BUSINESS ANALYSIS MODEL FOR THE CANADIAN INSTITUTE FOR FUEL CELL INNOVATION (IFCI)

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ABSTRACT

Canada is currently at the forefront of fuel cell research and development. The Canadian government has charged the Institute for Fuel Cell Innovation (IFCI) to support the Canadian fuel cell industry in creating a global leadership position for Canada in the commercialization of fuel cells. To efficiently fulfil its mandate, IFCI must collaborate with external organizations on projects that provide the maximum benefit to the Canadian fuel cell sector.

Literature regarding the financial and non-financial methods of evaluating projects is discussed, along with the advantages of using scoring models instead of purely financial models. The external and internal environments of IFCI are analyzed. Through this review and analysis, a business analysis model based on a scoring model was developed for IFCI. The business analysis model will assist IFCI's management in prioritizing and selecting projects. The IFCI Project Evaluation Model will allow IFCI to effectively and uniformly assess future project proposals.

Keywords: Scoring Models, Clusters, Project Evaluation.

This paper is dedicated to

my wonderful and loving wife, Saru.

She has been a major source of

support and inspiration for me throughout my MBA program.

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GLOSSARY

CISTI	Canada Institute for Scientific and Technical Information
CTFCA	Canadian Transportation Fuel Cell Alliance
DMFC	Direct Methanol Fuel Cell
DND	Department of National Defence
FCC	Fuel Cells Canada
IP	Intellectual Property
IRAP	Industrial Research Assistance Program
IRAP	Industrial Research Assistance Program
MCFC	Molten Carbonate Fuel Cell
NFCP	National Fuel Cell Program
NRCan	Natural Resources Canada
NRC	National Research Council
PEM	Project Evaluation Model
PEMFC	Proton Exchange Membrane Fuel Cell
RTI	Research Technology Institute
SOFC	Solid Oxide Fuel Cell

1 INTRODUCTION

Fossil fuels, which include Oil, Natural Gas and Coal, have traditionally formed the backbone of the energy supply of the industrialized countries of the world. However, escalating global demand for energy has forced the governments of these countries to identify and support the development of alternative sources of energy that are both renewable and sustainable. Additionally, concerns over global warming leading to climate change are focusing global attention on the reduction of emissions to comply with the emissions targets specified by the Kyoto Protocol. Fuel cells are an attractive alternative energy source, as they have no emissions and by-products besides water and heat. Due to the future benefits offered by fuel cells, many companies and countries have focused their resources to make them commercially viable for a broader range of applications in the next few years.

1.1 Introduction to fuel cells

Fuel cells generate electricity from an electrochemical reaction in which oxygen (air) and a fuel (e.g. hydrogen) combine to form water. There are different types of fuel cells such as Proton Exchange Membrane Fuel Cell (PEMFC), Solid Oxide Fuel Cell (SOFC) and Direct Methanol Fuel Cell (DMFC) but the concept is similar. All fuel cells are based around a central design that consists of two electrodes, a negative anode and a positive cathode. They are separated by a solid or liquid electrolyte that carries electrically charged particles between the two electrodes. A catalyst such as platinum is often used to speed up the reactions at the electrodes (Fuel Cells Today, 2006).

To increase the power output of fuel cells, individual fuel cells are combined to form a fuel cell stack (Fuel Cells Today, 2006). The electricity produced from a fuel cell can be used to power all sorts of devices such as cars and buses to laptops and mobile phones. The by-product heat from some of the fuel cells is also used for providing heating for houses.

1.2 Project background and stakeholders

The objective of this project is to develop a business analysis model that will allow the National Research Council of Canada's Institute for Fuel Cell Innovation (IFCI) to assess future and present project proposals. Dr. Yoga Yogendran on behalf of IFCI sponsored the project. The IFCI currently has a process for evaluating projects; the model will build on the existing process to create a framework that can be uniformly applied to assess all projects. In 2005, Helen Whittaker and Benjamin Sparrow developed a methodology for resource allocation for IFCI (Whittaker & Sparrow, 2005); the business analysis model developed as a result of this work will be used to select projects within that resource allocation. The stakeholders in this project are the IFCI, the hydrogen and fuel cell cluster in Vancouver, the Canadian fuel cell sector and the academic director in charge of the MBA programs.

1.2.1 Corporate background of IFCI

IFCI is a Canadian applied research organization that supports Canada's fuel cell and hydrogen industry. IFCI is located on the University of British Columbia's campus in Vancouver, British Columbia (B.C.). IFCI was located in B.C. to emphasize federal support for B.C.'s Hydrogen fuel cell cluster, which is one of the largest concentrations of fuel cell expertise in the world (Government of Canada, 2003). IFCI is involved in the research, development, demonstration, and testing of hydrogen and fuel cell systems. IFCI works independently and in collaborative projects with universities, government agencies and companies. IFCI's mandate is to support the Canadian fuel cell industry in creating a global leadership position for Canada in the commercialization of fuel cells. IFCI also focuses on research to overcome cost, performance, durability and reliability challenges of hydrogen and fuel cell technologies faced by Canadian industry and identified in the Canadian fuel Cell Commercialization Roadmap. IFCI's activities are aligned with the province of British Columbia's Hydrogen and Fuel Cell Strategy.

1.2.2 Structure of the report

This report begins with a review of literature related to clusters, the Stage-Gate model, financial models, different methods of project evaluation, and scoring models. A partnership evaluation model used by Natural Resources Canada is reviewed. An external analysis of the fuel cell industry is followed by an internal analysis of IFCI. Drawing on the literature review and this analysis, the IFCI Project Evaluation Model is developed. The use of the model is then demonstrated and suggestions are made for its implementation within IFCI. Recommendations and lessons learned from this project are noted at the conclusion of the report.

2 LITERATURE REVIEW

Fuel cells are a radical technology, which may have a great impact on the global economy as well as on the environment. As with other new technologies with such potential, national governments are interested in supporting the firms, which may commercialize fuel cells. One way that governments try to support new technology based firms is through the development and support of a cluster of related firms and supporting infrastructure in a geographic region. Supporting infrastructure may consist of a government research technology institute (RTI) with its human resources, physical facilities, and potential for early stage collaboration on research and development projects.

Commercialization of a radical new technology requires that inherently risky projects be undertaken and supported. Even though government RTIs are meant to work on risky projects, the commercialization process and the associated risk can and should be managed. Some of the tools that can be used to manage risk and evaluate projects are reviewed in this section, including the Stage-Gate model, financial models, and scoring models. Prior relevant scoring models are also reviewed in this section. These tools and models form the foundation for the IFCI Project Evaluation Model that is subsequently developed in chapters 5 and 6.

2.1 Clusters

Michael E. Porter introduced the "diamond" framework related to the innovation environment in clusters in his book The Competitive Advantage of Nations (Porter, 1990). Clusters are geographic concentrations of interconnected firms and institutions in a particular field. Porter and Stern (2001) noted that innovation and the commercialization of new technologies take place disproportionately in clusters. The presence of related and supporting firms in a cluster creates a virtual vertical integration effect. As a result, firms can rapidly source new components, services and machinery; this allows them to concentrate on their core capabilities. The presence of government RTIs that support a cluster through government programs and financial funding increase the attractiveness of a cluster for firms deciding to relocate to a location more conducive to innovation. RTIs form a network that includes universities and firms; the strength of a cluster is dependent upon the strength of the linkages between the different participants of the cluster.

According to Porter's diamond of advantage (Porter, 1990) clusters provide the following benefits to the firms in the cluster. The competition between the firms in a cluster leads to frequent benchmarking and continuous improvement in productivity and increased product innovation. The firms due to their geographical concentration attract skilled labour and capital to the cluster. The geographical proximity of the firms in related industries increases the formal and informal exchange of ideas and information between them. Government RTIs can facilitate this exchange between the firms in the cluster.

2.2 The Stage-Gate model

Robert G. Cooper developed the Stage-Gate model as a method of managing the risk involved in technology commercialization (Cooper, 1998). The Stage-Gate model functions as a framework for overall resource allocation on technology commercialization and new product development. There are 5 distinct stages separated by decision gates. All the tasks in a project preceding a decision gate have to be completed before the project can be assessed at a decision gate. Each decision gate has criteria specified by management that a project needs to meet in order to advance to the next stage. Projects that are not successful in meeting gate criteria can be terminated, projects that successfully meet gate criteria proceed to the next stage in the process.

The Stage-Gate model is used by a number of companies to improve their product development processes. The Stage-Gate model regulates the product development process due to the use of decision points or decision gates before each stage. The decision gates allow management to specify criteria that projects have to meet in order to progress to the next stage. The Stage-Gate model enables companies to efficiently and effectively allocate resources and terminate non-productive projects. Due to the use of the Stage-Gate model, projects that meet management gate criteria are more likely to succeed in the market as they have been subjected to rigorous due diligence internally (Product Development Institute, 2006).

The Product Development Institute Inc states five key stages in the Stage-Gate model (Product Development Institute, 2006):

Stage 1 - Scoping: At this stage, the technical benefits and the factors that would affect the market success of a project are assessed.

Stage 2- Build business case: At this stage the technical marketing and business feasibility of a project is assessed. A business case for the project is developed that includes the project scope, the justification for the project and the project plan.

Stage 3- Development: At the stage, a number of key activities take place. The project team defines project deliverables based on the business case; the project team performs Product development activities; and operating plans, testing plans and plans to launch the product are defined and created.

Stage 4- Testing and validation: At this stage, the product and the economics of the project are tested and validated.

Stage 5- Launch: At this stage, the product the project team commercially launches the product. Based on the objectives of the project, a product may enter full-scale production at this stage.

2.3 Financial models

Financial models have been traditionally used to make project investment decisions and may be used as the criteria for project approval in a Stage Gate Model. The three models discussed in this section are Net Present Value, Expected Commercial value and Options Pricing. Net Present value and Expected Commercial value methods are similar to each other whereas Options Pricing uses assumptions that differ from those methods. According to Cooper et al. (1998), some of the financial models are:

1. **Using Net Present Value:** Using the Net Present Value (NPV) of a project as the decision criterion has been used to maximize the value of a project portfolio. The NPV for new product processes is calculated during the development of the business case and is hence readily available. The NPV is calculated just before the project enters the heavy spending stage where resource expenditures are significant enough to require management to make decisions between projects. The use of the NPV at gate decision points is a well-known procedure. The projects NPV along with the IRR (internal rate of return) calculation are compared to the cut-off criteria in order to make the Go/Kill decision. Usually the criteria are that the NPV must be positive and the IRR must be greater than a risk-adjusted hurdle.
2. **Expected Commercial Value (ECV):** the ECV method seeks to maximize the expected value or expected commercial worth of the project portfolio subject to certain budget constraints. One weakness of the NPV method is that it fails to consider and incorporate risk. The probabilities of technical and commercial success are not factored into the NPV model. The ECV method overcomes this weakness and is an extension of the NPV method that makes it appropriate for portfolio management. ECV is calculated by taking into account the probabilities of commercial and technical success and costs incurred during the development and commercialization of the product. The ECV is hence different from the simple NPV and is a more accurate depiction of the project. By ignoring the fact that the probabilities of success of most projects are less than 100 percent, the NPV approaches overvalue projects, which on a cumulative basis overvalue the entire portfolio of projects.
3. **Options Pricing Theory (OPT) or Real Options:** recognizes that investment in a high risk project need not be made all at once but can be made in stages. This assumption is contrary to the investment assumption made in the NPV methods (where it is assumed that investment is made all at once). Management has the option to kill a project after each incremental investment is made.

Cooper et al. (1998), compared the OPT approach with results obtained with NPV and found that when the project is high-risk, that is, when the probability of technical and commercial success is low and the costs to undertake the project are high, then NPV approaches considerably understate the true value of the project. This could result in organizations killing otherwise valuable projects it they use traditional NPV. On the other hand, as the ECV method includes probabilities of outcomes and a stage-wise process with options, it comes considerably closer to OPT with regards to the correct valuation of a project than does the NPV method. Details of the of the OPT or real options method are fairly complex and beyond the scope of this work.

2.4 Methods of project evaluation

When evaluating projects, organizations need to decide which projects to pursue that would provide the maximum benefit to them. A number of different approaches are available to the decision maker. Cooper et al. (1998) covered some of these approaches, along with developing the Stage Gate Model, which provides the overall structure for project evaluation. Organizations can use financial as well as non-financial or qualitative factors to evaluate projects. In this section the disadvantages of relying only on financial criteria in making project decisions and factors that management should consider in evaluating projects are discussed.

According to the study conducted by Cooper et al. (1998), organizations were concerned that over reliance on strictly financial data and criteria may lead to wrong project portfolio decisions. Incorrect financial data may lead to a wrong basis for financial criteria based project selection decision. Regardless of the financial approach used, Cooper et al. (1998) found that the sophisticated financial methods gave incorrect results due to the poor quality of financial data. They found that senior management often does not commit enough resources to get good market and financial information at the start of the project on which many of the financial approaches are based. Additionally, many of the financial variables remain unknown until the later stages of the project. In the absence of critical data, estimates are used and these may contribute to the poor output of the financial models.

Another concern expressed by the organizations about the over reliance on financial data to make project selection decisions was the realization that major high risk and breakthrough projects would get penalized, while minor modifications and smaller lower risk projects would score more highly. The option pricing method portray high-risk projects in a more favourable economic light than NPV, traditional NPV calculations use the "all or nothing" investment assumption (a single investment decision rather than an incremental investment decision). Breakthrough projects are also penalized by most of the financial methods of evaluation as the expected outcomes and payoffs are harder to quantify and prove in the early days of the project.

Based on their findings about financial models, Cooper et al. (1998) suggest that organizations should consider financial data and criteria at the early decision points, however they should not base the entire decision on those measures. They suggest that organizations should use non-financial measures in addition to the financial methods to assess return on investment and make decisions on projects. Further they suggest organizations should improve the quality of information and in particular market information at the "Go to Development" decision points. Management should insist that proper research and analysis is conducted regarding a project before it is evaluated and assessed. To help organizations in determining the reliability of financial estimates made early in the life of a project and to improve these estimates over time, Cooper et al. (1998) recommend that organizations track their financial estimates over the life of the project. A post launch review can be held 12 to 18 months after launch, when they can compare actual results to those forecast when the project was approved. Evaluation methods using scoring models assess projects from a qualitative perspective as well as the quantitative perspective. Scoring models are discussed in detail in section 2.5.

2.5 Scoring Models

Scoring models are used to make investment decisions at the corporate, business unit, and project levels (Kaplan and Norton, 1992; Cooper et al, 1998). As discussed in section 2.4, scoring models often provide a closer alignment to strategy intent than do financial metrics. For the early stages of project evaluation, scoring models may be particularly relevant as they have a better chance of predicting project success than the use of purely financial metrics.

A number of characteristics of new product projects are strongly correlated with success and hence become excellent proxies for success and profits (Cooper et al, 1998). A number of studies have found out that some of the important success factors that are correlated with the profitability of the new product are the following:

- **A unique and superior product:** A product that is can be differentiated from its competitors, offers the customer unique benefits and offers a unique value to the customer.
- **Targeting attractive markets:** A large market that is growing, where the competition is weak, there is low competitive resistance but at the same time where the profit margins are good.
- **Leveraging internal strengths:** Products and services that are built or developed using the internal strengths of the organization both in technology and marketing.

All of the above characteristics are known to the organization relatively early in the project. Further Cooper et al. (1998), cite a major study that found that correlations between some of these success factors and ultimate profitability are far stronger than the correlation between the NPV calculated prior to development and the product's eventual profits.

Many organizations have developed scoring model systems that incorporate qualitative factors and success proxies to help them rate and rank proposed projects. According to a large sample study of firms' portfolio practice and performance conducted by Cooper et al. (1998), those organizations that relied on scoring models as their portfolio management method achieved a superior portfolio of projects on several important performance dimensions. Cooper et al.

(1998), hence conclude that the theoretical justification (qualitative factors are strongly linked to success and can be used as predictors) and superior performance in practice that they observed is a strong indicator that scoring models be considered by organizations as a tool to evaluate new projects and create effective project portfolios.

2.5.1 Developing scoring models

There are general sets of rules that help in developing effective scoring models (Cooper et al, 1998). First, a list of criteria that are known to discriminate between projects that have a higher chance of profitability and success and projects that may not have a good return and chance of success be developed. The projects must then be rated on these criteria usually on 1-5 or 0-10 scales. The ratings scores may then be multiplied by weights and then summed across all the criteria to get an "attractiveness" score for each project. Scoring models can be used at gate review meetings to make Go/Kill decisions by comparing the "project attractiveness score" to a cut-off criterion or they can be used to prioritize projects based on the "project attractiveness score". Organizations can develop scoring models based on their individual needs and requirements.

2.5.2 The Celanese (formerly Hoechst) scoring model

The Celanese-U.S. Corporate Research & Technology constructed an exemplary scoring model (Cooper et al, 1998). The Celanese scoring model was constantly improved and its scores were validated against actual results of the projects. The Celanese scoring model is of particular relevance to this work because of the similarity of the type of projects that IFCI and Celanese-U.S. Corporate Research & Technology group undertake. The group at Celanese was used to focusing on "larger, higher-risk, more step-out, and longer-term major projects". Thus, the IFCI-PEM that the author developed in chapter 6 for the IFCI is a modified Celanese scoring model that has been adapted to be applicable to IFCI.

The Celanese scoring model consists of 19 questions in five categories. The five factors that Celanese used to prioritize projects are:

- Business strategy fit
- Strategic leverage
- Probability of technical success
- Probability of commercial success
- Reward to the company.

Within these five factors, management scores 19 characteristics. The scoring points used in this model are 1, 4, 7 and 10. Addition of the scores within each factor gives five factor scores. The factor scores are then weighed and added together to arrive at the overall project score.

2.6 Review of project evaluation model used by Natural Resources Canada

In order to benchmark the IFCI-PEM developed for IFCI in chapter 6, it is important to review project evaluation models at other Canadian institutes/organizations. In this section, the project evaluation model used by Natural Resources Canada (NRCan) to evaluate demonstration projects undertaken by the Canadian Transportation Fuel Cell Alliance (CTFCA) is discussed. This model has been used to successfully evaluate projects in the fuel-cell sector, hence a review of this model provides validation that the scoring model based IFCI-PEM developed for the IFCI as a result of this paper can be a very useful tool to evaluate new project opportunities in the fuel-cell sector.

2.6.1 CTFCA program background

In June 2001, with a view to maintain and enhance the leadership position of Canada in fuel-cell technology, the government of Canada invested $23 million in the CTFCA program. The program focuses its efforts on "showcasing refuelling demonstration projects, evaluating different fuelling routes for light-, medium- and heavy-duty fuel-cell vehicles, monitoring the resulting green house gas emission reductions, and developing the necessary supporting framework for the fuelling infrastructure, including technical codes and standards, training, certification, and safety". NRCan, in an effort to ensure that the project is successfully managed, established a core committee, a project advisory committee and five working groups. The NRCan Management committee is responsible for management of the budget, the strategy and activities of the CTFCA. The committee will review the projects referred by the project advisory committee. The NRCan Management committee acts as the final decision maker on all projects (Natural Resources Canada, 2006).

2.6.2 The project evaluation process

The project advisory committee evaluates the project proposals, while; the core committee is responsible for monitoring trends in the fuel-industry and set strategic direction for the CTFCA. The project advisory committee is composed of 12 members from the federal and provincial governments as well as expert advisors. Projects are assessed according to the following criteria (Natural Resources Canada, 2006):

- How the project addresses technical and market barriers.
- The potential to replicate the project.
- How well the project achieves the reduction of green house gases and other emissions.
- How the project engages strategic industries.
- How the project benefits Canada.
- How the project provides leverage for Canada.
- Does the project have adequate and appropriate management?
- Does the project have sufficient financial and technical resources?

The criteria and weights discussed in the scoring model were developed based on discussions with members of the CTFCA and NRCan. The model is scored out of a total of 100 points. A project needs to score a minimum of 75 points to be accepted by the committee. The model consists of both mandatory considerations that are not scored and optional considerations that are scored. The intension of the criteria and weights is to (Natural Resources Canada, 2006):

- Provide common criteria for comparing different project proposals.
- Provide guidance to project proponents in preparing their project proposals.

Once the committee evaluates a project proposal against its scoring model, they make a consensus recommendation to the NRCan Management Committee to either accept the project, return the project to the working committee or to reject the project (Natural Resources Canada, 2006).

3 EXTERNAL ANALYSIS

This section provides the external context in which the IFCI-PEM was developed for IFCI. IFCI's external environment is analysed from a strategy and geographic perspective. The global fuel cell sector and the Canadian fuel cell sector are analyzed in this section. The analysis of the global fuel cell sector includes a discussion of the activities of Germany, Japan and the U.S. in the fuel cell sector. The Canadian fuel cell research spectrum is analysed and IFCI's position in the research spectrum is discussed.

3.1 The global fuel cell sector

Many of the fuel cell companies in the world are focused on replacing the internal combustion engine (ICE) with fuel cells in automobiles, however it has been argued that other applications will lead the commercialization of fuel cells in automobiles. A study by Phoenix-based research firm Energy Business Reports predicts that electric power generation and consumer electronics, not automobiles, will lead in using fuel cell technology in the future. According to the report, the automobile sector where fuel cells have received support will take a long time to reach commercialization. Some of the problems faced by fuel cells in reaching commercialization in the automotive sector are achieving parity with the price of ICEs and the development of hydrogen fuelling infrastructure. (Electrical Construction & Maintenance, 2006).

The global fuel cell sector is primarily concentrated in the U.S., Canada, Japan and Europe (PwC, 2005) It is still in the early stages of commercialization, with $331 million in revenues, $716 million in R%D expenditures, and 6300 employees estimated worldwide, based on PricewaterhouseCoopers's 2005 Worldwide Fuel Cell Industry Survey (PwC, 2005). The survey was compiled based on information volunteered by the members of US Fuel Cell Council

(USFCC), Fuel Cell Europe, Fuel Cell Commercialization Conference of Japan (FCCJ) and Fuel Cells Canada (FCC). Data was collected in the areas of corporate profile, sales, R&D expenditure and employment. The survey results are based on 158 responses (PwC, 2005).

Based on PwC's survey, there are still more public organizations involved in the global fuel cell sector than private firms, and the majority of organizations have been in operation for 10 years or less. Fuel cell developers or manufacturers and fuel cell suppliers accounted for 42% of the respondents, while17% of the respondents identified themselves as research organizations and 13% of the respondents identified themselves as being professional services firms (PwC, 2005).

The survey identified that the majority of the fuel cell companies and organizations are concentrated in the U.S., Canada, Japan and Germany. These companies and organizations carry out a significant portion of their fuel cell activities in their country of origin. From a technology focus point of view, 55% of the respondents are focussed on the Proton Exchange Membrane technology and 18% of the respondents are focussed on the Solid Oxide technology and 10% of the respondents are focussed on the Direct Methanol technology (PwC, 2005).

With commercialization of fuel cells the primary focus of most of the fuel cell industry, the market focus of companies assumes importance. The survey found that almost 24% of the respondents were focussed on the small stationary market. The small stationary market is defined as output of less than 50kW. About 20% of the respondents were focussed on the portable market, 16% of the respondents were focussed on the large stationary market, defined as output 50kW. 15% of respondents reported being focused on the fuelling infrastructure, 14% on auxiliary power units for vehicles and 11% on the vehicle drive market (PwC, 2005). Based on the market focus of the various companies, it can be determined that the companies are focussing on early application markets for fuel cells while at the same time, a significant number of companies are working on developing an infrastructure for the application of fuel cells eventually in the automobile sector.

R&D expenditure data was provided by 77% of the survey respondents. While the actual numbers do not represent the amount of money being spent on fuel cell R&D, the R&D expenditure by country is an important indicator. The maximum amount of money spent on R&D was by the U.S. at 62% of the total reported expenditure, followed by Canada at 19%, Germany at 10%, Japan at 4% and the rest of the world at 5%. R&D expenditure information shows that the majority of the funds being spent on fuel cell research are concentrated in only four countries, namely, the U.S., Canada, Germany and Japan (PwC, 2005).

As the majority of the fuel cell R&D is carried out in the U.S., Canada, Germany and Japan, there is a lot of collaboration between the organizations in these countries. In May 2006, Los Alamos National Laboratory entered into collaboration with Japan's New Energy and Industrial Technology Development Organization (NEDO) and the National Institute of Advanced Industrial Science and Technology (AIST). This collaboration includes information sharing, conferences, and joint publication (Los Alamos, 2006). Collaboration and partnerships between private companies and government organizations between these countries have been instrumental in the advancement of fuel cell technology, as the fuel cell sector moves towards commercialization, these partnerships will become increasingly important to derive a common set of international codes and standards that can assist in the broad based market adoption of fuel cells in various consumer and industrial applications.

3.1.1 Activities of Germany, Japan and U.S. in the fuel cell sector

The activities of Germany, Japan and the United States in the fuel cell sector are briefly discussed in this section. As the Canadian fuel cell sector is competing with the fuel cell sectors in these countries, a discussion of their activities provides valuable insight for the Canadian fuel cell sector.

Germany is one of the leaders in hydrogen and fuel cell technology research and development in the world and the European Union. Since 1995, R&D has been focused on fuel cells with the German federal government agencies having a budget of 8-10 million Euros ($10.5-$13 million) per year. Additional 15 million Euros ($19.5 million) per year is available for basic research in the Helmholtz research centres with the support of the Ministry of Research and Education. Additional public funds have been made available for fuel cell R&D by the German federal states. Since 2000, two federal states have allocated 153 million Euros ($202 million in current conversion) to 72 projects and one federal state provides an annual funding of 5-6 million Euros ($6.5-$8 million) per year. In order to align itself with the German industry and to efficiently use public funds, German federal R&D funding has been used to concentrate on the development of PEMFC, DMFC, MCFC, and SOFC. German R&D efforts are focused on reducing the cost, increasing the lifetime and increasing the durability of fuel cell systems and components to enable the introduction of fuel cells into the market. Germany has four federal departments; four research institutes and the private sector involved in the fuel cell sector. The German government is working to capitalize on German strengths in Engineering and Automobile technology to become a world leader in the hydrogen and fuel cell sector (OECD & IEA, 2004).

The Japanese fuel cell program is focused on achieving early commercialization of fuel cells. The Japanese fuel cell program works in close partnership with the Japanese fuel cell industry. The Japanese government invests $260 million in hydrogen and fuel cells annually. The Japanese fuel cell program performs R&D on all the components of fuel cell systems with focus on PEMFC, large scale MCFC and SOFC systems and on micro DMFCs that can be used in portable applications. The Japanese fuel cell strategy is centred on a three-stage commercialization plan through the year 2020. The Japanese commercialization strategy integrates the development of fuel cell systems, hydrogen production systems, hydrogen transportation systems and hydrogen storage systems along with the concurrent implementation of hydrogen and fuel cell demonstration programs, sales of fuel cell based vehicles, the construction of hydrogen refuelling infrastructure and development of codes and standards for the new hydrogen and fuel cell systems being developed. The Japanese fuel cell commercialization strategy is aimed at increasing the consumer market for fuel cell vehicles and systems. The Japanese hydrogen and fuel cell program is funded and guided by the Ministry of Economy, Trade and Industry (METI). The Japanese New Energy and Industrial Technology Development Organization (NEDO) is focused on the R&D of hydrogen energy technology in joint partnership with industry, government and universities (OECD & IEA, 2004).

The United States (U.S.) has one of the most advanced programs in hydrogen and fuel cell technology. The US Department of Energy (USDOE) is the main agency that coordinates and leads the development of hydrogen and fuel cell technology in the U.S. The U.S. hydrogen and fuel cell development program is headed by the USDOE, which works closely with the U.S. national laboratories, universities and federal agencies and partners within industry to overcome the barriers faced by fuel cells in commercialization. The majority of the U.S. R&D on hydrogen and fuel cells is conducted under the “Hydrogen, Fuel Cells and Infrastructure Technologies Program”. The USDOE leads this program, which is used to provide funds for R&D and validation activities with respect to public sector and private sector partnerships. The activities of U.S. government agencies such as the Department of Defence, the Department of Transportation, and the Environmental Protection Agency are integrated under this program. U.S. government funds are focused on high-risk applied research in the early phase of fuel cell development so that the private sector can make decisions on whether the technology can be commercialized. In 2004, the program had a budget of $147 million. R&D is currently focused on transportation and building applications for fuel cells, with a major focus on developing reliable and high-performance fuel cell components at a low cost. The U.S. fuel cell program in addition to conducting R&D in fuel cell technology, creating test demonstrations, and creating standards and codes also focuses on educating target audiences on the impact and the future benefits of hydrogen and fuel cell technology. (OECD & IEA, 2004).

3.2 The Canadian fuel cell sector

The Canadian fuel cell sector is a recognized leader in the development and commercialization of fuel cells in the world (Innovation in Canada, 2002). Canadian fuel cell companies are concentrated predominantly in the fuel cell cluster in Vancouver, with some companies located in Ontario and Quebec. In this section information collected by PricewaterhouseCoopers (PwC) in its 2005 Canadian Hydrogen and Fuel Cell Sector Profile and as identified in the Canadian Fuel Cell Commercialization Roadmap is analyzed.

PwC conducted surveys to profile the Canadian hydrogen and fuel cells cluster in 2004 and 2005. A total of 82 organizations responded to the PwC 2005 survey, which represented a 66% rate of response. Since 2001, the Canadian fuel cell sector has posted growth in all the key areas (PwC, 2005b):

- **Growth in Revenue** from $97 million in 2001 to $133 million in 2004 representing an increase of 37%.
- **Growth in R&D expenditure** to $237 million per year in 2004, an increase of 32%.
- **Growth in employment** to 2,056 in 2004, an increase of 14%.

The Canadian fuel cell sector is focussed on developing products for the export market to ensure its long-term survival (PwC, 2005b). There is significant Canadian investment in the Canadian fuel cell sector, however increasingly foreign investment has been growing as many international firms buy stakes in publicly traded Canadian fuel cell companies and provide venture capital funding to new and start-up fuel cell firms.

According to the survey, out of the respondents, 43% of them identified themselves as private companies and 32% of them identified themselves as public companies or subsidiaries of public companies. Most of the respondents at 54% were involved for less than 10 years in the fuel cell and hydrogen sector, which indicates a young sector. Research expertise at 27% accounted for the largest area of specialization followed by Professional Services at 24%, Suppliers at 23%, fuel cell developers at 16%, and fuel cell distributors at 5%. 21% of the respondents were categorized under the other category (PwC, 2005b).

The survey indicated that 52% of the respondents had a Proton Exchange Membrane technology focus, 14% were focused on Solid Oxide and 5% were focussed on Direct Methanol. Technology focus of the companies in the Canadian fuel cell sector is significant for IFCI, as they would like to allocate their technical resources to correspond to the technology focus of the sector that it serves. From a market focus perspective, 31% of the companies reported that they were focused on the Stationary market, 30% of the companies reported that they were focussed on the Mobile market, 25% of the companies reported that they were focussed on developing Fuelling Infrastructure and 14% of the companies reported that they were focussed on the portable market (PwC, 2005b).

Investment in the Canadian fuel cell sector is crucial for the long-term growth and development of the sector. Respondents to the survey estimated total capital requirements for the period of 2006 to 2011 to be at $1.21 billion. They expected the money to be raised via a combination of public capital markets, government funding, private equity, venture capital investment and angel investment. In 2003 respondents expected only 16% of the funding to come from the public markets while the current survey found that 49% of the respondents expected funding to come from the public capital markets (PwC, 2005b). This major change represents the acknowledgement from the respondents that as the Canadian fuel cell sector matures and grows, the significant capital requirements for expansion, market diversification, creation of production facilities and commercialization activities can only be raised via the public capital markets. The average venture capital funding in Canadian companies lags far behind American companies. For the first nine months of 2006, average venture financing in Canadian companies was $3.8 million compared to $9.6 in the U.S. (Vancouver Sun, 2006) As fuel cells move towards mass market adoption, Canadian fuel cell companies will come increasingly in competition with their American counterparts, the scale of capital investment required for them to compete can only be raised via the public capital markets.

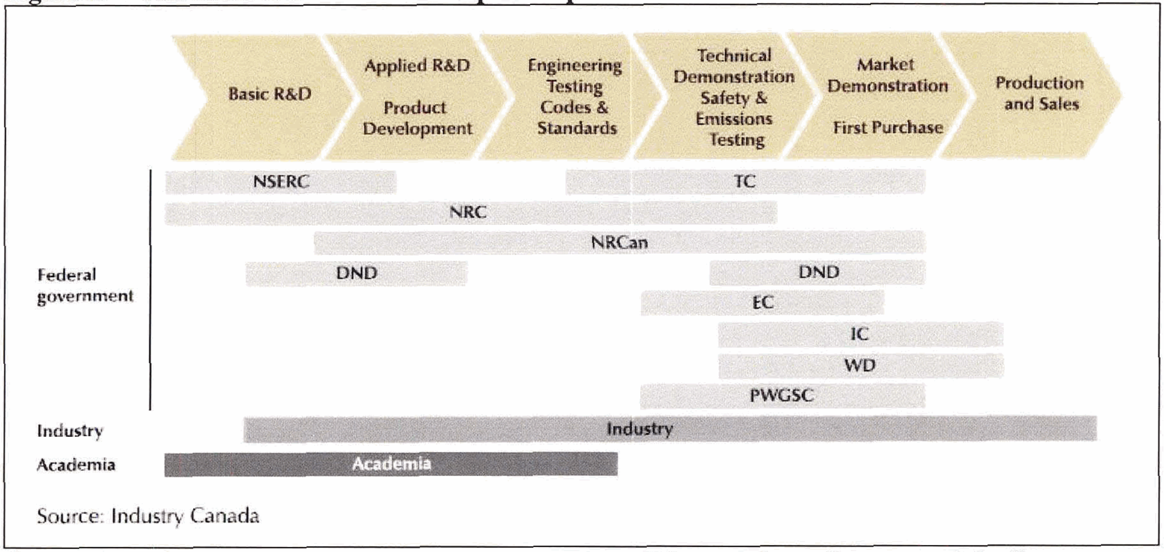
The 5% increase in the number of strategic alliances from 256 in 2003 to 270 in 2004 shows the importance to partnerships and alliances to the Canadian fuel cell sector. The largest number of alliances as reported by the respondents was between the hydrogen and fuel cell developers followed by energy providers. Automotive original equipment manufacturers (OEM), which were the most dominant group of strategic partners in 2003, account for only 6% of the alliances in 2004 (PwC, 2005b). The major change in focus away from the automobile application market shows the acceptance of the Canadian fuel cell sector that concentrating on the early markets for fuel cells will not only generate revenue to sustain their operations but will also build the confidence of the public in fuel cell technology. This approach is expected to increase the potential for the application of fuel cells in the automobile industry.

Ballard Power Systems remains the most successful Canadian fuel cell company, in addition a number of companies have been contributing to the growth of the Canadian fuel cell industry. Some of those companies are: Angstrom Power Inc, Cellex Power Products Inc, General Hydrogen, Hydrogenics Corporation, QuestAir Technologies Inc, Tekion Inc, and Xantrex Technology Inc. Many of these companies are focusing on early application markets for fuel cells such as replacement battery packs in forklifts and back up and portable power applications for various consumer devices. The Canadian fuel cell sector has a good distribution of companies across the entire fuel cell value chain. The fuel cell cluster in British Columbia has the largest concentration of fuel cell companies in the world. The IFCI in Vancouver is focussed on developing linkages between the companies and the academic institutions in the province to increase the innovative capacity of the cluster.

3.2.1 The Canadian fuel cell development spectrum

The development spectrum for the Canadian fuel cell sector is shown in **Figure 1**.

Figure 1: The Canadian fuel cell development spectrum



Source: Canadian Fuel Cell Commercialization Roadmap, PricewaterhouseCoopers and the Government of Canada. Image reproduced with permission.

The development spectrum for the Canadian fuel cell sector consists of the following components: Basic R&D, Applied R&D and Product Development, Engineering, Testing, Codes & standards, Technical Demonstration, Safety & Emissions Testing, Market Demonstration and First Purchase, and Production and Sales. **Figure 1** clearly shows the involvement of the federal government in all aspects of fuel cell development beginning with Basic R&D and supporting the sector via market demonstration activities and early procurement programs.

Some of the most important federal departments involved in the sector are the Department of National Defence (DND), Natural Resources Canada (NRCan) and the National Research Council (NRC). The DND is involved in the initial Basic and Applied R&D and in Product Development. The DND is then involved in the Technical and Market demonstration of fuel cell products and participates in the early procurement program for fuel cell products. NRCan is involved from the Applied R&D and Product Development until the Market demonstration and First Purchase. NRCan supports the Canadian Transportation Fuel Cell Alliance (CTFCA) program that develops demonstration projects to showcase fuel cells in transportation and hydrogen fuelling infrastructure.

NRC is involved in the spectrum right from the Basic R&D to the Technical demonstration and Safety & Emissions Testing stage. IFCI as a division of NRC is the primary institute that supports the Canadian fuel cell sector. IFCI is located in Vancouver, specifically to provide NRC support for the Vancouver fuel cell cluster. The strong involvement of the federal government in the Canadian fuel cell development spectrum shows the government's commitment to ensure that Canada maintains its leadership position in the global fuel cell industry.

3.3 Canadian "Fuel Cell Commercialization Roadmap"

The Canadian Fuel Cell Commercialization Roadmap was developed by members of the Canadian fuel cell industry and supported by the government of Canada and Industry Canada. The objective of the roadmap was to identify the challenges and barriers to the adoption of fuel cell technologies faced by Canadian fuel cell industries and suggest strategies to overcome them. The challenges that were identified in the roadmap are faced by the Canadian fuel cell industry regardless of the product or stage of development (Government of Canada, 2003). By addressing some of these challenges when considering project decisions IFCI can align to industry needs.

Some of the challenges faced by industry and actions recommended to overcome them as identified in the roadmap are discussed in Table 1.

The challenges faced by the fuel cell industry in the commercialization of fuel cells and their recommended actions to mitigate them form the foundation of the strategy pursued by the IFCI. As the roadmap was an industry-led process, the Canadian fuel cell industry was able to focus the attention of the government on the immediate and medium term needs of industry for the commercialization of fuel cell technology. By addressing these challenges when evaluating projects, IFCI will be aligning its strategy with expressed Canadian industry needs.

Table 1: Challenges identified in Canadian Fuel Cell Commercialization Roadmap

Canadian fuel cell industry need	Challenges	Actions
Stimulating early market demand – will result in the increase of production volume, decrease of production cost and decrease in the price of fuel cell products	Creating market awareness Gaining knowledge of markets	Development of demonstration projects to showcase fuel cell technology and gain performance data. Development of public information and educational programs Creation of early purchase and fuel cell procurement programs
Improvement in product quality and reduction in cost – will enable fuel cell products to compete with widely accepted incumbent technology	Continuous improvement in product quality Continuous reduction in costs Development of a supply chain for fuel cell power systems	Identification of performance and cost barriers and creation of strategies to overcome them Increase in collaborative R&D on components and materials to gain reduction in costs Creation of demonstration projects to showcase proven fuel cell performance Establish a supply chain forum to share information between fuel cell producers, suppliers and the research community
Financing – will result in increase in the scale and scope of production and marketing activities	Gain access to Capital	Development of financial incentives for fuel cell products to reduce risk profile of investments in the fuel cell industry. Strengthening the geographic clusters to attract development, creation of tax credits for research and development and matching funds for investments
Creation of supporting infrastructure – will result in the creation on	Accessing skilled resources Development of fuelling	Development of a human resources strategy to ensure supply of skilled resources for the fuel cell sector and

Canadian fuel cell industry need	**Challenges**	**Actions**
code and standards, a fuelling infrastructure and skilled personnel to support the fuel cell systems	infrastructure Development of codes and standards	identify skills gaps. Development of curriculum material for students, teachers and academic institutions. Demonstration of fuelling infrastructure solutions and Canadian participation in the setting of codes standards for fuel cell systems.

Source: Canadian Fuel Cell Commercialization Roadmap, PriceWaterhouseCoopers and the Government of Canada

3.4 External analysis summary

The external analysis of both the global fuel cell sector and the Canadian fuel cell sector indicate some important trends. Fuel cell companies are primarily focused on developing the Proton Exchange Membrane Fuel Cell (PEMFC) and the Solid Oxide Fuel Cell (SOFC). Companies are also focussed on developing products for the stationary and portable markets. This indicates an acceptance that the early markets for fuel cells will not be the automotive market as initially envisioned by the fuel cell industry, but the portable and stationary fuel cell products that are used as power sources for consumer devices and backup power systems.

The U.S., Canada, Germany and Japan are the leaders in the fuel cell industry in terms of the number of companies and their investment in R&D for the fuel cell sector. Although the U.S investment in fuel cell R&D is higher than Canada, Canada has a large number of fuel cell companies that are the acknowledged leaders in the field. The federal government of Canada invests in the Canadian fuel cell sector through a number of federal institutes that cover the entire fuel cell development spectrum. IFCI, which is part of the NRC, is focussed on providing support to the Canadian fuel cell sector to ensure that Canada is able to maintain its leadership position in the global fuel cell industry. Based on the analysis of the hydrogen and fuel cell activities of Germany, Japan and the U.S., the Canadian government will have to ensure that it forms strategic alliances with key partners to ensure that the Canadian fuel cell industry and Canadian technology can perform an important role in the future.

4 INTERNAL ANALYSIS

The internal analysis of a firm is essential to understand and assess its current position. The analysis also provides an opportunity to highlight internal constraints and practices that may inhibit the firm from achieving its desired objective. The internal analysis of a firm provides information about the competitive advantages and disadvantages of the firm, the resources available to a firm, its core competencies, the sustainability of its core competencies and the areas of synergy within the firm. In this section, the internal characteristics of IFCI are analyzed based on the resources inventory framework (Vining & Boardman, 2003). The different resources are analyzed in terms of their strengths and weaknesses.

4.1 IFCI's Strategy

IFCI's strategy is focused in the short term on building Canadian research capacity in the area of hydrogen and fuel cells, in the intermediate term to work with companies to overcome technological challenges and in the long term to create breakthrough technology in the hydrogen and fuel cells research areas. IFCI's strategy till the year 2010 is focused on providing support to the Canadian hydrogen and fuel cell sector through Science and Technology programs and industry partnerships and community stewardship. IFCI's focuses 85% of its resources on the Science and Technology program. The Science and Technology program has three major focus areas, PEMFC, SOFC and hydrogen technologies (NRC-IFCI Strategies, 2006).

The firms in the B.C. fuel cell cluster are focused on PEMFC technology. To support the technology focus and requirements of the B.C. fuel cell cluster, 60% of IFCI's Science and Technology program budget is allocated to the PEMFC program. IFCI's PEMFC support program is focused on research to increase the reliability, durability, and performance of the fuel cell systems and reduce the cost of the fuel cell components. The PEMFC program is divided further into High Performance, High Temperature and Direct Fuel platforms. To support and increase SOFC expertise in Canada, 30% of IFCI's Science and Technology program budget is allocated to the SOFC program. IFCI's SOFC support program is focused on research to decrease operating temperatures and system complexity while reducing cost of the fuel cell components. To support the hydrogen generation and storage industry in Canada, 10% of IFCI's Science and Technology program budget is allocated to support hydrogen systems. IFCI's Hydrogen systems support program is focused on research in new materials development and technologies to generate purify and compress hydrogen (NRC Strategies, 2006).

IFCI's partnerships and community stewardship program includes supplying infrastructure for research and development projects, development of a demonstration centre to test and showcase Canadian capability in the fuel cell sector and to organize events for exchanging information and help build partnerships in the Canadian fuel cell sector. IFCI's strategy is aligned with the needs of the Canadian and B.C. fuel cell sector and it is therefore well placed to provide value to them (NRC Strategies, 2006).

4.2 Resources available at IFCI

IFCI is an applied research organization with a mandate to support the Canadian fuel cell and hydrogen industry. Accordingly, IFCI is staffed with the resources and its operations are aligned to deliver on its mandate. In this section IFCI's physical facility, equipment, human resources, intellectual property and financial resources are discussed.

4.2.1 Physical facility and equipment

IFCI has had a facility on the University of British Columbia (UBC) campus since 2001. On September 12th 2006, IFCI officially opened a new 65,000 sq ft facility built at the cost of $20 million. The new facility is very important to the Canadian fuel-cell industry, as it provides space dedicated for the incubation of start-up fuel cell companies (NRC-IFCI News, 2006). While having space available in itself may not necessarily benefit start-up companies, the NRC reports on the number of companies utilizing the space as part of its Key Performance Indicator framework. A number of metrics related to space utilization by start-up companies are reported under the Technology Cluster component of the framework. The reporting framework creates an incentive for IFCI to actively ensure that the start-up fuel cell companies utilize the facilities efficiently.

By May 2006, more than 10 start-up fuel cell companies had used the IFCI facility. Cellex Power Products (Cellex) is one of the most successful companies that have graduated from the IFCI facility. Cellex has currently more than 40 employees and is working to replace battery power modules with its fuel cell systems in forklifts (IFCI Business Case, 2006). The availability of the dedicated facility has helped IFCI to attract companies to develop demonstration facilities, use it as a venue for fuel-cell networking events and to showcase the products from the Canadian fuel cell and hydrogen technology industry (IFCI Business Case, 2006). Hence from a facilities point of view, the IFCI facility gives it a competitive edge in terms of negotiations with prospective partners, as it can locate projects at its facility. Additionally, as the facility is located in Vancouver, any projects located on the site can take advantage of the very strong local fuel cell cluster.

The IFCI facility contains equipment that is crucial to support the commercialization of fuel cells. The fuel cell related equipment available at the IFCI consists of (NRC-IFCI Facilities, 2006):

- Nine fuel safe labs
- Hydrogen Environmental Chamber (HEC)
- Fuel cell test stations
- Facilities to demonstrate integrated energy demonstrations
- Hydrogen fuelling station
- Facilities to produce, store and dispense hydrogen

The fuel cell equipment is centrally located at the IFCI facility and is available to companies for a fee. The high capital outlay required for setting up the fuel cell equipment is a major deterrent for many fuel cell companies. Additionally, as most of the Canadian fuel-cell companies currently do not generate revenues, setting up fuel cell equipment is not feasible. Hence the availability of the equipment on-site confers IFCI with a major advantage over other institutions and research labs.

4.2.2 Human resources

IFCI is an applied research institute; hence the most important resource for R&D is human resources. IFCI has a team of 110 researchers, which includes university researchers working onsite. Additionally, IFCI has 35 scientists working for it through other affiliated NRC institutes (NRC-IFCI Facilities, 2006). IFCI has partnerships with six universities in Canada, which includes three universities in B.C., namely, Simon Fraser University (SFU), University of British Columbia (UBC), University of Victoria (UVic), and British Columbia Institute of Technology (BCIT). IFCI currently holds five joint academic positions with UBC and SFU and provides opportunities for research to over fifty graduate students. The partnership with the local universities has created a knowledge hub that directly supports the fuel cell cluster (IFCI Business Case, 2006).

IFCI has strong competencies in advanced materials & processing, modelling and numerical simulation, architecture design, prototyping & system testing and sensing &

diagnostics. Human resources are an area of strength for IFCI, as it has a large number of researchers who are available and capable of working on a broad range of fuel cell issues. Access to this large pool of very talented researchers will provide IFCI with a strong competitive advantage against other fuel cell research technology institutes while competing for collaborative projects.

4.2.3 Patents and intellectual property

IFCI has a very strong research and development focus and tracks its patents and intellectual property using the Key Performance Indicator framework. Starting from an empty patent portfolio in 2001, IFCI has expanded it to 1 fuel cell licence, 16 pending fuel cell applications, and 25 fuel cell innovation disclosures. Additionally, IFCI has increased the number of fuel cell publications from 6 in 2001 to more than 85 currently (IFCI Business Case, 2006). IFCI's stated mission is not to use a patent to commercialize fuel cell products, but to licence the patent to industry. As IFCI increases its patent portfolio, it becomes attractive for organizations to partner with them. Organizations can licence the intellectual property developed by IFCI to commercialize fuel cell products. Additionally, even though IFCI holds the intellectual property created as a result of collaborative research, companies are allowed to licence it at a very low cost, hence it decreases the risk that companies face when conducting collaborative research.

IFCI is working on creating a flexible structure within the NRC policy framework that is acceptable to its industrial partners to ensure that it is able to develop partnerships with industry in developing intellectual property (IFCI Business Case, 2006). With its large team of researchers dedicated to fuel cell research, IFCI is in a unique and strong position to increase its patent portfolio and hence this resource is assessed as one of IFCI's major strengths.

4.2.4 Financial resources

IFCI has two sources of funding to finance its operations. IFCI intends to use its internal or permanent funding (A-base funding) to finance its operations and overhead. The A-base funding consists of $20 million over 5 years. The funding is used by IFCI to build its core competencies based on PEMFC and SOFC technologies. IFCI intends to use its cluster support funding (B-base funding) to work with industry, international organizations and universities via partnerships and collaborative projects to support the commercialization of fuel cells in transportation, mobile and niche markets. The goal of the cluster funding is to make the B.C. fuel cell cluster a global leader in fuel cell related technologies and services. The next phase of B-base funding is expected to be $20 million over the next 5 years starting 2007. In addition to its funding, IFCI also has access to funds through affiliated NRC institutes totalling an additional $4 million per year. Hence IFCI has access to $14 million per year to support its internal operations and the Canadian fuel cell industry.

A major risk identified by IFCI in its business case (IFCI Business Case, 2006), is the reduction or termination of its B-base funding. Loss of the funding would limit the activities that IFCI can support. As a result of the loss of funding, IFCI may be forced to reduce its staff and decrease the number of initiative and programs it can support. Additionally, IFCI may have to concentrate on research and partnerships that are more short-term in nature and deliver a good return on investment. This poses a significant risk to IFCI as a loss of funding could severely impact its cluster support activities.

4.3 IFCI's partners

IFCI's mandate and vision for the Canadian fuel cell industry is supported by a number of key partners. IFCI has relationships with Hydrogen and Fuel Cells Canada, NRC-IRAP and NRC-CISTI, Ballard Power Systems, the Province of British Columbia and the major

Universities in British Columbia. IFCI's relationship with these key partners is discussed in the section below:

- **Hydrogen and Fuel Cells Canada (H2&FCC):** is a national industry association that is focussed on advancing the leadership position of the Canadian fuel cell industry. H2&FCC is headquartered at the NRC-IFCI facility in Vancouver. H2&FCC has worked with IFCI to create testing and demonstration capacity. The partnership between H2&FCC members, government departments and IFCI resulted in the development of the Pacific hydrogen fuelling station and the Hydrogen Technologies Environmental Chamber (IFCI Business Case, 2006).
- **NRC-IRAP Pacific Region and NRC-CISTI:** are both located at the NRC-IFCI facility in Vancouver. NRC-IRAP and NRC-CISTI work with IFCI to provide technical intelligence and technology support for small and medium enterprises (SMEs) (IFCI Business Case, 2006). This partnership with NRC-IRAP and NRC-CISTI allows IFCI to offer comprehensive financial and technology support to start-up fuel cell companies.
- **Ballard Power Systems:** IFCI has a memorandum of understanding (MOU) with Ballard Power Systems to collaborate on R&D and fuel cell test services with a goal of improving the performance and reliability of PEMFCs (IFCI Business Case, 2006). This collaboration on PEMFCs with Ballard provides IFCI researchers with knowledge and expertise that can be used to support other Canadian PEMFC projects and provides an opportunity for IFCI to support the development of Ballard's PEMFC based products.
- **The Province of British Columbia:** IFCI has an MOU with the BC Ministry of Energy and Mines and Petroleum Industries to work jointly to develop and deploy fuel cell and hydrogen technologies. IFCI is working with the province through this ministry to create fuel cell demonstration projects and creating a fuel cell knowledge hub in B.C. (IFCI Business Case, 2006). The support of the province of British Columbia is important because British Columbia accounts for about 60% of the Canadian fuel cell and hydrogen companies.
- **University of British Columbia, Simon Fraser University, and University of Victoria:** IFCI has MOUs with all three B.C. universities for research collaboration, co-hire arrangements and student projects on fuel cell and related technologies. Through partnership with the universities, IFCI commercialization support for fuel cell and hydrogen technology developed through university research.

4.4 IFCI's advisory board

The advisory board at IFCI consists of representatives from industry and academia. The board provides strategic direction to IFCI. Currently, the board is composed of representatives from some of the most influential organizations in the Canadian fuel cell industry. The organizations represented in the current board are: Hyteon (fuel cell products, headquartered in Quebec); The Ministry of Energy & Mines, B.C. (B.C. Ministry, headquartered in B.C.); Xantrex Technology Inc. (advanced power electronics, headquartered in B.C.); Ballard Power Systems (fuel cell products, headquartered in B.C.); University of British Columbia (faculty of applied science, headquartered in B.C.); Alberta Energy Research Institute (Alberta government institute, headquartered in Alberta); BC Hydro (B.C.'s electric utility, headquartered in B.C.); Suncor Energy Inc. (integrated energy and oil sands developer, headquartered in Alberta); Hydrogenics corporation (fuel cell systems, headquartered in Ontario); and Natural Resources Canada (national institute, headquartered in Ontario).

As the representatives on IFCI's advisory board represent fossil fuel industries, fuel cell companies, electric utilities, government agencies, provincial government and academia, IFCI benefits from their perspective. They can define the strategy that IFCI can follow to support the broad based adoption of hydrogen and fuel cells. Representation from the fossil fuel sector as well as the fuel cell sector will ensure that the strategies followed by IFCI take advantage of Canada's rich fossil fuel resources. Additionally, as some of the biggest fuel cell companies in Canada are represented on the advisory board, IFCI focuses on strategies that directly benefit the needs of the Canadian fuel cell industry.

4.5 Internal analysis summary

Analysis of the internal characteristics of IFCI demonstrates that IFCI is well positioned to support the Canadian fuel cell industry. IFCI's strategy and its allocation of the Science and Technology operating funds are aligned with the activities of the Canadian and the local B.C. cluster. The dedicated IFCI facility allows it to showcase Canadian fuel cell technology, employ in-house researchers, provide fuel cell and hydrogen equipment to industry and provide space for start-up fuel cell companies. IFCI's core competencies in fuel cell research and testing give it a competitive edge in the fuel cell industry compared to other institutes and fuel cell companies; IFCI scientists are available to work with private industry in collaborative projects or through fee for service contracts. Although IFCI's cluster support functions may be at risk in the future if cluster funding is not approved, IFCI currently has funding of $14 million per year to support the Canadian fuel cell sector. Additionally, IFCI has an advisory board composed of representatives from the Canadian energy sector and academia provides it with strategic direction to support the development and adoption of fuel cell and hydrogen technologies.

5 DEVELOPMENT OF IFCI PROJECT EVALUATION MODEL

The development of a Project evaluation model for the IFCI is disused in this section. This section starts with a description of the process used by IFCI to review projects. The challenges faced by government funded RTIs while pursuing partnership opportunities are briefly reviewed, followed by a discussion of the considerations in developing the components of the IFCI Project Evaluation Model (IFCI-PEM). The IFCI-PEM was developed to assist in the business analysis of project proposals received by IFCI from external and internal clients. IFCI-PEM is a weighed scoring model and the weights for the individual components may be adjusted by IFCI as required. While all attempts have been made to capture factors that may influence the evaluation of a project, IFCI management may use additional criteria when and as needed. The IFCI-PEM is meant to provide a framework for the structured analysis of a project opportunity. It is not the intent of IFCI-PEM to be used as the only decision-making tool by management.

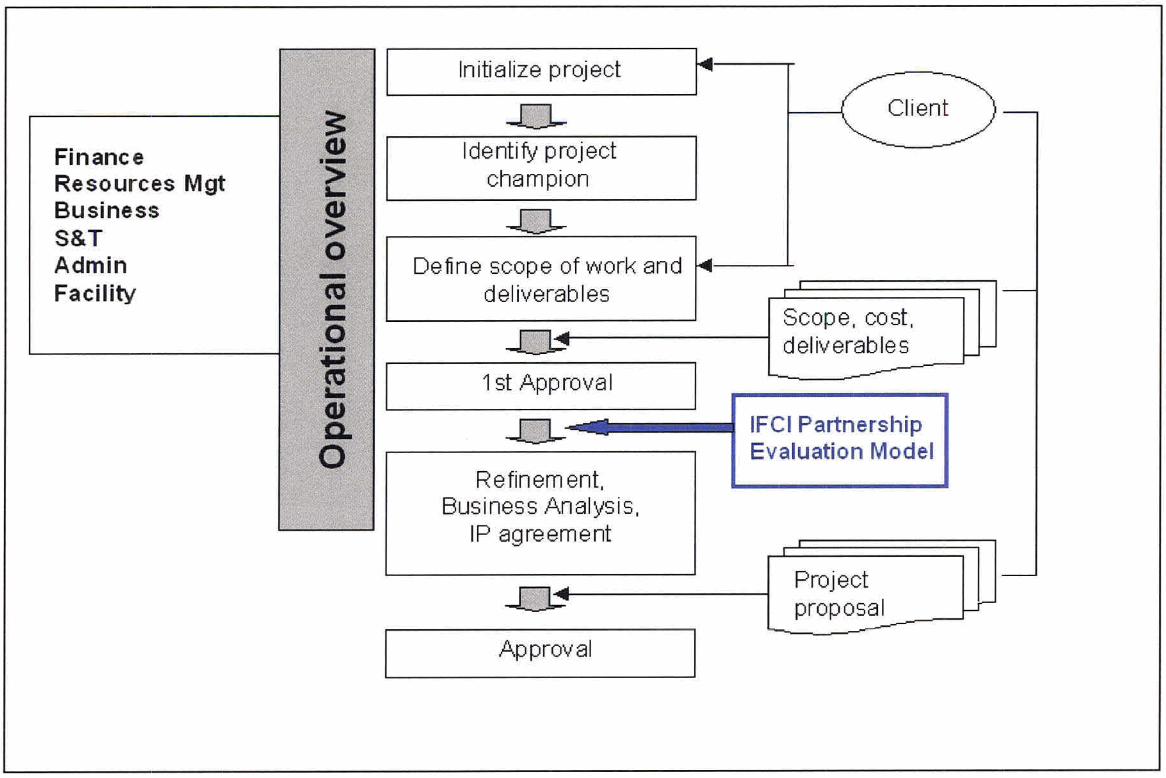
5.1 Project Review Process (PRP) at IFCI

IFCI currently uses a project evaluation and review process called the Project Review Process (PRP). A project that is being evaluated using the PRP is promoted to the next stage only if it meets the criteria set in the previous stage. The various steps in the PRP are detailed in **Figure 2** and discussed in the sections below.

5.1.1 Initialize project

This is the first step in the project evaluation process. Members from the Business Development Office (BDO) and Science and Technology (S&T) are involved in this initial stage. If an external client has proposed the project, then they are involved at this stage as well. This is the ideation stage, where initial discussions about the project take place. Once there is an agreement that a project can be initiated, the project passes into the next stage, which is the identification of a project champion.

Figure 2: IFCI's Project Review Process (PRP) and the role of IFCI-PEM



Source: Adapted from Internal IFCI documents.

5.1.2 Identify project champion

Only members from the S&T department are involved in this stage. This stage is important, because it creates the sense of ownership for a project. If an external client proposes the project, having an internal champion in the S&T department is important for creating internal ownership at IFCI. Once a project champion has been identified, the project moves into the next stage of the process, which is the definition of the scope of work and deliverables.

5.1.3 Define scope of work and deliverables

Members from S&T and the project champion at IFCI are involved in this stage. This stage creates a scope of work and deliverables document. If an external client is involved in the project, then the client contributes to the scope and deliverables document at this stage. This document functions as the input document for the next stage where the first approval for the project takes place.

5.1.4 1st approval

Members from the project steering committee, BDO and the project champion are involved in this stage. Based on the scope of the project and its deliverables, the project is evaluated from a financial and availability of facilities perspective. Once the project is granted a first approval, it moves to the next stage where the project proposal is further developed and detailed evaluation of the project takes place.

5.1.5 Refinement, Business Analysis, IP Agreement

Business Analysis is the most important stage in the PRP. Members from the steering committee, BDO and Finance are involved in this stage. The main task of this stage is to recommend whether and under which conditions a project can be approved. Based on the analysis, recommendations are made to the next stage, which is the project approval stage. The IFCI-PEM has been developed to contribute to this stage in the PRP. IFCI-PEM is a business analysis model that will enable the participants at this stage of PRP to perform a structured evaluation of the project proposal with respect to its benefits and associated risks. The IFCI-PEM is detailed and discussed in Chapter 6. Once the project has been evaluated, the project evaluation report functions as the input to the approval stage.

5.1.6 Approval

Members from IFCI management, Finance and the BDO are involved in this stage. Based on the project evaluation report provided by the preceding stage in the PRP, the decision whether to approve or reject a project proposal is taken at this stage. It is crucial that the project evaluation reports submitted to this stage clearly identify the benefits and risks associated with a project and provide metrics that can be used by members at this stage to rank and prioritize projects. The IFCI-PEM developed as a result of this work attempts to create a project scorecard that will make it easier for management and members from Finance and BDO to compare and rank different projects and based on their scorecard characteristics approve or reject them. Once approved, based on the project score, projects can be prioritized.

5.2 Challenges facing government-funded RTIs

Government-funded Research Technology Institutes (RTIs) face challenges in project prioritization, speed of execution and accountability with respect to partnerships and collaborative projects with private organizations. RTIs have to balance a number of priorities and concerns that arise as a result of using government supplied funds. RTIs are often perceived as being slow to react to changing conditions. They would like to ensure that they work at the same pace as the private sector so that they are seen as attractive partners. Hence RTIs have to move quickly so as to be relevant to industry needs while at the same time be cautious with the manner in which funds that have been allocated to them are used. Due diligence before any funds are used to support a project proposal is absolutely critical. Government funded Institutes like the IFCI have to ensure that they have good intelligence to aid their decision making process for any partnership or project proposal. Additionally, the metrics and measures used to evaluate potential partners need to be well defined and aligned with the stated strategy of the RTI to get the maximum benefit for the funds invested.

5.3 Projects as opportunities

IFCI can consider getting into projects and collaborative alliances with firms and organizations in the fuel cell sector to take advantage of those alliances in the future. The projects undertaken with partners in those alliances can be considered in the real options theory context as creating or buying an option. Although future market conditions and market demand cannot be predicted, partnering with companies and organizations via pilot projects can help IFCI learn and form alliances for the future. Building alliances is critical in industries where large network effects are required for the broad based large-scale adoption of a technology by the market. Partnering in this manner will also help IFCI to quickly assess different technologies and focus its resources on technologies with the greatest potential for commercialization.

5.4 Considerations in developing the IFCI-PEM

Whereas the goal of corporations is to maximize shareholder value, the end-goal for RTIs is not confined to a financial end result. In fact, it may be in the interest of the RTI to even lose money on a business venture if it means that some of its strategic goals are achieved. According to the specifications of the project, the components of the business analysis model developed need to link to the key performance indicator framework at IFCI (NRC-IFCI Indicators, 2006). The IFCI-PEM links to a subset of those indicators, as they appear relevant to the evaluation process. In the following sections some of the factors that RTIs like the IFCI need to consider before making a decision on a project proposal are discussed.

5.4.1 The financial aspect

While the financial aspect or the financial return on investment (ROI) may not be a very important consideration in a research project, due to the limited funds at the disposal of most RTIs, they expect a reasonable return for the amount of money invested in the project. Even if the financial ROI is not a concern in the project, the financial aspect of a project must be taken into consideration to ensure that funds are available to cover the operating costs of the project. Due to limited funds, the financial aspect is an important criterion for IFCI while making decisions on project proposals.

5.4.2 The core competency aspect

Projects that are undertaken that require skills very different from the core competency of the RTI may force it to over extend itself beyond its normal technical limits. The technical skills required to complete a project should be evaluated to ensure that the proper personnel are available to work on the project or can be made available as required. If the project requires a set of skills that the RTI does not posses or cannot acquire, then the partnership opportunity may not be feasible. On the other hand, the project or partnership can be evaluated as an opportunity for the RTI to build a new competency. The addition of skills to a RTI's skills competency can help it to better position itself in the future.

5.4.3 The learning aspect

Collaborative projects in research areas are very often undertaken to gain a better understanding about a particular technology area. The learning aspect of a project is an important component of a project evaluation model. The knowledge captured as a result of the project may benefit the RTI in the long term or may allow it to compete for more projects in the future. Hence the learning outcome from a partnership project may sometimes outweigh the financial aspect of the project if the RTI is prepared to consider a long-term return on investment. Additionally, even if the RTI does not pursue opportunities in that particular technology area, its partner RTIs can leverage lessons learned by it.

5.4.4 Risk aspect

Although risk is inherent in research and development, risk assessment and management is essential to ensure that the party assuming the risk takes an acceptable level of risk. Risk assessment forms an important evaluation component. Risk can be classified as either business risk or technical risk. Based on the type of risk involved; a different weight can be assessed to each by the parties making the assessment. All else being equal, high levels of technical or business risk lead to less attractive score for a project.

5.4.5 Contractual aspect

While partnering with another company or organization, the details of the contract are essential while evaluating the opportunity. Specifically exit clauses and additional partners are significant. Exit clauses ensure that the partnership can be dissolved in an amicable manner if both parties agree to discontinue or abandon a project. Additionally, if at a latter time, additional partners need to be brought into the partnership, such a provision needs to be specified in the contract. A proper assessment of contracts is essential to prevent a partner from leaving the partnership before the successful completion of a project.

5.4.6 Intellectual Property aspect

Research and development projects with partners may result in the creation of intellectual property (IP). If the firm submitting the partnership proposal has very rigid policies about IP ownership and control, this aspect of the evaluation may make the partnership seem unfavourable. If IP issues are negotiable between the partners, the IP aspect of the project evaluation may be the most important part of the partnership evaluation process.

5.4.7 Country of origin aspect

Country of origin aspect is an important component of a project evaluation model. RTIs that are dedicated to supporting industry in their country of origin have to use this component as an important criterion for screening project proposals. IFCI has a mandate to support the Canadian fuel cell and hydrogen industry. Although there are times when IFCI may have to partner with international partners to form international alliances, IFCI needs to ensure that it does not adversely impact the competitive capability of the Canadian fuel cell sector.

5.4.8 Cluster impact aspect

IFCI may be approached with project proposals that can help build capabilities in technology areas other than the technology areas focussed on by the local fuel cell cluster. However based on its business and strategic plan, IFCI needs to consider the impact on the cluster both positive and negative before accepting the project proposal. Partnering with organizations to work in technology that the local cluster companies do not focus on may not benefit the cluster. Hence evaluation of the project proposal from this aspect is important to ensure that projects undertaken by IFCI are aligned with the needs of the local cluster.

5.4.9 Commercialization aspect

Although research and development are essential in an innovation driven environment, the commercialization potential of a technology is also important to IFCI. While evaluating a project proposal, the commercialization potential of the technology should be considered. If the analysis reveals that the commercialization potential of the technology after development is low, the technology should receive a low score on this aspect of the assessment. Although the project may still be pursued, IFCI management should be advised of its economic potential before the beginning of the project to manage the expectations of commercially exploiting the technology.

5.4.10 Time/Schedule aspect

The time frame for a project or a partnership needs to be assessed as part of the project evaluation. A project may be very short term or very long term and both of these scenarios may be a cause for concern. A project on a very short timeline may be in danger of being not adequately staffed or documented. On the other hand a project that requires the commitment of resources for a long period of time may not be very attractive as it may make the resources of the institute unavailable for other projects for its duration.

5.4.11 Operational/Infrastructure aspect

Even though a project may be very attractive, it may not be feasible due to its infrastructure requirements. Projects need to be evaluated to ensure that the existing infrastructure is adequate to satisfy the project requirements. If existing infrastructure is not suitable for the project, it should be available in a finite amount of time or can be built in reasonable time and at reasonable cost. If infrastructure is not available, infrastructure constraints can make the project opportunity less attractive than initially determined. Although IFCI has hydrogen-testing facilities on site, this evaluation component ensures that their availability is confirmed before a project is approved.

5.4.12 Human resource availability aspect

The human resources aspect of a partnership project is an important component while evaluating a project. Research projects in the fuel cell industry require very specialized personnel to be dedicated to the project. Based on the time commitment required, the appropriate scientific personnel may be unavailable to staff the project. Additionally, the project may overlap with the start of other more important project; resources may be available for only a fraction of the time required by the partnership. In view of these factors, it is important to assess the project based on the human resources requirement and assign a score to it accordingly.

Also, projects in specific technology areas can attract scientific personnel who have an interest in pursuing the technology to an RTI or a country. Hence an RTI may undertake a project to attract scientific personnel to the country or the region.

5.5 NRC IFCI Key Performance Indicators

IFCI maintains a list of key performance indicators (KPI's) that are used as metrics to measure its performance. The project evaluation model is expected to link to some of these performance indicators. The performance indicators that are relevant to this work are discussed below. The goal of the project evaluation model is to positively impact the KPI's.

According to documentation from IFCI, KPI's are classified under five broad categories, namely, outstanding people-outstanding employer; excellence and leadership; technology clusters, value to Canada and global reach. These categories contain individual measures that are used by the IFCI to measure their success. The KPI's ensure that IFCI focuses on projects and partnerships that involve a return on investment which are not limited to financial factors. The KPI framework allows the IFCI to undertake projects that may even lead to a negative return on investment from a financial perspective, but may position the institute as a centre of excellence that attracts high-profile scientists. Some of the individual measures within the five categories that the IFCI-PEM will link to are briefly discussed below:

Outstanding people-outstanding employer: This category measures IFCI's success from a human resources perspective. Fifteen measures are defined and measured in this category; only two of the measures that may be impacted by the IFCI-PEM are defined in **Table 2.**

Table 2: **Outstanding people-outstanding employer – Key Performance Indicators**

Key Performance Indicator	Definition
Number of external awards	Awards and honours, attributed by an organization outside NRC, received by the institute's/Program's employees during the fiscal year.
Number of internal awards	Awards and honours, attributed by NRC or an NRC Institute/Program, received by its employees during the fiscal year.

Source: Table created by author from information provided by IFCI

Excellence and leadership: This category measures the impact that IFCI has on the global fuel cell industry. Twelve measures are defined and measured in this category; four of the measures that may be impacted by the IFCI-PEM are defined in **Table 3.**

Table 3: **Excellence and leadership – Key Performance Indicators**

Key Performance Indicator	Definition
Total papers in refereed journal	Total number of articles or co-written by employees of an institute/program and published in referred journals during the calendar year.
Total papers in refereed conference proceedings	Total number of papers written or co-written by employees of an institute/program and published in referred conference proceedings during the calendar year.
Total technical reports	Total number of technical reports written or co-written by employees of an institute/program during the calendar year.
Other types of publications	All other reports and publications not included in refereed articles, papers in refereed conference proceedings or technical reports produced during the calendar year.

Source: Table created by author from information provided by IFCI

Technology clusters: This category measures the value that IFCI provides to partners in terms of available space at the institute. Four measures are defined and measured in this category; three of the measures that may be impacted by the IFCI-PEM are defined in **Table 4.**

Table 4: Technology clusters – Key Performance Indicators

Key Performance Indicator	Definition
Total number of co-locators and industry partnership facility (IPF) tenants during the fiscal year	Total number of external organizations that were co-locating at the institute or were tenants in the institute's IPF during the fiscal year.
IPF space occupied	Total area of space dedicated to office and laboratories for for-profit corporations occupied by for-profit corporations as of March 31st.
Number of graduated tenants/co-locators	Total number of tenants/co-locators, that left the IPF facility as on-going successful operations during the fiscal year.

Source: Table created by author from information provided by IFCI

Value to Canada: This category measures the value that IFCI provides to Canada and to the Canadian fuel cell industry. Twenty-seven measures are defined and measured in this category; twenty-three of the measures that may be impacted by the IFCI-PEM are defined in **Table 5.**

Table 5: Value to Canada – Key Performance Indicators

Key Performance Indicator	Definition
Total number of new products and processes	Total number of new products and/or processes developed by the institute/program and introduced directly, or through partners, to the commercial market through the fiscal year.
Number of fee-for-service clients	Total number of fee-for-service clients during the fiscal year. These services include expert advice, testing, and calibration services, contract research and sales.
Number of spin-offs formed during the year	Total number of new companies formed by former employees of the institute/program around a core technology transferred from NRC during the fiscal year.
Number of spin-ins formed during the year	Total number of new companies formed by outside people and with a core technology transferred from NRC for a commercialization purpose during the fiscal year.
Total value of Canadian formal collaborative agreements	Total dollar value over the life of the agreement, as stipulated in the agreement, for all Canadian collaborative agreements (majority partner contributions are from Canadian partners) active during the fiscal year.
Total number of formal collaborative agreements with Canadian partners	Total number of active formal collaborative agreements during the fiscal year, signed with a Canadian partner (industrial partners, universities, or public organizations).

Key Performance Indicator	Definition
Number of Canadian industrial partners with formal collaborative agreements	Total number of Canadian industrial partners with whom a formal collaborative agreement is active during the fiscal year.
Number of Canadian public organizations with formal collaborative agreements	Total number of Canadian public organizations with whom a formal collaborative agreement is active during the fiscal year
Number of Canadian universities with formal collaborative agreements	Total number of Canadian universities with whom a formal collaborative agreement is active during the fiscal year
Total number of Canadian collaborative agreements signed during the year	Total number of formal collaborative agreements, which were signed during the fiscal year, with a Canadian partner (industrial partners, universities or public organizations).
Total value of Canadian collaborative agreements signed during the year	Total dollar value of contributions (cash and in-kind), made by NRC and its collaborators, for the life of the agreement, of all Canadian collaborative agreements signed during the fiscal year
Cash contributions of partners to Canadian collaborative agreements signed during the year	Estimate of the total dollar value of cash contributions, made by NRC's collaborators, for the life of the agreement, for all Canadian collaborative agreements signed during the fiscal year.
In-kind contributions of partners to Canadian collaborative agreements signed during the year	Estimate of total dollar value of in-kind contributions, made by NRC's collaborators, for the life of the agreement, as stipulated in the agreement, of all Canadian collaborative agreements signed during the fiscal year.
NRC gross contribution to agreements signed during the year:	Estimate of total dollar value of both cash and in-kind contributions, made by the institute/program, for the life of the agreement, as stipulated in the agreement, of all Canadian collaborative agreements signed during the fiscal year.
Leverage impact of NRC's investment nationally	The ratio of NRC gross contribution to agreements signed during the fiscal year over the sum of cash contributions of partners to agreements and in-kind contributions of partners signed during the fiscal year".
Total number of active patents in Portfolio	Total number of active patents (licensed or unlicensed) in the institute's/program's portfolio as of March 31.
Number of patent applications	Total number of applications filed with any official patent office for which application numbers have been received during the fiscal year.
Total number of patents issued	Total number of all the patents issued from any official patent office during the fiscal year".

Key Performance Indicator	Definition
Total number of patents issued in Canada	Total number of patents issued from the Canadian Intellectual Property Office during the fiscal year.
Total number of patents issued in U.S.	Total number of patents issued from the U.S. Patents and Trademark Office during the fiscal year.
Number of licenses issued	Total number of license agreements executed during the fiscal year.
Total licensing revenue from intellectual property	Total revenue received from royalties, initial fees, options and assignments on NRC's intellectual property during the fiscal year.
Total number of material transfer agreements	Total number of material transfer agreements signed during the fiscal year.

Source: Table created by author from information provided by IFCI.

Global reach: This category measures the financial impact of IFCI's partnerships and the relevance of IFCI on the international stage. Fifteen measures are defined and measured in this category; eleven of the measures that may be impacted by the model are defined in **Table 6.**

Table 6: Global reach – Key Performance Indicators

Key Performance Indicator	Definition
Total number of formal collaborative agreements –international partners (multinational or foreign organizations)	Total number of formal collaborative agreements, which were active during the fiscal year and were signed with a foreign partner (industrial partners, universities or public organizations).
Total value of international collaborative agreements	Total dollar value over the life of the agreement of all international collaborative agreements (majority of the contributions are from international partners) active during the fiscal year
Number of multinational/foreign industrial partners with collaborative agreements	Total number of multinational or foreign industrial partners with whom a formal collaborative agreement was active during the fiscal year
Number of multinational/foreign public organizations with collaborative agreements	Total number of multinational or foreign public organizations with whom a formal collaborative agreement was active during the fiscal year
Number of multinational/foreign universities with collaborative agreements	Total number of multinational or foreign universities with whom a formal collaborative agreement was active during the fiscal year
Total number of international collaborative agreements signed during the year	Total number of formal collaborative agreements signed during the fiscal year with a foreign partner (industrial partners, universities or public organizations)

Key Performance Indicator	Definition
Total value of international collaborative agreements signed during the year	Total dollar value of contributions (cash and in-kind), to be made by NRC and its collaborators, over the life of the agreement for all international collaborative agreements signed during the fiscal year
Cash contributions of partners to international collaborative agreements signed during the year	Estimate of the total dollar value of cash contributions, made by NRC's collaborators, over the life of the agreement for all international collaborative agreements signed during the fiscal year
In-kind contributions of partners to international agreements signed during the year	Estimate of the total dollar value of in-kind contributions, made by NRC's collaborators, over the life of the agreement for all international collaborative agreements signed during the fiscal year
NRC gross contribution to agreements signed during the year	Estimate of total dollar value of both cash and in-kind contributions made by the institute/program, over the life of the agreement for all international collaborative agreements signed during the fiscal year
Leverage impact of NRC's investment internationally	The ratio of NRC gross contribution to agreements signed during the fiscal year over the sum of cash contributions of partners to agreements and in-kind contributions of partners signed during the fiscal year

Source: Table created by author from information provided by IFCI.

6 IFCI PROJECT EVALUATION MODEL

The IFCI Project Evaluation Model (IFCI-PEM) was developed by the author from reviewing literature, research, internal IFCI documents, and via consultation with Dr. Yoga Yogendran (Director; Commercialization), Mr. Francois Girad (Business Development Office) and Ms. Kerry Whelan (Finance). The author customised IFCI-PEM to fit IFCI's strategy, technology focus and current project evaluation processes. After the IFCI-PEM was developed, it was refined based on discussions with Dr. Yoga Yogendran and Mr. Francois Girad.

6.1 Components of the IFCI-PEM

The IFCI-PEM is adapted from the Celanese Scoring Model (Cooper et. al, 1998). IFCI-PEM consists of five categories and 28 characteristics. The characteristics within IFCI-PEM are scored on a scale of 0 to 10, with 0 representing a low score (unfavourable) and a 10 representing a high score (favourable). The categories and characteristics that form the IFCI-PEM are described below.

1. **Business Strategy Fit:** This component of the IFCI-PEM determines the fit between the project or partnership proposal and IFCI's strategy. If a project scores very high on this component, the project is considered a strong fit with IFCI's business strategy and would generally be considered as attractive. Some of the characteristics of this component determine how the project or partnership addresses the needs of the industry as outlined in the Canadian Fuel Cell Commercialization Roadmap. The individual characteristics of this component on which the project is evaluated are:

    - **Fit with IFCI's Strategy:** This characteristic measures the fit of the project with IFCI's strategy. If the project is only a marginal fit, it is awarded a low score (0-2) and if the project is a strong fit, it is awarded a high score (8-10)

- **Impact on the Canadian fuel cell industry:** This characteristic measures the impact of the project on the Canadian fuel cell industry. If the project has only minimal positive impact, it is awarded a low score (0-2) and if the project will enhance the competitiveness of the Canadian fuel cell industry, it is awarded a high score (8-10)
- **Cluster impact:** This characteristic measures the impact of the project on the fuel cell cluster. If the project has only minimal positive impact, it is awarded a low score (0-2) and if the project enhances the competitiveness of the local cluster companies, it is awarded a high score (8-10)
- **Project may result in reliability improvements for fuel cell systems:** This characteristic measures the impact of the project on the reliability improvements for fuel cell systems, a critical challenge expressed by the Canadian industry. If the project has a low possibility of improving reliability, it is awarded a low score (0-2) and if the project has a strong possibility of improving reliability, it is awarded a high score (8-10)
- **Project may result in durability improvements for fuel cell systems:** This characteristic measures the impact of the project on the durability improvements for fuel cell systems, a critical challenge expressed by the Canadian industry. If the project has a low possibility of improving durability, it is awarded a low score (0-2) and if the project has a strong possibility of improving durability, it is awarded a high score (8-10)
- **Project may result in performance improvements for fuel cell systems:** This characteristic measures the impact of the project on the performance improvements for fuel cell systems, a critical challenge expressed by the Canadian industry. If the project has a low possibility of improving performance, it is awarded a low score (0-2) and if the project has a strong possibility of improving performance, it is awarded a high score (8-10)
- **Project may result in cost improvements for fuel cell systems:** This characteristic measures the impact of the project on the cost improvements for fuel cell systems, a critical challenge expressed by the Canadian industry. If the project has a low possibility of improving cost, it is awarded a low score (0-2) and if the project has a strong possibility of improving cost, it is awarded a high score (8-10)

Once the scores for the individual characteristics have been assigned, the total score for the Business Strategy Fit component is calculated by averaging the individual scores. This score is then posted to the Project Scorecard for this project.

2. **Strategic Leverage:** This component of the IFCI-PEM determines the strategic leverage created for IFCI by the project or partnership. If a project scores very high on this component of the model, the project is considered to create strong strategic leverage for IFCI and would

generally be considered as attractive. The individual characteristics of this component on which the project is evaluated are:

- **Proprietary position of the technology that may be developed as a result of this project:** This characteristic determines the proprietary position of the technology that may be developed as a result of this project. If the technology that may be developed is easily copied, it is awarded a low score (0-2) and if patents protect the technology that may be developed, it is awarded a high score (8-10)
- **Technology as a growth platform:** This characteristic measures the project from a growth perspective. If the project is a one of a kind project, it is awarded a low score (0-2) and if the project will allow IFCI to diversify, it is awarded a high score (8-10)
- **Technical and market durability:** This characteristic measures the technical and market durability of the technology that may be developed as a result of the project. If the technology can be easily copied, it is awarded a low score (0-2) and if the technology has a long lifecycle, it is awarded a high score (8-10)
- **Synergy with other projects at the institute:** This characteristic measures the synergy of the project with other projects at the institute. If the synergy is limited to a single project, it is awarded a low score (0-2) and if the project has synergy with a number of projects at the institute, it is awarded a high score (8-10)

Once the scores for the individual characteristics have been assigned, the total score for the Strategic Leverage component is calculated by averaging the individual scores. This score is then posted to the Project Scorecard for this project.

3. **Probability of Technical Success/Technical Risk:** This component of the IFCI-PEM determines the technical risk of the project or partnership. If a project scores very high on this component, the project is considered to be of low technical risk for IFCI and would generally be considered as attractive. The individual characteristics of this component on which the project is evaluated are:

   - **Gap between required technical knowledge and technical knowledge at IFCI:** This characteristic determines the gap between currently available knowledge and technical knowledge required in the project. If there is a large gap and strong research is required, it is awarded a low score (0-2) and if the project is more engineering in focus, it is awarded a high score (8-10)
   - **Complexity:** This characteristic measures the complexity of the project. If the project is complex, it is awarded a low score (0-2) and if the project is not complex, it is awarded a high score (8-10)

- **Competency in the technical area:** This characteristic measures if ICI has the necessary technical skills to undertake this project. If the technology being developed as part of the project is new to the institute and IFCI does not have the technical skills, it is awarded a low score (0-2) and if the technical skills to develop the technology is widely available in the institute, it is awarded a high score (8-10)
- **Project Schedule:** This characteristic assesses the schedule of the project. If the project schedule is too ambitious, it is awarded a low score (0-2) and if the project schedule is well planned, it is awarded a high score (8-10)
- **Availability of personnel:** This characteristic assesses the availability of personnel for the project. If no personnel are available for the project, it is awarded a low score (0-2) and if the personnel are available immediately, it is awarded a high score (8-10)
- **Availability of facilities:** This characteristic assesses the availability of facilities for the project. If no facilities are available for the project, it is awarded a low score (0-2) and if the facilities are available immediately, it is awarded a high score (8-10)

Once the scores for the individual characteristics have been assigned, the total score for the Technical Risk component is calculated by averaging the individual scores. This score is then posted to the Project Scorecard for this project.

4. **Probability of Commercial Success/Business Risk:** This component of the IFCI scoring model determines the business risk of the project or partnership. If a project scores very high on this component of the model, the project is considered to be of low business risk for IFCI and would generally be considered as attractive. The individual characteristics of this component on which the project is evaluated are:

   - **Market demand:** This characteristic determines whether the project addresses a market need. If the project does not address a current market need, it is awarded a low score (0-2) and if the project creates a technology that can lead to a product desired by the market, it is awarded a high score (8-10)
   - **Competition:** This characteristic measures the level of competition in the space where the project is going to create technology. If the level of competition is high, the project is awarded a low score (0-2) and if the level of competition is low, the project is awarded a high score (8-10)
   - **Partner's commercialization skills:** This characteristic measures the in-kind contribution that IFCI would have to make in the project to support the partner in the commercialization of any technology developed as a result of this project. If the project requires a lot of support for commercialization from IFCI, it is awarded a low score (0-2) and if the project requires no support for commercialization from IFCI, it is awarded a high score (8-10)

- **Regulatory impact:** This characteristic assesses the regulatory impact of the project. If the regulatory impact of the project is negative, it is awarded a low score (0-2) and if regulatory impact of the project is positive, it is awarded a high score (8-10)

Once the scores for the individual characteristics have been assigned, the total score for the Business Risk component is calculated by averaging the individual scores. This score is then posted to the Project Scorecard for this project.

5. **Return on investment (ROI):** This component of the IFCI-PEM determines the ROI of the project or partnership. If a project scores very high on this component, the project is considered to have a good ROI for IFCI and would generally be considered as attractive. The individual characteristics of this component on which the project is evaluated are:

- **Financial leverage – in-kind:** This characteristic determines the in-kind financial leverage achieved by the project. If dollar value of IFCI's in-kind contribution to the project is expected to be more than 50% of the cost of the project, it is awarded a low score (0-2) If dollar value of IFCI's in-kind contribution to the project is expected to be less than 25% of the cost of the project, it is awarded a high score (8-10)
- **Financial leverage – cash:** This characteristic determines the cash financial leverage achieved by the project. If dollar value of IFCI's cash contribution to the project is expected to be more than 50% of the cost of the project, it is awarded a low score (0-2) If dollar value of IFCI's cash contribution to the project is expected to be less than 25% of the cost of the project, it is awarded a high score (8-10)
- **Publications as a result of the project:** This characteristic assesses the possibility of publications for IFCI as a result of the project. If there is a low possibility of publications due to the project, it is awarded a low score (0-2) and If there is a strong possibility of publications due to the project, it is awarded a high score (8-10)
- **Creation of Intellectual Property (IP) as a result of the project:** This characteristic assesses the possibility of creation of IP for IFCI as a result of the project. If there is a low possibility of IP creation due to the project, it is awarded a low score (0-2) and If there is a strong possibility of IP creation due to the project, it is awarded a high score (8-10)
- **Project will result in the increase in the profile of IFCI as a destination for fuel cell R&D:** This characteristic assesses how the project could contribute to the increase in profile of ICFI. If the project does not enhance IFCI's profile, it is awarded a low score (0-2) and if the project strongly enhances the profile of IFCI, it is awarded a high score (8-10)

- **Future impact/benefits:** This characteristic assesses if project creates future impact for IFCI. If the project does not give IFCI any future benefits, it is awarded a low score (0-2) and if the project strongly enhances the competitiveness of the Canadian fuel cell sector, it is awarded a high score (8-10)
- **Social impact:** This characteristic assesses the social impact of the project If the social impact of the project is neutral, it is awarded a low score (0-2) and if the project has a strong impact on high profile social issues, it is awarded a high score (8-10)

Once the scores for the individual characteristics have been assigned, the total score for the ROI component is calculated by averaging the individual scores. This score is then posted to the Project Scorecard for this project.

The project scoreboard contains the scores from the five components. The five factors are assigned weights based on their importance to IFCI. The Strategic Fit and Strategic Leverage factors are assigned a weight of 3 each. The Return on Investment factor is assigned a weight of 2 and the Probability of technical success and the Probability of commercial success factors are assigned a weight of 1 each. The weighed factor scores are calculated by multiplying the factor scores with their corresponding weight. The final project score is the sum of the weighed factor scores. The maximum final project score that a project can attain is 100. While the weights assigned to the different factors signify the relative importance of these factors to IFCI in evaluating projects, IFCI can modify these weights as per their requirements.

6.2 Summary

IFCI initiated this applied research project to create a business analysis model that would allow it to assess project opportunities. According to the requirements of the project, the model was to be based on the business plan of IFCI and allow it to assess the cost and benefit of each opportunity and to quantify the risk associated with those opportunities. The IFCI-PEM created as a result of this work addresses the goals outlined by IFCI. IFCI-PEM assesses project opportunities from a cost benefit point of view, determines the fit of the opportunity with IFCI's strategy as outlined in its business plan, determines the ROI of the opportunity both in terms of financial as well as non-financial factors, links to the performance indicator framework of the institute and quantifies the risk associated with the opportunity by codifying it via the scoring mechanism. The IFCI-PEM facilitates the comparison and prioritization of different types of projects on the basis of the final project score obtained by a project after evaluation.

7 IMPLEMENTATION PLAN

This section discusses the plan for the implementation of the IFCI-PEM at IFCI. The challenges that IFCI may encounter in the implementation of the IFCI-PEM are demonstrated via a case study. The author and Mr. Francois Girad used the IFCI-PEM to evaluate a hypothetical Enzymatic fuel cell project proposal. The detailed evaluation including the final project scorecard is presented. The lessons learned from that case study are discussed and recommendations for the implementation of IFCI-PEM developed as a result are discussed.

7.1 Demonstration of the IFCI-PEM

The author along with Mr. Francois Girad evaluated an Enzymatic fuel cell project proposal as a hypothetical case to test the difficulties that IFCI may encounter in the IFCI-PEM implementation. The project proposal evaluated using the IFCI-PEM was scored based on the assessment provided by Mr. Francois Girad and the final project score for the project was determined. Although the case study discussed does not refer to any specific past of present project proposal received by IFCI, it is similar to potential project proposals that IFCI may have to evaluate in the future using the IFCI-PEM.

7.1.1 Case Study: Enzymatic fuel cell project proposal

The Enzymatic fuel cell project is a proposal to initiate research on an enzymatic fuel cell where enzymes are immobilized on electrodes and act as catalysts. The final application of the technology developed as a result of this project is in implantable biomedical devices. At present no Canadian companies are involved in working in this research area. To successfully complete this project, IFCI can rely on two Canadian strengths: biotechnology and fuel cells. There is not a significant patent population in this area of research and no patents in the area of "the cathode to overcome the oxygen deficit", the project proposes to solve technical problems in this area.

The opportunity was evaluated using the IFCI-PEM. The assessment scorecard along with the scores assessed and the comments observed is as shown in **Tables 7** through **11**. **Table 12** provides an overall summary of the project assessment.

Table 7: Case Study- Enzymatic fuel cell-Factor 1: Business Strategy fit

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Fit with IFCI's strategy	Marginal fit with IFCI's strategy	Moderate fit with IFCI's strategy	Good fit with IFCI's strategy	Strong fit with IFCI's strategy	4	Moderate fit with IFCI's strategy. This represents a new area of opportunity.
Impact on Canadian fuel cell industry	Minimal positive impact	Moderate positive impact	Good positive impact	Could enhance the overall competitiveness of the Canadian fuel cell sector	2	No immediate impact on the fuel cell industry
Cluster impact	Minimal positive impact	Moderate positive impact	Good positive impact	Could enhance the overall competitiveness of the fuel cell cluster	5	Project has the potential to create a new competency for the local cluster
Project may result in reliability improvements in fuel cell systems	Low possibility	Medium possibility	Good possibility	Strong possibility	2	Project does not address immediate concerns of the industry
Project may result in durability improvements in fuel cell systems	Low possibility	Medium possibility	Good possibility	Strong possibility	2	Project does not address immediate concerns of the industry
Project may result in performance improvements in fuel cell systems	Low possibility	Medium possibility	Good possibility	Strong possibility	2	Project does not address immediate concerns of the industry
Project may result in cost improvements in fuel cell systems	Low possibility	Medium possibility	Good possibility	Strong possibility	5	Project could result in cost improvements related to the catalyst involved
Average Component Score					3.14	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

Table 8: Case Study- Enzymatic fuel cell- Factor 2: Strategic Leverage

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Proprietary position of the technology that may be developed as a result of this project	Technology developed can be easily developed by competitors	Technology developed is protected, however that may not be a deterrent for competitors	Technology developed can be protected by patents	Technology developed can be protected via patents and access to suppliers/distribution channels	7	The project may create intellectual property that can be patented.
Project as a platform for growth	None, single project	Creates new business opportunities for IFCI	Creates new opportunities for business diversification for IFCI	If successful, this project could allow IFCI to explore new technical and commercial business areas	10	A new area for IFCI or other NRC institutes for business growth
Technical and market durability of the technology that may be developed as a result of this project	Technology developed may not have unique characteristics and can easily be copied by competitors	Technology developed may allow IFCI to lead competitors by a few years	Technology developed may have a moderate lifecycle (3-4 years). There may be little opportunity for incremental improvement	Technology developed may have a long lifecycle. There may be opportunity for incremental improvement.	8	Technology developed can be improved incrementally
Synergy of the project with other projects at the institute	May be limited to a single project	May be limited to a few projects	Some aspects of the project could be adopted by other project teams or have application to other projects	Many aspects of the project could be adopted by other project teams or have application to a number of other projects	7	Project has the potential to add value to other projects at IFCI or other NRC institutes
Average Component Score					8	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

Table 9: Case Study- Enzymatic fuel cell -Factor 3: Probability of Technical Success

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Gap between required technical knowledge and technical knowledge at IFCI	Large gap between current knowledge and project objective; fair amount of R&D required	Gap between current knowledge and project objective; R&D required	Incremental change; some R&D required	Minimal; project is more Engineering in focus	4	There is some research knowledge in the field of enzymatic sensors
Project complexity	Project is complex. There are a number of technical difficulties to overcome	Project is somewhat complex. There are a number of technical difficulties to overcome	Project is a challenge, however it can be accomplished	Project has low complexity	4	The project is complex
Competency in the technical area	Technology to be developed is new to IFCI, there is no technical skill base at IFCI	IFCI has some R&D experience with the technology to be developed, but it may be insufficient	IFCI has a skill base in the Technology to be developed. Although not widely practiced.	IFCI has a skill base in the Technology to be developed. It is widely practiced.	4	There is some expertise at IFCI, complimentary expertise is available at other NRC institutes
Project Schedule	The project schedule is ambitious. Low probability of project completion on schedule	Tight schedule. There is a possibility that the project may not complete on schedule	Good probability of project completion on schedule	Schedule is well planned. There is a high probability of project completion on schedule	7	The project is more long term in view as it is basic applied research based

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Availability of personnel	No suitable personnel available. Must hire for the project	Shortage of personnel, they can however be accessed	Personnel are available, but may be involved in other projects, there is a need to plan in advance	Personnel are available	6	Resources may have to be accessed from other NRC institutes
Availability of facilities/equipment	No suitable facilities exist. Must build for the project	Some facilities/equipment are not available. IFCI can however access them through the external market	Facilities are available, but may be involved in other projects, there is a need to plan in advance	Facilities are available	6	Equipment may have to be accessed from other NRC institutes
Average Component Score					5.2	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

Table 10: Case Study- Enzymatic fuel cell-Factor 4: Probability of Commercial success

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Market demand for the technology developed as a result of this project	There is no apparent customer need. Market development may be required	There is a market for the product. However some market development may be required	There is a relationship between the product and customer needs.	Product could appeal to customer needs and may act as a substitute for existing products	8	Project may contribute to the development of products like pace makers and sensors
Competition	High	Moderate/High	Moderate/Low	Low	10	Very low, at this point of time there is no significant activity
Partners expertise in commercialization of technology developed as a result of this project	Partner needs the support of IFCI to commercialize the technology	Partner has some expertise, needs some support for IFCI	Partner has expertise, would welcome some support from IFCI	IFCI's support not required as partner has most of the expertise	2	Very few players in this space, hence product development required
Regulatory impact	Negative	Neutral	Favourable	Positive impact	4	Neutral impact, will not change any regulations
Average Component Score					**6**	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

Table 11: Case Study- Enzymatic fuel cell-Factor 5: Return on Investment (ROI)

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Financial leverage (Cash)	Dollar value of IFCI's cash contribution to the project is expected to be more than 50% of the cost of the project	Dollar value of IFCI's cash contribution to the project is expected to be 50% of the cost of the project	Dollar value of IFCI's cash contribution to the project is expected to be less than 50% of the cost of the project	Dollar value of IFCI's cash contribution to the project is expected to be less than 25% of the cost of the project	2	Institute has to provide a significant portion of its cost.
Financial leverage (in-kind)	Dollar value of IFCI's in-kind contribution to the project is expected to be more than 50% of the cost of the project	Dollar value of IFCI's in-kind contribution to the project is expected to be 50% of the cost of the project	Dollar value of IFCI's in-kind contribution to the project is expected to be less than 50% of the cost of the project	Dollar value of IFCI's in-kind contribution to the project is expected to be less than 25% of the cost of the project	2	Institute has to provide a significant portion of its cost.
Publications as a result of the project	Low possibility	Medium possibility	Good possibility	Strong possibility	10	There is a strong possibility of getting publications as a result of this project
Creation of Intellectual Property (IP) as a result of the project	Low possibility	Medium possibility	Good possibility	Strong possibility	10	There is a strong possibility of developing an IP portfolio as a result of this project
Project will result in the increase in the profile of IFCI as a destination for fuel cell R&D	Does not enhance IFCI's reputation as an R&D centre	Somewhat enhances IFCI's reputation as an R&D centre	Enhances IFCI's reputation as an R&D centre	Strongly enhances IFCI's reputation as an R&D centre	7	Project will increase the profile of IFCI in the area of bio-fuel cells for high value applications

	Rating Scale (Rating is on a scale of low to high)					
Key factors	**2**	**4**	**7**	**10**	**Score**	**Comments**
Future impact/benefits as a result of the project	Project may not provide IFCI with any future benefits	Project may have a limited number of future benefits	Project may create new technical and commercial opportunities for IFCI and Canadian fuel cell companies	Project may help IFCI and Canadian fuel cell companies achieve a leadership position	7	Project may result in creating new competencies and a market leadership position for Canadian fuel cell companies
Social impact	Neutral	Favourable	Positive impact	Strong positive impact on high profile issues	7	Impact on high profile issues: Health Care
Average Component Score					6.42	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

Table 12: Case Study- Enzymatic fuel cell-Final Project Scorecard

Key Factors	Factor Score	Weight	Weighed Factor Score	Comments
Strategic Fit	3.14	3	9.42	The project scores the lowest score on this component.
Strategic Leverage	8	3	24	The project scores the highest score on this component.
Technical Risk	5.2	1	5.2	The project represents a medium technical risk.
Commercial Risk	6	1	6	The project represents a medium commercial risk.
ROI	6.42	2	12.84	The project has a medium ROI profile.
Final Project Score			**57.46**	

Source: Table created by author from information provided by Mr. Francois Girad (IFCI)

The Enzymatic fuel cell project proposal was assessed at the score of 57.46. The project achieved a low score in the strategic fit component, but achieved a high score in strategic leverage and ROI components.

7.1.2 Lessons learned

After using the IFCI-PEM to evaluate the case study, Mr. Francois Girad and the author evaluated a fee-for service project proposal. The fee-for service project was for IFCI services in a research area where IFCI has strong competencies. The fee for service project proposal was assessed with a final project score of 51.49. The project achieved a low score in the strategic leverage component but achieved a high score on the probability of technical success and strategic fit components. When the factors in the model were not weighed, the project in the case study and the fee-for service project achieved similar scores, 28.76 and 29.16 respectively. However, once weights were assigned to the factors, the final scores obtained by the two projects allowed Mr. Francois Girad and the author to distinguish between the two projects.

It is important that proper weights be assigned to each of the components in the IFC-PEM to ensure that the final project scores help IFCI management to distinguish between different projects. Additionally, the team that uses IFCI-PEM for ranking projects should be comprised of representatives from different IFCI departments. This will ensure that the scores assigned to the components accurately capture the challenges IFCI may face if it decides to initiate the project. The IFCI-PEM facilitates the qualitative and quantitative assessment of a project proposal, hence it is essential that the members assessing the project document the justification for the individual scores in the comments section.

7.2 Recommendations

Based on the results of the case study and review of literature, the author developed the following recommendations for IFCI to facilitate the successful implementation of the IFCI-PEM.

- **The IFCI-PEM should be evaluated by all IFCI stakeholders:** The IFCI-PEM will be used as a decision making tool by IFCI management. To ensure that all stakeholders use the tool, the IFCI-PEM should be evaluated and tested in meetings where members from the S&T, BDO and IFCI management are present.
- **The IFCI-PEM should be implemented at the IFCI in stages:** Initially the IFCI-PEM should be tested with a number of previous project proposals. The projects should be scored based on the scoring criteria and ranked in terms of the final project score. The list of projects obtained as a result of this evaluation should be compared to the actual prioritization by IFCI. If the project priority sequence is incorrect, IFCI should re-examine the weights of the individual elements of the IFCI-PEM. Through a sequence of iterations, IFCI should adjust the IFCI-PEM until it accurately captures the decision of the IFCI project selection committee.

- **The weights for the IFCI-PEM should be "locked down":** After the model has been tuned by the IFCI, the weights for the IFCI-PEM should be "locked down" (Cooper et al., 1998) by the BDO. Keeping the weights for IFCI-PEM constant ensures that projects are evaluated using the same set of criteria.
- **New components and annual or periodic review:** The IFCI-PEM will maintain its relevance as a tool to IFCI only if it is constantly reviewed and updated. New components can be added to the IFCI-PEM based on changes in IFCI or the fuel cell sector. Additionally, an annual or periodic review of the weights assigned to the different components will ensure that IFCI-PEM reflects any changes in IFCI's strategy or focus.

7.3 Application of the IFCI-PEM to existing IFCI projects

IFCI follows a Stage-Gate process for managing projects. Projects go through decision gates after specific stages in a project have been completed. The IFCI-PEM, in addition to its use as a tool to evaluate and screen new projects, can also be used to evaluate projects at the later decision gates. After a project has been initially evaluated using the IFCI-PEM, and the project proceeds through the development phase, new information regarding market applications for the technology developed as a result of the project may become available. At the decision gates, the project can be re-evaluated and ranked in comparison to other projects at that decision gate to ensure that only the projects that provide the maximum value to IFCI are pursued. Decision between which projects should be pursued assumes more importance at later gates in IFCI, as IFCI typically increases its investment in a project as a project moves from initial screening to the implementation stage.

7.4 Summary

The evaluation of the Enzymatic fuel cell project proposal using the IFCI-PEM clearly demonstrated that the model developed as a result of this work could successfully evaluate projects for IFCI. Although the IFCI-PEM is a tool that will help facilitate IFCI's management to make decisions regarding project proposals, the score that a project achieves from the IFCI-PEM should not be used as the final decision making criteria. If a project does not score high on the IFCI-PEM and IFCI's management team feel that the project should be supported by IFCI, the project can be supported despite the IFCI-PEM score. Even if a project is approved in spite of its poor IFCI-PEM score, the evaluation components should be completely filled out in the IFCI-PEM. This will ensure that the various components of the project have been discussed and documented by the project evaluation team, and may lead to updating of the IFCI_PEM criteria and/or weightings.

8 DISCUSSION AND CONCLUSION

The IFCI-PEM was developed and discussed in this report as a tool to evaluate potential projects. The IFCI-PEM will remain relevant to IFCI's needs only if it is reviewed and updated whenever IFCI's business strategy or focus changes. The IFCI-PEM can be a useful tool for the IFCI as it assesses and ranks projects on the financial and non-financial measures that are reported by IFCI under the Key Performance Indicator framework.

Management of risk is an important consideration for Research Technology Institutes (RTIs) as they try to fulfil their mandate with the limited funds available to them. IFCI with its assured A-Base funding and with a B-Base funding that is subject to government priorities is especially concerned with making the most efficient use of its funds. Evaluation of risk via the IFCI-PEM will allow the IFCI management team to focus discussion on the risks associated with a project both from a technical and a business point of view. Internal risks such as the risk associated with the shortage of personnel and appropriate equipment and facilities are also assessed and evaluated in the IFCI-PEM.

Although it is not advisable for IFCI to use the project scores obtained via the IFCI-PEM as an absolute measure, the scores do point towards the advantages and disadvantages of a project proposal. Individual component scores achieved by a project in the IFCI-PEM can be used to map its profile based on a ROI versus Technical or Business risk to create impact versus risk graphs.

IFCI is focused on forming partnerships and alliances that will enable it to support the commercialization of fuel cells. However, limited resources require strategic prioritization of projects opportunities. The IFCI-PEM will allow for this strategic prioritization. In addition, it can stimulate transparent discussion of the aspects of projects under consideration.

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