell market.

D.5 Dominant Design Paradigm

This section reports on our investigation into the Dominant Design Paradigm.

Measurements are based upon reviewing public announcements found in the LexisNexis database for statements that indicate the state of the firm's technology. In particular, we sought out the most recent announcements, and used particular keywords and phrases to help discriminate:

- Pre-Dominant Design Paradigm: demonstration, demonstrate, trial, commercialize, commercialization, to create, pilot, emerging fuel cell industry, advance fuel cell technology, develop and commercialize, emerging, laboratory tests, prototype, early market, strategically access, early-adopter, early-adopting, prototype manufacturing, concept.
- Post-Dominant Design Paradigm: shipping production units, commercially available, started deliveries.

The results are presented in Table 28. Referencing Table 28, we observe that all firms but one have been assigned a value of pre-Dominant Design Paradigm. These measurements support Industry Canada's (Industry Canada, 2003) determination of the general availability of fuel cell technology. In particular, Industry Canada predicts that general availability of stationary and portable fuel cells will commence in the period 2006-2008; and general availability of fuel cells in the transportation sector will commence in the period 2008-2012.

firm	Dominant Design Paradigm (00z)
Aluminum-Power Inc	000
Angstrom Power Inc	000
Astris Energi Inc.	000
Ballard Power Systems Inc.	000
Cellex Power Products Inc	000
DuPont Canada Inc	000
Energy Visions Inc	000
Fuel Cell Technologies Inc	000
FuelCell Energy Ltd	000
GreenVOLT Power	**001**
Hydrogenics Corporation/Inc	000
Kinectrics Inc	000
MagPower Systems Inc	000
Palcan Fuel Cells	000
PEM Technologies	n/a
PowerDisc Development Corporation	000
Siemens Canada Limited	000

Table 28: Summary of measurements for firm's Dominant Design Paradigm

The remainder of this section enumerates in the alphabetic order of the firm's names text extracted from announcements that support of the measurements in Table 28.

Aluminum-Power Inc: pre-Dominant Design Paradigm (000)	
Source	**Text**
Business Wire, May 2, 2002	Trimol Group, Inc. (OTC BB:TMOL) announced today that in line with its focus on new technologies and alternative energy, it has stepped up its plans for the commercialization and distribution of products, devices and systems that make use of metal-air fuel cell technologies. Concurrently, the Company is continuing its joint efforts with Aluminum-Power Inc. to commercialize the aluminum-air fuel cell technology licensed to it by Aluminum-Power for use in portable consumer electronics, at their shared International Research & Development Center in Toronto, Ontario, Canada.
Business Wire, April 30, 2001	Trimol Group, Inc. (OTC:BB: TMOL) announced today that it has completed the assignment of a Cooperation Agreement with SAGEM SA, a leading European manufacturer of sophisticated electronic systems and equipment, to jointly develop an aluminum-air fuel cell application for SAGEM portable electronics focusing on commercial as well as military applications. SAGEM is one of the world's largest manufacturers of cellular telephones and anticipates working with the Company to commercialize its aluminum-air fuel cell technology for use in portable consumer electronics that will be designed to provide significantly longer power than batteries currently available.

Angstrom Power: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canada NewsWire, May 1, 2002	Angstrom Power Inc., a developer of micro-structured fuel cells, announced today it has secured US$2.85 million in its first round of financing. The syndicate, led by Vancouver based Chrysalix Energy LP and Ventures West, also includes OPG Ventures, GrowthWorks Capital, and the Micro-Generation Technology Fund. Angstrom is applying micro-fabrication techniques to create a novel micro- structured fuel cell system based on patented architecture. This fuel cell will have favorable operating characteristics and higher power densities, while being simple and inexpensive to manufacture. Initial target applications could include battery replacement and portable power.

Astris Energi Inc: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canadian Corporate Newswire, October 7, 2004	Astris Energi Inc. (OTC Bulletin Board - ASRNF), the world's leading alkaline fuel cell (AFC) technology company, reported today that it has completed construction of Phase 1 of its pilot production line and preliminary production trial runs are meeting expectations. The pre-commercial production line for Astris' POWERSTACK(TM) MC250 alkaline fuel cell stacks was built at Astris' 30%-owned (soon to be 100%-owned) affiliate Astris s.r.o. in Vlasim, Czech Republic. The semi-automatic line provides a ten-fold increase in production capacity and a more efficient and accurate production of components and final assembly than was previously possible with hand assembly, with a resulting increase in quality control. So far the production trials have been successful, meeting and in some cases exceeding expectations. As a result, Astris s.r.o. is on target to ramp up to 100kW of capacity per year with one shift and reach the 200kW level in 2005.
Canadian Corporate Newswire, September 29, 2004	Also on display will be Astris' Freedom Golf Car, the world's first alkaline fuel cell powered golf car fuelled by hydrogen. Freedom was developed as a demonstration vehicle for showcasing the practicality of Astris' technology for mobile applications. It is powered by Astris' E6 Power Generator, which increases the utility of this vehicle when compared to conventional battery versions by increasing range, eliminating "fade" and allows quick refuelling while maintaining quiet and emission free operation. The car is fuelled by a 33-litre, refillable, carbon fibre hydrogen tank that will last over three days under typical usage

Ballard Power Systems: pre-Dominant Design Paradigm (000)	
Source	**Text**
Business Wire, November 3, 2004	Ballard Power Systems (NASDAQ:BLDP)(TSX:BLD) reported its financial results for the third quarter ending September 30, 2004. All amounts are reported in U.S. dollars unless otherwise noted. "Ballard is pleased with our third quarter results, which reflect our focus on financial sustainability, as we continue to control expenses and conservatively manage our cash," said Dennis Campbell, Ballard's President and Chief Executive Officer. "Ballard continued to demonstrate its industry leadership as our

	Alliance partner, DaimlerChrysler, delivered vehicles powered with Ballard(R) fuel cells to customers in the United States, Australia, Singapore and Germany, while Ford, our other Alliance partner, began production of its fuel cell vehicle demonstration fleet."
Business and Industry October 2004	Ballard Power Systems (www.ballard.com) is providing three heavy-duty fuel cell engines to Daimler Chrysler to help combat air pollution from Mercedes-Benz Citaro buses used in Beijing, China. The two-year demonstration program seeks to support further development of fuel cell technology and to demonstrate the viability of fuel cell power for buses in heavily congested areas. Fuel cells and hydrogen are seen as critical to achieving a sustainable transportation strategy in China where increased demand for automobiles has had a significant impact on urban air quality. Thirty-three other buses in 11 cities worldwide are already running on 205-kW fuel cell engines. Ballard says it also has had successful demonstrations of fuel cell-powered buses in Chicago, Palm Springs, Calif., and Vancouver.

Cellex Power: pre-Dominant Design Paradigm (000)	
Source	**Text**
Wireless News, September 22, 2004	BOC and Cellex said they are working together to develop complete hydrogen supply solutions to power forklift trucks used in large distribution warehouses in North America. Cellex will supply the hydrogen power units that go into the trucks; BOC will provide the indoor hydrogen refueling facilities. The next round of customer trials of the hydrogen powered forklift trucks is expected to last three months and will take place at customer sites in the U.S. and Canada. "These trials will show customers how hydrogen fuel cells can improve truck productivity significantly by removing the downtime and performance loss seen in battery-powered trucks, and reducing the health and safety risks associated with handling lead acid batteries. Also, hydrogen refueling systems are considerably smaller than a typical battery recharging facility, which frees up additional floor space within the distribution center," said John Carolin, global director, hydrogen energy, BOC. "Cellex's power units have logged hundreds of truck days to date from its field trials program which began in February 2002," noted Tom Hoying, Vice President, Sales and Marketing, Cellex Power. "The next step in the field trials will demonstrate the safe and efficient fueling of hydrogen at

	customer locations."
Canada NewsWire, May 25, 2004	Cellex Power(TM) announced today that the logistics subsidiary of Wal-Mart Stores, Inc. will participate in its next set of field trials designed to test Cellex's fuel cell products for powering electric lift trucks.

Dupont Canada: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canada NewsWire, February 22, 2002	DuPont Canada Inc. and Technology Partnerships Canada (TPC) today announced a four-year program to develop key components for the emerging fuel cell industry. [omitted text] "This business and government partnership through DuPont Canada is an important part of DuPont's global effort to advance fuel cell technology and expand our offering beyond Nafion(R) membranes into fuel cell components, and highlights the closely integrated network of DuPont business and technical resources focused on this important growth opportunity," said David L. Peet, global business director for DuPont Fuel Cells. "Industry and consumers both have high interest in and expectations for fuel cell technology. Focused technology development and incremental successful commercialization of fuel cells are key to driving progress."
CHEMICAL BUSINESS NEWSBASE, February 14, 2001	DuPont has formed a Fuel Cell business unit to pursue growth in the emerging proton exchange membrane fuel cell market. The company intends to apply its integrated expertise in polymer, coatings and electrochemicals technology to become the leading supplier of materials and components to the emerging worldwide fuel cell market. DuPont is seeking a strong presence in what it believes will be a $10 bn total market for fuel cells by the year 2010. The formation of DuPont Fuel Cells provides the business platform from which to develop and commercialize technologies from the company's Fluoroproducts, iTechnologies, Engineering Polymers, Corporate Research and Development and DuPont Canada organizations.

Energy Visions: pre-Dominant Design Paradigm (000)	
Source	**Text**
Business Wire, November 13, 2003	Dr. Doug James, EVI Vice President and General Manager of EVI's Fuel Cell Division based in Calgary, Alberta, presented a technical paper at the international 2003 Fuel Cell Seminar (Fuel Cells for Secure, Sustainable Energy) on November 5, 2003 in Miami Beach, Florida. The paper, entitled "Flowing Electrolyte Direct Methanol Fuel Cells: A Demonstration," was co-authored by scientists from EVI's partner organizations, the Alberta Research Council and the University of Graz. EVI's DMFC technology has achieved in laboratory tests the energy density needed to allow commercially acceptable manufacturing costs when combined with rechargeable batteries in an 'all-electric' hybrid system. EVI expects to expand its demonstration program to include an entire DMFC 'Hybrid' system in 2004
Business Wire, January 30, 2003	Energy Visions Inc., is a portable power technology developer and integrator with activities in direct methanol fuel cells and in rechargeable battery technologies. It is in process of manufacturing a demonstration hybrid fuel cell system at EVI's Fuel Cell Research and Development facilities in Calgary, Alberta and in Graz, Austria. Such hybrid system, which will combine a direct methanol fuel cell with Nickel Zinc batteries, will, EVI anticipates, be completed in the second quarter of 2003.

Fuel Cell Energy: pre-Dominant Design Paradigm (000)	
Source	**Text**
PR Newswire, October 21, 2004	Versa Power Systems (VPS) announced today that it is acquiring the assets of FuelCell Energy's Canadian solid oxide fuel cell (SOFC) operations, FuelCell Energy Ltd., formerly known as Global Thermoelectric Corporation. This acquisition will greatly strengthen and advance critical energy technology development under the U.S. Department of Energy's (DOE) 10-year, $139 million Solid State Energy Conversion Alliance (SECA) Program. "This move is important for our customers, for energy consumers, and for the nation's energy future," said Dr. Robert Stokes, CEO of VPS. Stokes noted that " ... the merging of Versa's research operations and intellectual property with FuelCell Energy Ltd.'s full scale power plant system demonstration and state-of-the-art manufacturing capabilities is an unbeatable combination -- it will accelerate the development of the distributed generation marketplace of tomorrow, meeting a key goal of the SECA program."
Canada	Global Thermoelectric Inc. ("Global" or the "Company") today

NewsWire, May 6, 2003	reduced its workforce in its fuel cell division by approximately one third, or 47 employees, which will result in reduced research and development expenditures of approximately $5 million annually. [omitted text] The Company is retaining sufficient system capability to develop and assemble prototype and demonstration fuel cell systems and will be in a position to deliver Global's next generation natural gas fuel cell prototype --- "Aurora" --- in 2003. The commercialization timeline for core SOFC components such as the fuel cell membrane and fuel cell stack are unaffected by today's announcement.

Fuel Cell Technologies: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canada NewsWire, May 13, 2004	During the first quarter 2004, FCT announced a further two firsts in the company history. The 5 kW SOFC operating in Alaska as part of a demonstration project by the University of Alaska Fairbanks and Fairbanks Natural Gas exceeded 5,000 hours of operation, and FCT was awarded an Electricity Generation Licence by the Ontario Energy Board. The latter, while not expected to be a material revenue source for FCT is important because it allows power generated as part of the manufacturing process to be exported to the grid
Canada NewsWire, November 14, 2003	Fuel Cell Technologies Ltd. (FCT) is pleased to report that the Honourable Herb Dhaliwal, Minister of Natural Resources Canada, has announced that NRCan is contributing to a $260,000 project to demonstrate the first installation of a residential fuel cell in a house in Canada. FCT reports that its 5 kilowatt (kW) product will be the focus of this project. The installation will be at the Canadian Centre for Housing Technology (CCHT) at the National Research Council campus in Ottawa

GreenVOLT Power: post-Dominant Design Paradigm (001)	
Source	**Text**
Business Wire, January 16, 2002	GreenVOLT will focus on volume marketing of the PM-120 SAM-Cell(TM), for moderate emergency power application anywhere. "We have seen strong world-wide interest and demand for our simple, inexpensive and effective SAM-Cell(TM) (Saltwater-Air-Magnesium Fuel-Cell) technology and are shipping production units now." says Faul. As GreenVOLT continues to develop alternative energy sources, it has successfully started deliveries of its first

	commercially available 40-60 Watt DC power generating PM-120 SAM-Cell(TM). The PM-120 Emergency Power Generating Fuel-Cell has shown that a simple and reasonably priced Fuel-Cell is in great demand. The lightweight, low price, ecologically neutral character of the PM-120 has created a positive cash flow for GreenVOLT. Path Two - Expand Existing SAM-Cell(TM) Product Range GreenVOLT will work on the development of the PM-250 SAM-Cell(TM) (250 Watt @ 12 Volt DC) and PM-450 (450 Watt at 6 Volt DC) units. Ease and simplicity of operation has created a demand for smaller as well as larger versions of this popular SAM-Cell(TM). We now need to expand our size range as well as our volume production capability. We will be expanding our product range to meet substantial customer requests for products ten times smaller and ten times larger than the PM-120 SAM-Cell(TM). Faul put it in perspective by saying, "Our PM-120 SAM-Cell(TM) has the power to run a 40 to 60 watt bulb. Now we are developing a tiny unit to light a 7 watt night light bulb and a more powerful unit which can handle a 440 watt flood light." The larger units, the PM-250 SAM-Cell(TM) (250 Watt @ 12 Volt DC) and PM-450 (450 Watt at 6 Volt DC) units, will not only be suitable for stationary power anywhere but also for powering electric vehicles. These units will provide a 2,000 mile + range for light weight 2 and 4 passenger LSVs (Low Speed (24 MPH max) Vehicles). This is planned for the latter part of 2002 with initial "beta" units to be field tested in late 2002 and early 2003. Path Three - Create Strategic Partnerships and Generate Funding for Development of New Product Line GreenVOLT will next complete initial contracts for wind-turbine-generator energy storage systems to be "beta" tested in early 2003.
Business Wire, May 23, 2001	Greenvolt Power Corp, a development stage company, focuses on the commercialization of alternative, efficient and affordable sources of energy through the utilization of unique, frost-proof and emission-free modular Alkaline Fuel Cell (AFC) systems and products, with a future eye on exploring other alternative energy sources such as Solid Polymer fuel cells and Magnesium Air Water fuel cells

Hydrogenics Corporation: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canada NewsWire, November 2, 2004	a designer and manufacturer of hydrogen and fuel cell systems, announced two additions to its HyPM(R) product line at this week's 2004 Fuel Cell Seminar in San Antonio, Texas. The two additions are the HyPM 7 (kW) unit and the HyPM 65 (kW) unit, both with which the Company will strategically access additional early market opportunities that exhibit long-term potential, specifically in light mobility and backup power applications. Last year, at the same event, the Company launched the newly commercialized design of its HyPM 10 fuel cell power module. To date, 26 units of the HyPM 10 have been shipped to a diversity of early-adopting markets, from light mobility to backup and auxiliary power. A new generation of the original HyPM 10 is also under development and will be re-released next year with an enhanced power rating of 13-14 kW. "This new phase of power module commercialization is an exciting step for Hydrogenics," said Pierre Rivard, President and CEO of Hydrogenics.
Canada NewsWire, September 27, 2004	Hydrogenics Corporation (Nasdaq: HYGS; TSX: HYG), a designer and manufacturer of hydrogen and fuel cell systems, and the Toronto Waterfront Revitalization Corporation (TWRC) are announcing the signing of a memorandum of understanding today at the Hydrogen and Fuel Cells 2004 Conference in Toronto. Together the two organizations will explore ways in which hydrogen fuel cell technologies and hydrogen production can support and build on the sustainable development goals of the TWRC. "Toronto is uniquely positioned to leverage Canada's strong leadership position in fuel cell technology and commercialization," said Pierre Rivard, President and CEO of Hydrogenics Corporation. "By engaging the local expertise we can enhance and accelerate the development of a roadmap for sustainability for this city. We are excited by the opportunities that working with the TWRC might provide Hydrogenics and the entire Canadian hydrogen fuel cell industry." TWRC and Hydrogenics have agreed to explore potential opportunities including specific demonstration projects, which showcase hydrogen and fuel cell technology and its benefits for waterfront revitalization. Potential projects could include: hydrogen-powered water shuttles; hydrogen-powered police patrols; and hydrogen-powered fleet projects.

Kinectrics Inc: pre-Dominant Design Paradigm (000)	
Source	**Text**
Canada NewsWire, March 4, 2003	Ontario Power Generation and Siemens Westinghouse today announced that the University of Toronto at Mississauga (UTM) will be the location for the first pre-commercial demonstration of the world's largest solid oxide fuel cell (SOFC) power plant. The unit will be incorporated into the existing physical plant at (UTM) in the fall of 2003, following extensive testing at Kinectrics Inc., the key engineering and system integrator on the project. According to Tapan Bose, Director of the Hydrogen Research Institute at the University of Quebec at Trois Rivieres and President of the Canadian Hydrogen Association, this will mark the first time anywhere that this leading-edge R&D technology will be tested on a commercial platform. Advantages of this technology include high rates of energy efficiency and virtually no emissions.
Canada NewsWire, March 22, 2001	OPG is co-funding an $18 million project to build and operate the world's largest pre-commercial solid oxide fuel cell power plant in the world. Other partners in this innovative project are the Canadian government, Siemens Westinghouse Power Corporation and the U.S. Department of Energy. While not, strictly speaking, a green power source, this type of fuel cell can reduce the environmental impacts of electricity production. The fuel cell system will be installed at the Toronto facilities of OPG's affiliate, Kinectrics.

MagPower Systems Inc: pre-Dominant Design Paradigm (000)	
Source	**Text**
www.magpowersystems.com (Nov 15th, 2004)	MagPower has developed a highly efficient and powerful, environmentally benign, Magnesium-Air Power Cell and intends to license its patented technology to selected licensees who will manufacture and distribute the MAPC on a worldwide basis
Canadian Corporate Newswire, May 22, 2003	Gentrx has an exclusive North American license with MagPower Systems Inc. ("MagPower") to market and sell a Magnesium Air Power Cell that produces a reliable and environmentally friendly non-toxic alternative power source that generates electricity through a saltwater electrolyte using MagPower's patent pending hydrogen inhibitors, and to develop, market and sell any future product that uses MagPower's hydrogen inhibitors. From a strategic perspective Gentrx will initially focus on two product areas, the development, production and sale of products using MagPower's Hydrogen Inhibitors as well as the distribution of the Magnesium Air Power Cell. These products/processes will be developed concurrently.

Palcan Fuel Cells: pre-Dominant Design Paradigm (000)	
Source	**Text**
Business Wire, August 30, 2004	Palcan's two businesses, fuel cell and metal hydride hydrogen storage, continue to make long term commercialization progress. In the fuel cell business, activities can be grouped into three areas: (1) fuel cell stack and system development; (2) fuel cell prototype manufacturing; and, (3) related business development. In fuel cell development, significant progress has occurred in the development of Palcan's latest fuel cell stack, the "PC5", that is targeted for the 500 Watt class fuel cell power module. Initial designs have also been completed on the related power module, building on the experience that Palcan has obtained in operating its current 250 Watt power module. Palcan has also decided to continue the development of the 250 Watt module to a next generation version to develop a range of product offerings that better match customer requirements for fuel cell power. In the area of fuel cell prototype manufacturing, Palcan is continuing to push forward with its strategy of developing prototype manufacturing capability in China. This strategy reduces the cost of Palcan's prototypes today. However, more important, it sets in motion low cost, supply chain development in China and opens up significant opportunities for both funding

	from the Government of China and participation in the many fuel cell demonstration programs that are in various planning stages throughout China. An appropriate location in the Shanghai region has been identified and discussions with high level Chinese government officials are ongoing.
Business Wire, June 8, 2004	Palcan Fuel Cells Ltd. (TSX VENTURE:PC) is pleased to announce that it has completed the engineering design concept of its extended runtime uninterruptible power supply (UPS). The UPS is powered by a proton-exchange membrane (PEM) fuel cell with metal hydride hydrogen fuel storage delivering extended run time, and is fully self-contained in a single package. [omitted text] "The engineering design concept UPS was a key goal that we set for 2004. The next engineering stage in this product's evolution is the alpha prototype of our fuel cell power module, work on which has already begun," added Dr. John Shen, Palcan's President and CEO.

PEM Technologies: undetermined	
Source	**Text**
	No (0) announcements were found.

PowerDisc Development Corporation: pre-Dominant Design Paradigm (000)	
Source	**Text**
http://www.powerdisc.ca/files/News%20Release%20Diagnostics%20June%207_04.pdf	MONDAY, June 7th, 2004 --- Chilliwack, BC, CANADA --- PowerDisc Development Corporation (the "Company") is pleased to announce the completion of an internal corporate diagnostics study utilizing the services of a local, NRC endorsed consulting company. The conclusion of the study is to focus resources toward the commercial development of the PowerWedge™ fuel cell bi-polar plates and stacks for demonstration to industry and our collaborative partners.

Siemens Canada Limited: pre-Dominant Design Paradigm (000)	
Source	**Text**
Pittsburgh Post – Gazette, January 31, 2004	The decision to abandon the Munhall move was based on market realities, said Flower. In the years since the 2001 ground breaking attended by then-Gov. Tom Ridge, an economic slowdown has made potential customers less willing to take a risk on innovative, but expensive, fuel cell technology. That convinced company officials that it will take until at least 2007 to build a market, several years later than originally hoped. "My target is to make this a commercial, viable business," said Flower. The 140-employee fuel cell operation in Churchill is a tiny part of Siemens AG, a German company employing more than 400,000 people worldwide. Yet, Flowers said the corporation believes in the potential of the technology being developed in the southwestern Pennsylvania facilities. The original work came out of Westinghouse labs in the 1970s. When Siemens acquired the operation in the late 1990s, it continued to invest in the research. Basically, the truck-sized solid oxide fuel cells make electricity through a chemical reaction but produce very low emissions, require little maintenance because there are no moving parts and work independent of utility grids. Since the 1980s, 17 demonstration units have been shipped out of the Churchill plant. Siemens is scheduled to deliver two more next year, one to a utility in Germany and another to BP Alaska.
Canada NewsWire, March 4, 2003	Ontario Power Generation and Siemens Westinghouse today announced that the University of Toronto at Mississauga (UTM) will be the location for the first pre-commercial demonstration of the world's largest solid oxide fuel cell (SOFC) power plant. The unit will be incorporated into the existing physical plant at (UTM) in the fall of 2003, following extensive testing at Kinectrics Inc., the key engineering and system integrator on the project.