University of Alberta

Innovation through Collaborative Research and Technology Development in the Energy Sector

by

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This thesis is dedicated to my parents,
P.A. Hakkim and Alli Hakkim,
who helped me to achieve the best possible education.

Abstract

Open innovation generates new technology by combining the technology developed internally within an organization and that developed externally by sources outside the organization. Using a case study methodology in the context of the energy sector, this thesis studies the practical application of open innovation to generate and apply technologies to solve the kinds of major problems that an organization cannot resolve on its own. Findings from five case studies create the framework for a new Collaborative Research and Technology Development (CRTD) model, which can be used by organizations with similar interests to collaborate to develop technology. The CRTD approach allows for the sharing and transfer of technology among organizations, reducing the burden on internal R&D and helping organizations to overcome their technological limitations.

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List of Abbreviations

AACI	AERI/ARC Core Industry Research Program
AAET	Alberta Advanced Education and Technology
AEC	Alberta Energy Corporation
AED	Alberta Economic Development
AERI	Alberta Energy Research Institute
AEUB	Alberta Energy and Utilities Board
AOSI	Alberta Oil Sands Industries
AOSTRA	Alberta Oil Sands Technology and Research Authority
ARC	Alberta Research Council (Alberta Innovates Technology Futures)
bbls	barrels
bpd	barrels per day
C$	Canadian Dollar
CANMET	Energy, Mines Resources Canada
Carbonates	Carbonates R&D Program
CNPC	China National Petroleum Corporation
CNRL	Canadian Natural Resources Limited
CO_2	Carbon dioxide
CRTD	Collaborative Research and Technology Development
CSS	Cyclic Steam Simulation
EOR	Enhanced Oil Recovery
ESAGD	Enhanced Steam Assisted Gravity Drainage

ET	External Technology
EV	Economic Value
GHG	Green House Gas
IEA	International Energy Agency
IP	Intellectual Property
IT	Internal Technology
JACOS	Japan Canada Oil Sands Ltd.
JIVE	Joint Implementation of Vapour Extraction
KM	Knowledge Management System
KMS	Knowledge Management
MC	Management Committee
OIM	Open Innovation Model
P&P	Policy and Program
PTRC	Petroleum Technology Research Centre
R&D	Research and Development
SAGD	Steam Assisted Gravity Drainage
SDTC	Sustainable Development Technology Canada
SOR	Steam-Oil Ratio
SRC	Saskatchewan Research Council
SVX	Solvent Vapour Extraction
TC	Technical Committee
TG	Technology Generation
THAI	Toe to Heel Air Injection

TI	Technology Integration
UofA	University of Alberta
UTF	Underground Test Facility
Weyburn	Weyburn CO_2 Monitoring and Storage Project First Phase

Chapter 1 Introduction

1.1 Research Motivation

Both availability of new technology and improvements to the existing technology are important for the survival of a business. Organizations are using Research and Development (R&D) to generate new technology. The burden on an organization's internal R&D is huge if the R&D functions are based on only the technology generated from within.

Collaborative research is a process in which different parties collaborate to develop technology. From an industry-wide perspective, innovative performance depends on the contributions of a number of different external actors who are willing to work within and outside of the firm to introduce strategic idea development (Akyuz, 2005; Chesbrough, 2003a). As Chesbrough (2003) notes, innovators in the manufacturing industry "must integrate their ideas, expertise and skills with those of others outside the organization to deliver the result to the marketplace, using the most effective means possible" (p. 41).

Currently, external technological sources are available from companies that are willing to collaborate with other companies. The use of external technological sources is one method to reduce the burden on internal R&D, but the effectiveness of innovation depends on how a company uses these sources. Organizations have always been sensitive about revealing their R&D activities. In the past, the idea of sharing R&D activities, especially with competitors, was either never well received or difficult to implement. However, if enough evidence demonstrates that innovation through collaboration provides more benefits, creates more economic value, and provides more leverage on

R&D investment than other forms of innovation, then companies will have enough interest in this innovation method to adopt and implement it.

1.2 Research Focus

The overarching research question of this dissertation is: How and when should collaborative research be used in the energy sector?

The following specific questions were developed as the study progressed:

RQ1: How can the innovation process be improved?

RQ2: How can an organization innovate effectively?

RQ3: How can an organization identify circumstances where the most economic value be created through collaborative research?

1.3 Research Purposes

This research had the following purposes: (1) to develop a technological innovation method by combining internal and external sources of technology, (2) to develop a new model to help find solutions to complex technical problems and assist industries in using and implementing collaborative research for their R&D needs, and (3) to identify circumstance where collaborative research provides better economic value than other innovation methods. Developing a successful innovation model was the overarching goal of this research program.

This thesis also addresses related R&D issues such as technology constraints, resource constraints, budget constraints, and the time required to complete R&D activities. Collaborative research is only one of several methods for improving innovation effectiveness. Collaborative research is developed from the concept of open innovation and collaboration. This innovation method does not fit well in all sectors. For example, collaborative research might not be the best innovation model for the military services, where technology development remains confidential. The scope of this thesis is limited to developing models for using collaborative research in the energy sector.

1.4 Research Methodology

The thesis uses the case study methodology described in detail in Chapter 3. The case studies consist of five cases of real-life innovation practices in the energy sector. The findings from the case studies are converted into specific conclusions in order to develop the collaborative research model. The initial plan was to conduct case studies in the following sectors: (1) Energy sector, (2) Environment, (3) Life Sciences, and (4) Manufacturing. Later, it was decided to focus the case studies on only the energy sector. The case studies were conducted with the support of the Alberta Energy Research Institute (AERI), Alberta Research Council (ARC),[1] Petroleum Technology Research Centre (PTRC) and University of Alberta (UofA).

Five cases, AOSTRA UTF SGAD, the AACI R&D Program, Weyburn CO2 Capture and Storage, the Carbonates R&D Program and the JIVE R&D Program, where new technology was developed through collaboration, are discussed in this thesis. The historiography (Komery & Cyr, 1998) of R&D in the energy sector in Alberta reveals that a shift in the traditional R&D pattern started occurring in the late 1970s. Industries started to show their willingness to collaborate with the government on R&D in the energy sector. This development represented a total change from the “conducting one’s own research and development” method. The industries’ willingness to collaborate with the government on R&D was most evident in the technology development related to the

[1] Alberta Research Council was recently combined with Alberta Innovates Technology Futures.

Alberta oil sands and led to the beginning of a government / industry collaboration in R&D (Komery & Cyr, 1998). In 1984, the Alberta Oil Sands Technology and Research Authority (AOSTRA) decided to develop the gravity drainage concept of R.M. Butler. At this time, the government and industries had already expressed their willingness to collaborate. Eleven companies eventually decided to join AOSTRA to develop Underground Test Facility Steam Assisted Gravity Drainage (UTF SAGD) technology. The UTF SAGD project was selected for the first case study in this thesis. UTF was successfully completed with a pilot test project and went into commercial operation in 1997. The UTF SAGD project adopted a concept of collaboration similar to open innovation to develop SAGD technology. The Government of Alberta launched another R&D venture at almost the same time, aimed at developing technologies for improving bitumen production in the oil sands. The AERI/ARC Core Industry Research Program (AACI) program also adopted a concept of collaboration similar to open innovation. Embracing the success of AOSTRA UTF SAGD, government and industry continued to use their collaborative R&D model for complex technology development. The Government of Saskatchewan and industry started the Weyburn CO2 Monitoring and Storage Project (Weyburn) a collaborative R&D project in 2000, and Joint Implementation of Vapour Extraction (JIVE) in 2006. The Government of Alberta and industry started Carbonates in 2007. This research program adopted the concept of collaboration for technology development from the case studies and then developed it to generate a collaborative research model. The case study methodology used for this thesis is explained in detail in Chapter 3: Case Study Methodology.

The following specific questions were developed for the case studies:

1. What is the R&D management style? How is R&D controlled?
2. Who are the participants?
3. What are the benefits received by various communities, such as the participants in the R&D, and the Government, the industries, and the public?
4. What were the total project investment, the source of funds, and the investment by the participants?
5. Was there a prototype demonstration of the developed technology?
6. How is the intellectual property protected and managed?
7. What are the participants' intellectual property rights?
8. Is the technology developed through the R&D program available to industries who did not participate in the R&D?
9. Is the technology developed through the R&D program available to the public?

1.5 Organization of Thesis

This is a research thesis. Chapter 1 presents the introduction to this thesis. This chapter provides the research background, problem statement, scope, goals, limitations, significance, and research methodology. Chapter 2 provides the definitions of innovation, open innovation, and closed innovation. Chapter 3 provides the details of why the case study methodology was adopted in this research, and how the case studies were implemented. Chapter 4 introduces the cases selected for the thesis. This chapter provides a preamble to the case study projects. Chapter 5 presents the five case studies conducted as part of the research program. This chapter explains the scope of the case studies and the methodology used in conducting them. Chapter 6 discusses Intellectual Property (IP) management in open innovation. Five case studies were conducted on IP Management, with the help of AERI, ARC and PTRC. Chapter 7 presents the analysis of the case studies and the major findings from them. Chapter 8 introduces the concept of collaborative research and discusses its necessity. Chapter 9 describes the derivation of the CRTD model from the case study findings and explains the key elements in collaborative research. This chapter also explains the pilot test for the demonstration of the technology and IP management related to collaborative research. Different IP management scenarios and a recommended IP management model are also discussed in this chapter. Chapter 10 discusses the CRTD Model. This chapter explains the CRTD process, the different R&D phases in CRTD, and the framework and components of the CRTD Model. Chapter 11 explains when using open innovation makes sense, the effects on market share, and the limitations and challenges of open innovation. This chapter also answers the question of whether open innovation is a preferred alternative. Chapter 12 provides a conclusion for CRTD. This chapter provides an overview of the major differences between open and closed innovation, and the factors influencing an organization's decision to adopt open innovation. Chapter 13 provides the conclusions for this thesis, provides lessons learned and makes recommendations for future research.

Chapter 2 Introduction to Open Innovation

2.1 Overview

Organizations that innovate regularly are generally the ones that achieve success, sustainable competitiveness and prosperity (Chesbrough, 2003a). Innovation consists of converting an idea into an application and then introducing that application into the market. Schumpeter (1943) demonstrated that if, within the circular flow of both money and the economy, no business or technological innovations and no ground-breaking activities occur, the economy slows down to a stationary state.

The innovation process in which various parties create new technology collaboratively is called open innovation, which consists of collaborating to convert an idea into an application and to introduce that application into the market. Open innovation provides access to technology created by others outside the organization. Research in open innovation provides an opportunity to study collaborative technology development. Here, new technology is created by combining technology generated by internal R&D within the organization and technology created by others outside the organization. Open innovation reduces the burden on internal R&D, since an organization can depend more on the global technology landscape and technology leveraging than would be possible otherwise. Companies that do not collaborate to convert ideas to applications and to market their applications use the closed innovation process. Technology created by external sources is not used in closed innovation.

This chapter explains the differences between invention and technological innovation, and introduces two types of innovation, open innovation and closed innovation. An introduction to the role of research and development (R&D) in open innovation is also provided in this chapter.

2.2 Invention and Technological Innovation

The generation of an idea is called invention. “The invention process covers all efforts aimed at creating new ideas and getting them to work” (Roberts, 1987, p.3). The steps involved in invention are generating technical ideas, developing these ideas so that they can be incorporated into products and services, and creating prototypes to ensure these products and services will work (Roberts, 1987).

The conversion of an invention into a business or other useful application is technological innovation. Technological innovation identifies means to improve the processes involved in product development (process innovation). The distribution of an organization’s resources between product and process innovation depends on the market phase of the relevant technology (Abernathy & Utterback, 1978). The purpose of technological innovation is to create a dominant design in a product class, which “is, by definition, the one that wins the allegiance of the marketplace, the one that competitors and innovators must adhere to if they hope to command significant market following” (Utterback, 1994, p. 34). This point is illustrated in Figure 2.1.

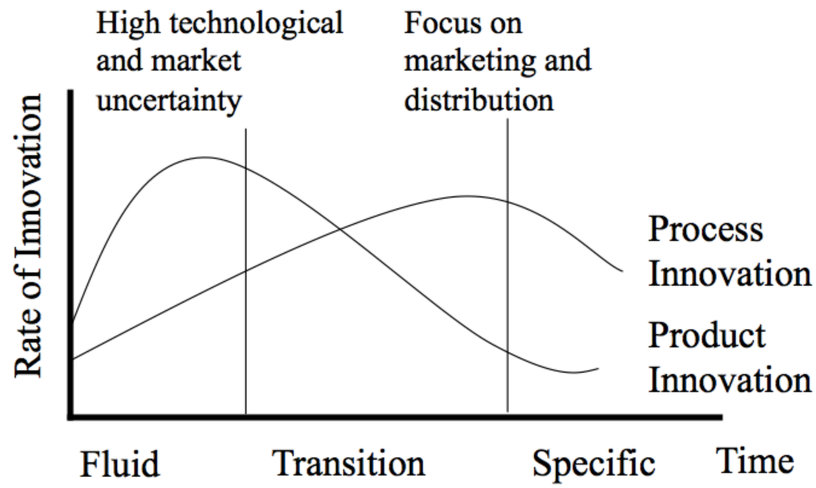


Figure 2.1 The Abernathy-Utterback Model of technological innovation

Figure 2.1 illustrates that support for new forms of innovation is now evolving, and that these forms are tied to both process and product development. Instead of emphasizing making and selling, organizations must be able to see themselves as part of a value-creation and delivery sequence. As Ameri and Dutta (2005) noted, in today's business environment, monolithic design teams such as those traditionally associated with R&D are no longer well placed to efficiently manage the product development effort. The primary cause of challenges in R&D, Ameri and Dutta (2005) argued, is organizational capacity for knowledge, and the ability to use knowledge from within and without the firm itself. These authors further argued that a "knowledge-intensive product development environment requires a computational framework which effectively enables capture, representation, retrieval and reuse of product knowledge" (Ameri & Dutta, 2005, p. 577). Therefore information must be gathered, organized and used purposefully. Loof and Heshmati (2002) noted, however, that a specific link exists between the ability of the firm to be innovative and its level of productivity. A positive relationship exists between the two: as innovation increases, so does productivity, and vice versa. The research shows, however, that “the growth rate of productivity increases only with innovations new to the market when manufacturing firms are considered” (Loof & Heshmati, 2002, p. 21).

New forms of innovation include interaction not only between customers and businesses, but also between firms and the scientific forms of academic research, between the different functions within any given firm, between producers and users at the interfirm level and between firms and the wider industry (Utterback, 1994). The innovation process requires the constant input of knowledge from various fields of science and technology, especially within an oligopoly with similar products (Utterback, 1994), such as the energy sector. The sources of this knowledge can be either internal or external. Innovation can occur when collaborators work with ideas from outside as well as inside an organization. The newly created ideas enter the market not only through the company that generated them, but also through the other collaborating companies. Collaborative work provides opportunities to overcome the limitations of technology. Figure 2.2 presents the invention and innovation process.

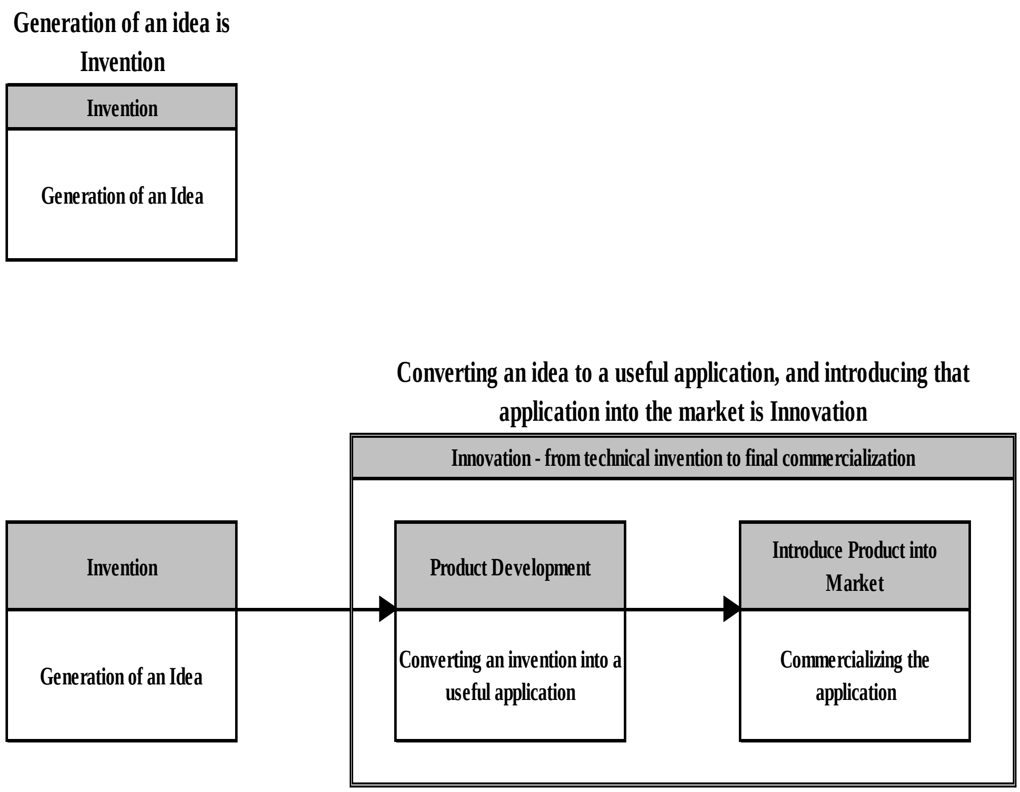


Figure 2.2 Invention and innovation

2.3 Closed Innovation

Closed innovation is a method that companies use to generate their own technology to develop products and market their own inventions. The technology available outside the organization is not used in closed innovation (Chesbrough, 2003a). In closed innovation, organizations focus primarily on the technology created by internal R&D laboratories and pay less attention to the technology developed by others. In closed innovation, all the ideas about a product remain within an organization, with no flow of ideas between the organization and the outside world. The closed innovation method is a good fit for some sectors such as the military sector.

2.4 Open Innovation

Open innovation is the process of introducing an idea into the market by gathering technology from different sources. Open innovation generates new technology by combining technology developed internally by internal R&D within an organization and technology developed externally by sources outside the organization (Chesbrough, 2003a). This innovation model uses all the technology, knowledge, and sources available globally to market products and serve customers. In open innovation, not only do organizations innovate collaboratively, but also the developed technology is introduced into the market through various organizations (Chesbrough, 2003a).

Open innovation involves finding outside technology and using it. Ideas can come from inside or outside a company. The focus of R&D is to identify the external technological sources. Once they have been identified, methods can be formulated to access them. This approach improves the quality of products and reduces the amount of time needed for products to reach the market. In open innovation, organizations do not necessarily have to invent all the required technology, but only to find a source for it. As a result, the burden on internal R&D is reduced. Companies can collaboratively work together to engineer products instead of developing an invention entirely by themselves and also have different channels available to market their products. The effectiveness of innovation depends on how a company uses external sources to develop products and services.

Open innovation is a viable solution since an organization can seek new technology from the outside world. In open innovation, a new technology is developed through the collaborative engagement of various parties. Stakeholders can benefit from the new innovation, which is spread among the members of the community. In open innovation, all the available information is used in the creation of a product, potentially resulting in high-quality products and services. The customer can benefit by getting high-quality service and technically innovative products at a reasonable price.

Kim and Mauborgne (2005) suggested that companies need to reach out beyond their boundaries in order to utilize a 'blue ocean' strategy. These authors posited that since market boundaries and industry structures are not a given, they can be reconstructed to meet the needs of the organization (Kim & Mauborgne, 2005). During open innovation, knowledge is created, shared, applied, and introduced into the market in the form of products and services. Companies can collaboratively work together to engineer products instead of developing an invention entirely by themselves and can also have different channels available to market their products.

2.5 Research and Development

The primary objective of R&D is to generate inventions. In open innovation, R&D also focuses on identifying external technological sources. Once they have been identified, methods can be formulated to access them. In open innovation, R&D assesses the knowledge required for the development of a product and then processes this knowledge into meaningful patterns during the process of product development. Changes will be made to the R&D to accommodate the incoming flow of external technology. The main function of R&D in open innovation is to search for technology in the global knowledge repositories. The functions of R&D need to be redesigned to access technology from these repositories. One of the main functions of R&D in open innovation is to identify who has the relevant knowledge and technology, so that these organizations can be approached when technology is needed.

2.6 Summary

This chapter introduced open innovation by defining it and distinguishing it from closed innovation. How open innovation differs from closed innovation, and how the R&D functions differ in open innovation were also explained in this chapter. Open innovation is derived on the basis of collaboration. In open innovation, multiple organizations are involved in the R&D. Similarly, the results of the R&D reach the end users through multiple sources. This feature makes open innovation entirely different from closed innovation. The commercialization of new technology is possible through innovation. Since the business success of an organization depends on the availability of new technology, organizations normally like to keep new technology-creation activity to themselves. However, in open innovation, technology is created with the complete engagement and participation of other organizations, which may include organizations in the same industry, and sometimes even competitors. This success of this method of innovation through collaboration is explained in the following chapters.

Chapter 3 Case Study Methodology

3.1 Overview

This research program was conducted by using a case study methodology. This chapter provides the details of the method adopted to conduct the case studies. The reasons for selecting the cases and the number of cases analyzed, as well as how the conclusions were reached, are explained in this chapter. Five projects that adopted collaborative R&D methods similar to open innovation were studied, and the features of these cases were used to arrive at the model developed in this thesis. This chapter was written by referring to the works of Yin, Hartley, Eisenhardt, and Mitchell, who extensively studied the use of case studies in conducting research.

3.2 Introduction to Case Study Methodology

A case study is an investigation in which either one case (a single case study) or a number of cases (multiple case studies) are studied in detail in their real-life context, and the data collected are analysed and generalized to build a theory (Dul & Hak, 2008). Yin (1993) pointed out that a case study provides an opportunity to investigate a phenomenon in its real-life context. Case studies are used to find answers to the how and why questions about a contemporary set of events (Leonard-Barton 1990). According to Hartley (1994), case studies are tailor-made for exploring either new processes or behaviours or ones that are little understood.

The case study method used in this research program consists of the detailed investigation of five cases, five R&D projects in the energy sector. These cases were selected to find answers to the research questions. The data gathered during multiple case studies allow the researcher to study the different aspects of the cases and to examine one case in relation to the others. In this thesis, case studies are used to demonstrate why collaborative research was adopted in five R&D projects, how collaborative research was executed, and what the results were.

Case studies can involve either single or multiple cases, and numerous levels of analysis (Eisenhardt, 1989). Multiple cases were used in this research program. A single case study is a case study in which data from one source are collected to achieve the research objective, and a multiple case study is one in which data from two or more sources are collected to achieve the research objective (Dul & Hak, 2008). The multiple case study method arrives at its conclusions by using different levels of analysis (Yin, 1993). Yin (1993) argued that the use of multiple cases strengthens the results and increases the confidence in the robustness of the theory generated.

A case study contributes to the development of theory by enabling the researcher to formulate new propositions based on the evidence drawn from the object of study (Dul & Hak, 2008). The objective of using case studies in this thesis was to develop a model about how and when to use collaborative research. For this thesis, the cases selected were R&D projects that applied collaborative innovation methods similar to open innovation. The methodology was chosen to develop a model by combining the observations and evidence collected from various (multiple) case studies.

Carrying out a case study consists of the following steps: Selecting the case(s), establishing data collection procedures, collecting the data, analyzing the data, and generalizing and developing the thesis.

3.3 Design of the Case Studies

These studies had the following objectives: (1) to learn how organizations join together to find R&D solutions to problems that one organization cannot resolve on its own, (2) to develop methods to initiate and manage collaborative R&D projects, and (3) to identify the technology transfer and sharing that occurs during collaborative research. The case studies were designed from the problem statement by considering what data would be needed to meet the research objectives. This consideration helped in the selection of cases. The sources of data (organizations, people) and specific data sets were carefully selected to meet the requirements of a case study.

3.4 Selection of Cases

The selection of the cases is an important aspect of building a theory or model from case studies. The cases required for this thesis were the R&D projects in the energy sector that were executed by using the collaborative innovation method. The cases selected were the (1) AOSTRA UTF SAGD, (2) the AERI/ARC Core Industry (AACI) Research Program, (3) the Weyburn CO2 Monitoring and Storage Project, (4) the Carbonates R&D Program, and (5) the Joint Implementation of Vapour Extraction (JIVE) project. These cases were selected after considering the complex technology they involved and the various levels of government and industry participation.

This multiple case study consists of five cases. The study of only a single case can involve limitations in generalizability and information-processing biases (Eisenhardt, 1989). Multiple cases allow for comparison and contrast among the cases as well as a deeper and richer look at each case. Establishing the scope of a case study helps to set its boundaries. The overall case study scope was divided into data sets. This division helped to organize the study and to build a structure for it.

Data were collected for each data set. The following are the data sets established for this thesis: Project Description, Technology Developed, Participants, Benefits, Field Test, and Intellectual Property management. The list of the cases and various data sets is shown in Figure 3.1.

Cases	Datasets					
	Project Description	Technology Developed	Participants	Benefits	Pilot Test	IP Management
AOSTRA UTF SAGD	X	X	X	X	X	X
AACI	X	X	X	X	X	X
Weyburn	X	X	X	X	X	X
Carbonates	X	X	X	X	X	X
JIVE	X	X	X	X	X	X

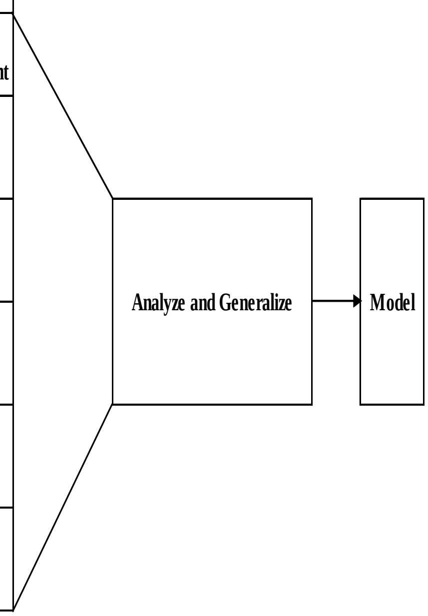


Figure 3.1 Cases and data sets

3.5 Data Collection

Various data collection methods are available for case studies. Document review, interviews, and observation were the data collection methods chosen for this thesis. The combined use of these three methods made the data strong enough to support the creation of the model. The data collection period is important, as the data reflect the status of the project. Table 3.1 shows the status of the five projects when the data were collected.

Table 3.1 Period for data collection

Project	Period Data Collected	Status of the Project
AOSTRA UTF SAGD	January 2007 to November 2008	Completed in 1997
AACI	December 2007 to September 2008	On-going
Weyburn First Phase	June 2008 to October 2008	Completed in 2004
Carbonates	August 2008 to December 2008	Completed in 2009
JIVE	August 2008 to December 2008	Completed in 2009

The methods adopted to collect data for this thesis included document review, interviews and observations.

Document review.

Documents were reviewed for each case, and data were gathered for each data set. Document review was the major source for data collection. Published articles, conference proceedings, and presentations provided information about the five projects. The documents such as weekly and monthly reports were useful for tracking the events that happened during a specific period during the projects. Quarterly reports and annual reports provided opinions about and analyses of the projects. The list of documents used for the case studies is given in Table 3.2, below.

Table 3.2 List of documents used for the case studies

Cases	Documents						
	Published Articles	Conference Proceedings	Annual and Quarterly Reports	Website Information	Independent Evaluation Reports	Weekly and Monthly Reports	Field Test Data
AOSTRA UTF SAGD	X	X	X	X		X	X
AACI	X	X	X	X	X		
Weyburn	X	X	X	X			
Carbonates	X	X	X	X			
JIVE	X	X	X	X			

Interviews.

The sources of the data collected through interviews are divided into the following categories: Leader representative for the project, senior managers for the project, government representatives for the project, industry representatives for the project, professionals from academia, independent R&D professionals, intellectual property managers for the program, and end users of the technology – industries currently using the technology.

Data were collected from multiple sources for each case study. The advantage of having multiple sources is that the validity of the information gathered from one source can be verified against that gathered from other sources. The data collected through the interviews can also be used to validate the data collected through the document review.

The main focus was on the professionals who were directly involved in these R&D projects, including the leader representative, senior managers, government representatives and industry representatives for the programs. Professionals from academia and independent R&D professionals were useful in validating the data collected from the previous group. The sources of the data collected through the interviews are provided in Table 3.3.

Table 3.3 Sources of data collected through interviews

Cases	Interviews							
	Leader Representative	Senior Managers	Government Representatives	Industry Representatives	Professionals from Academy	Independent R&D Professionals	Intellectual Property Managers	End Users
AOSTRA UTF SAGD	X	X	X	X	X	X	X	X
AACI	X	X	X	X	X	X	X	X
Weyburn	X	X	X		X	X		
Carbonates	X	X	X		X	X	X	
JIVE	X	X	X		X	X		

Observations.

The major strength of direct observation is that it is unobtrusive and does not require direct interaction with participants (Denzin & Lincoln 2005). According to Pettigrew (1990), direct observation can illuminate the discrepancies between what people say in the interviews and casual conversations and what people actually do.

The major sources of observation were archives, contract documents, commercials, confidential documents, field test data, and independent evaluation reports. Observation provided opportunities to gather more details about the cases and to validate the data collected from the document review and interviews. The combination of these three data-collection methods was helpful in counteracting any biases that occurred during the data collection.

3.6 Data Analysis

The data gathered through the above process were organized into categories, summarized, compared and analyzed. The data were divided into the following categories developed for the analysis: R&D Management, Participants, Technology Developed, Benefits, Budget, Field Test, and Intellectual Property Management. The data analysis was carried out in two steps: Within-case analysis and cross-case analysis.

Within-case analysis.

Before conducting within-case analysis, complete reports on each case study were prepared so that each case could be treated as a stand-alone case. A thorough analysis was conducted on the data collected under each category for each case. This analysis provided a clear understanding of the highlights, the inclusions and the exclusions of each category for each case. Thus, a summary of the findings for each case was developed. Each summary provided a unique pattern for each case.

Cross-case analysis.

After completing the within-case analysis, a cross-case analysis was conducted. For each category, similarities and differences were mapped between cases. When a pattern from one case was found to be similar to a pattern in another case, a trend among the patterns was generated. After studying the similarities and differences among the cases, those found to be similar in nature were grouped together. These groups were studied to find the within-group similarities and to generate within-group patterns. The series of the trends among the individual cases and the group patterns in the five cases as a whole eventually led to the generation of a model.

The primary input into the process of developing a model from case studies is the data. Within-case analysis and cross-case analysis provide an opportunity to validate and analyze the data. Since five cases were studied, this research program provide a great opportunity to validate the model generated from the case studies. The overall concept was developed from the patterns in the individual cases and the patterns common to all the cases. Through within-case analysis and cross-case analysis, a pattern was developed, which consisted of the common features in all the cases. The similarities among all the cases were extracted. The differences between the cases were studied and compared. An overall concept based on the similarities and differences was developed. After the completion of the analyses, an overall concept, a model, was developed, which consists of the common elements from all the cases studied.

3.7 Findings from the Case Studies

After the completion of the analyses, the findings were summarized into the following categories: The Leader, Collaboration, Participants, Duration of R&D, Practising rights for non-participants, Technology developed, and, IP Management. Figures and tables are used in this thesis to present the summaries of the findings.

3.8 Generalization and Thesis

In this phase of a case study, the overall concept derived from the study is explored and developed. For this thesis, the theories related to the following topics were developed after completing the analysis of the overall concept: The role of the leader and participants, the contribution of internal technology and external technology in the generation of new technology, the collaboration of the team, technology integration, technology generation, management of intellectual property, and economic value created. The framework for the thesis was developed from this analysis and generalization.

3.9 Summary

This thesis was developed by using the evidence collected from five case studies. This chapter explained how the case studies were conducted, and how the model was derived. The first step in conducting the case studies was their design, which consisted of selecting the cases, establishing the data sets, and establishing the data-collection process. The selection of cases included identifying the cases which could provide the data required to develop the model on collaborative research. The cases selected were five R&D projects in the energy sector that were executed by using the collaborative innovation method.

Chapter 4 Introduction to the Case Studies

4.1 Overview

Five case studies were conducted for this thesis. This chapter introduces the case studies and discusses the current situation in the energy sector and the changes that have occurred there during the last three decades. Five case studies were conducted for this thesis: AOSTRA UTF SAGD, AERI/ARC Core Industry (AACI) Research Program, Weyburn CO_2 Monitoring and Storage Project, Carbonates R&D Program, and Joint Implementation of Vapour Extraction (JIVE).

UTF SAGD

The UTF project is a prime example of collaborative research. This project was initiated by the Alberta Government and had eleven industry participants during its three major phases over a period of twelve years from 1986 to 1997. The UTF Project was implemented on AOSTRA's 20,000 hectare Athabasca lease located about 60 kilometres north north-west of Fort McMurray. The objective of the project was to prove the commercial viability of extracting bitumen by using the in situ twin horizontal well Steam Assisted Gravity Drainage (SAGD) technology.

AACI

The AACI program was initiated by the Alberta Government. AACI has been promoting collaborative R&D for the last 24 years, and currently has 21 participants from the oil industry along with AERI and ARC. The primary focus of the AACI Research Program is the in situ recovery of heavy oil and bitumen. The main research areas include primary heavy oil processes, solvent-based processes, hybrid steam-solvent processes, improvements to SAGD and Toe to Heel Air Injection (THAI), in-situ combustion processes, and evaluation projects.

Weyburn

The technique of monitoring the capture and storage of CO_2 plays a significant role in tackling climate change. In 2000, the International Energy Agency (IEA) Greenhouse Gas (GHG) international collaborative R&D program had been working on capturing and storing CO_2 for more than seventeen years. The IEA GHG Weyburn CO_2 Monitoring and Storage Project, launched by PTRC in July 2000, was a major research project studying the geological storage of CO_2. This collaborative R&D project's first phase had fifteen participants from the government and industry and employed twenty-two research and consulting organizations. The project's objective was to study the technical and economic feasibility of CO_2 storage in geological formations, with a focus on oil reservoirs. The Weyburn project provided a field-demonstration of carbon storage in the subsurface, at the Weyburn unit of Encana's CO_2 Enhanced Oil Recovery (EOR) project, located in the southeast corner of the province of Saskatchewan. This R&D project contributed significantly to the understanding of greenhouse gas management and enhanced oil recovery. This project's first phase was for a period of five years from 2000 to 2004.

Carbonates

Carbonates was a R&D program initiated by the Government of Alberta through AERI. The program had five industrial participants along with AERI and ARC. This project lasted for three years from 2007 to 2009. The program developed technology to extract bitumen from the Grosmont formation. This bitumen is trapped in rocks in the form of carbonates. The Carbonates program was initiated to study both reservoir characterization and the development and evaluation of recovery technologies. However, during R&D, the team decided to focus more on the reservoir characterization than the recovery technologies.

JIVE

JIVE was a technology-development project initiated by the Government of Saskatchewan through PTRC. The program had three industrial participants along with PTRC and two research providers. JIVE was started in 2006 and ended in 2009. This R&D project developed solvent vapour extraction technology, which was intended to increase the recovery rate from heavy oil reserves.

4.2 Preamble to the Case Studies

Before proceeding with the case studies, the circumstances during their execution will be explained. The context of the case studies is required to understand the situations that triggered these projects and made them necessary. Table 4.1 shows the periods when these projects were carried out.

Table 4.1 Period of case study projects

Sl No.	Case Study	Period
1	UTF SAGD	1984 to 1997
2	AACI	1985 to Ongoing
3	Weyburn First Phase	2000 to 2004
4	Carbonates	2007 to 2009
5	JIVE	2006 to 2009

During the 1970s, many of the companies in the energy sector were developing their own R&D capabilities and conducting their own R&D. Towards the latter half of this decade, industries started to realize the benefits of partnering with Government, gaining access to external expertise, and sharing R&D funding. During the early 1980s, the Government of Alberta started introducing programs that focused on R&D in the energy sector. In 1984, the UTF SAGD project was initiated by the Government of Alberta through AOSTRA, due to the demand for new technology to extract low recoverable bitumen from oil sands. One year later, AOSTRA started the AACI program, an initiative to develop better technology to improve bitumen extraction from the Athabasca oil sands. In 1987, when industries started realizing the need for new technology and understood the benefits of joining the UTF SAGD project, it became a government / industry collaborative project. In 1998, UTF SAGD was successfully completed, and the government / industry collaboration model started to receive more and more attention.

Towards the latter half the 1990s, a global focus developed on the need to reduce GHG emissions. Government agencies and world leaders started discussing the necessity to reduce carbon footprints, and the pressure on industries to reduce GHG emissions increased. In 2000, the Weyburn project was begun to study the geological storage of CO_2, and was initiated by PTRC in collaboration with IEA and Encana. This project responded to the global demand to monitor the capture and storage of CO_2 to reduce GHG emissions. Weyburn became an international collaborative project with six government participants, nine industry participants, fifteen research providers and nine government agencies participating from all over the world. The first phase of Weyburn was successfully completed in 2004, and the second phase was started in 2005 to improve the technology developed during the first phase. In 2000, through Weyburn, the Saskatchewan government start getting involved in the energy sector's R&D.

The energy sector is always calling for new and improved technologies, or technologies to unlock a large potentially valuable resource. Carbonates and the JIVE project are both government / industry collaborations initiated as a result of such demands. The demand for new technology to extract the oil sands trapped in rocks in the form of carbonates led to the Carbonates R&D project. The JIVE project's intention was to develop SVX technology that could improve the recovery rates of bitumen by up to 50%. The JIVE program developed post-primary recovery processes for generating continuing production from a heavy oil reservoir in which the primary recovery process is no longer commercially viable. These processes also help in the recovery of bitumen from untapped bitumen resources that are either too shallow for SAGD or too deep for conventional mining. By 2008, the AACI program had 23 industry participants and had become a proven government / industry collaborative model for innovation in the energy sector.

Table 4.2 shows the trends and events in the energy sector that occurred locally and globally during the period of the case studies' projects. This table reveals the trends and events in the energy sector that triggered these R&D projects.

4.3 Case Study Objectives

The primary objectives of the case studies were to learn how organizations join together to find R&D solutions to problems that one organization might not be able to resolve on its own, to develop methods to initiate and manage collaborative R&D projects, and to identify the technology transfer and sharing that occurs during collaboration. The case studies will help to develop the best innovation methods for government / industry collaboration. The findings will help companies in making decisions about becoming involved in collaborative R&D projects. This thesis will make recommendations for when companies should just license new technology, and for when and at what stages companies should become involved in collaborative innovation projects. The case studies will be used to determine how the companies that participated in R&D projects at an early stage benefited compared to the companies that did not participate, but instead, bought new technologies developed by other companies.

The following main topics are studied in the case studies: Why the organizations became involved in collaborative-type projects; if and how participants benefited from these projects; the participants' current use, if any, of the technology developed through these projects; the role of collaborative R&D in technology transfer, and the management of intellectual property in collaboration.

4.4 Case Study Methodology

The details of the case study methodology were explained in Chapter 3. The data for the case studies were collected from various sources: AOSTRA UTF SAGD**:** The data for the case study on UTF SAGD were collected from AERI, ARC, industries, and R&D consultants; AACI R&D Program**:** The data for the case study on AACI were collected from AERI, ARC, industry, and R&D consultants; Weyburn**:** The data for the case study on Weyburn were collected from PTRC, AERI, ARC, the University of Alberta, and R&D consultants; Carbonates**:** The data for Carbonates were collected from AERI and ARC; and JIVE: The data for the case study on JIVE were collected from PTRC and ARC.

Table 4.2 Trends in the energy sector that triggered the R&D projects

Period	Events
1970	Realization of the presence of heavy oil and bitumen resources in Alberta and the need to extract bitumen from oil sands
1975	Industries conduct their own R&D
1980	Government becomes more involved in the R&D in the oil sands
	Alberta Government start introducing programs to focus on R&D in the energy sector
	New technology required to extract low recoverable bitumen
1984	UTF SAGD project born, initiated by AOSTRA
1985	AOSTRA starts the AACI program
1987	Government / Industry collaboration starts on UTF SAGD
1997	Successful completion of UTF SAGD
	Government / Industry collaboration model starts getting more and more attention from industries
1998	Global focus and realization of the need to reduce GHG emissions
	Government agencies and world leaders start talking more about the necessity to reduce carbon footprints
	More pressure on industries to reduce GHG emissions
2000	Weyburn project born out of the global demand to study the geological storage of CO2 , initiated by PTRC in collaboration with IEA and Encana
	Weyburn becomes an international collaborative project with six government participants, nine industry participants, fifteen research providers and nine government agencies participating from all over the world
	Saskatchewan Government starts getting involved into the energy sector R&D
	AACI program attracts more and more industry participants
2004	First phase of Weyburn successfully completed
	Technology is needed to improve bitumen extraction methods and to reduce the operating cost for bitumen extraction
2005	Second phase of Weyburn starts in oder to improve the technology developed in the first phase
	Demand for technology to recover bitumen from oil sands that are not recoverable through existing technology
	New technology required to extract the oil sands trapped in rocks in the form of carbonates
2006	JIVE project is born (Government / Industry collaboration) initiated by PTRC, to develop SVX technology that could improve the bitumen recovery rates up to 50%
2007	Carbonates project started in order to develop technology that could extract bitumen from Grosmont formation. Carbonates has five industry and two government participants
2008	AACI program has 23 industry participants. A proven Government / Industry collaborative model for innovation in the energy sector

4.5 Summary

Five case studies were selected from R&D projects in the energy sector. This chapter explained their context. The changes that occurred in the energy sector and the changing attitudes that led industries and governments to collaborate on technology development over the last three decade were also discussed.

Chapter 5 Case Studies

5.1 Overview

This thesis includes five case studies, which were conducted to illustrate the process of collaborative technology development. The projects selected for the case studies either used or are using concepts of collaboration. The goal of the case studies is to learn how organizations join together to find R&D solutions to complex problems that one organization cannot resolve on its own. The case studies provide details of the real-life R&D projects executed by various organizations, for the period from 1986 to 2009. The case studies were conducted to gather information on what happened in the R&D projects and how they were executed.

5.2 First Case Study: AOSTRA UTF SAGD

Project background.

Canada's heavy oil and bitumen reserves are extensive, totalling more than 280 billion m^3. In Alberta, the major currently exploitable bitumen reserves are in Athabasca, Peace River, and Cold Lake, which contain about 170 billion m^3 "original-oil-in-place." About 10% of the Athabasca bitumen deposits, or 1.7 billion m^3, are located sufficiently near the surface to allow surface mining of the oil sands and extraction of the bitumen by the modified Clark Hot Water Extraction Process (Komery et al., 1999). The remaining original oil-in-place can be exploited by using new improved in situ thermal technologies like the SAGD process applied with twin horizontal wells. The Athabasca reserves alone have over 140 billion m^3 (900 billion barrels) of bitumen-in-place. Of this reserve, more than 50 billion m^3 (330 billion barrels) are recoverable by using the SAGD in situ process (Komery et al., 1999).

The AOSTRA owned and operated an UTF on the Athabasca oil sands deposit 60 km north northwest of Fort McMurray, Alberta, Canada. The SAGD technology developed at this facility is enabling industry in Alberta to access bitumen that is mostly inaccessible and has low recoverability (less than 20%). Surface mining operations can economically access less than 10% of the Athabasca deposit (906 billion) as the remainder is too deep for surface mining. The inaccessibility of this huge resource led the Alberta Government, through AOSTRA, to develop an in situ process, which has proved to be the key to economically accessing the deeper deposits of this resource. The SAGD technique consists of a pair of horizontal wells at the base of the reservoir, the upper steam-injection well being 5m above the lower production well (O'Rourke et al., 1991). The objective of the AOSTRA UTF SAGD project was to demonstrate the commercial viability of extracting the bitumen by using the in situ twin horizontal well SAGD technology.

The Athabasca oil sands have more than 330 billion barrels of bitumen, which can be recovered by using the SAGD in situ recovery process. By using the SAGD process, Alberta's current oil well production can be doubled, and the new production rate can be maintained for the next 200 years (Komery & Luhning, 1993). During the early 1980s, the gravity drainage of steam-heated heavy oil to horizontal wells was investigated and reported in publications by R.M. Butler, who was then with Imperial Oil Limited. In 1989, N.R. Edmunds, J.A Haston, and G.M. Cordell patented the SAGD process by using parallel horizontal wells at the UTF project on behalf of AOSTRA (Komery et al., 1999). The UTF SAGD project was implemented in 1984 at AOSTRA's 20,000-hectare Athabasca lease located about 60 kilometre (km) north north-west of Fort McMurray.

The objective was to prove the commercial viability of extracting the bitumen by using the in situ twin horizontal well SAGD technology.

In 1997, the UTF Project was renamed the Dover Project. Its operator was the Northstar Petroleum Corporation, which owned 58.33% of the project. Each of the following companies owned 8.33%: Chevron Canada Resources Limited, China National Petroleum Corporation (CNPC) Canada Limited, Imperial Oil Resources (ESSO) Limited, Petro-Canada (recently combined with Suncor Energy), and Gibson Petroleum Company Limited. The major phases of the UTF Project and the participants in each phase are listed in Table 5.1.

Table 5.1 UTF project parameters

Phase	Objectives	Companies
Pre-project Development (1984-1987)	• Road, Site & Facilities • Shafts & Tunnels • Drilling Rig	AOSTRA 100 %
Phase A (1987 - 1990)	• SAGD Concept • Shafts & Tunnels • 3 Horizontal Well (60M) Pairs	AOSTRA 50%, Industry 50%: Chevron, Mobil / Texaco, ESSO, Amoco, Shell, Petro-Canada
Phase B-1 (1990 - 1994)	• Tunnel-Drilled Commercial-Length Wells • 3 Well Pairs (600 M) • Test SAGD Commercial Performance	AOSTRA 25%, Industry 75%: Chevron, Texaco, ESSO, Amoco, Shell, Petro-Canada, Conoco, Japex, CNPC, Mobil
Phase B-2 (1994 - 1997)	• 3 New Surface Drilled Well Pairs • Final Technology Testing • Preparation for Commercial Development	AOSTRA 25%, Industry 75%: Gibson, Imperial, Amoco, Shell, Petro-Canada, Japex, CNPC, Suncor, Chevron
Dover Project (1997 onwards)	• Northstar Energy purchased Govt shares • Northstar became operator of renamed Dover Project • “D” & “E” Surface Wells for Commercial Project	Northstar Energy 58 1/3%, Chevron 8 1/3%, Imperial Oil 8 1/3%, Petro-Canada 8 1/3%, CNPC 8 1/3%, Gibson 8 1/3%

Source: Komery & Cyr, 1998

The UTF Project was started in 1984 with the construction of a road to the site. Industry participants began to join the project after the completion of the access stage (shafts, tunnels, Phase A wells) in late 1986. In December 1987, the Phase A test began with the injection of steam into three pairs of short (60 meter) horizontal wells. This activity was the first field test of the dual well process. The Phase B test began in December 1992 with the injection of steam into three pairs of longer (500 meter) horizontal wells (O'Rourke et al., 1994).

Project cost.

The preliminary engineering and cost estimates indicated that a C$225 million initial capital investment would be required to produce 30,000 BPD of bitumen. Over the 25-year life of the project, the additional tunnelling and replacement of 132 well pairs required an additional C$225 million capital expenditure. The average annual operating cost was about C$40 million (Komery & Chambers, 1993). The breakdown of costs and outputs included Initial Capital: C$225 million; Total Capital for 25 years: C$450 million; Annual Operating: C$40 million (C$3.65 / BBL); Bitumen Supply Cost: C$7.50 / BBL; and Annual Production: 10,000,000 BBLS (Komery & Luhning, 1993). The total gross cost of the UTF Project from its start in 1984 to its completion in 1996 was expected to be C$145 million, with C$50 million coming from industry, C$15 million from product sales, and the reminder from AOSTRA (O'Rourke et al., 1994).

R&D organization.

The potential was huge for the commercialization of the previously economically inaccessible reserves, which contain more than 300 billion barrels of recoverable bitumen. The commercial development of these reserves would contribute significantly to job and wealth creation in Alberta and Canada (Komery & Chambers, 1993). A UTF Task Force consisting of AOSTRA and industry participants managed the project's R&D. The task force, established to use the expertise of all the participants, was formed to define the project's scope and to identify issues / concerns. The task force established a commercial project consortium and selected a commercial project operator. AOSTRA's UTF project was well staffed and organized. It had a particularly strong technical staff. Mainly two committees, the Management Committee and Technical Committee, which had representatives from all participants, managed the R&D. The Management Committee approved capital expenditures and the annual operating budget and negotiated contractual terms between the main parties (AOSTRA and the industry participants). The Technical Committee ran the technical/operational side of the project, providing a forum where AOSTRA staff could inform industry participants about the project's progress and where all parties could discuss the observations and plan the next steps. AOSTRA's engineering and scientific staff also prepared a number of technical reports that were readily available to industry participants. The UTF model of separating the management and technical components of the project, and the dedication of its technical staff, were two of the key reasons for the success of the UTF project, both in terms of project execution and technology transfer (B. King, personal communication, Aug. 23, 2007).

AOSTRA was successful in providing industry with evidence for the following conclusions. First, the UTF SAGD technology was technically viable. The capital and operating costs were significantly lower than those for current commercial plants. The project's economic viability was strong enough to weather slight fluctuations in the world's crude oil prices. The tax and royalty regimes would need to be accommodating to allow the oil sands project to be an attractive investment in both the short and long terms. Some consideration by governments would be required to attract investment for using a new, improved extraction technology such as the UTF's SAGD.

AOSTRA established a project consortium for developing a commercial-sized oil sands project. This consortium would select an industry member or organization to be the "operator" of the consortium and to achieve its goals. This consortium established the most suitable options; determined the costs and economic viability for an adequately sized commercial project; established and secured markets for products; secured financing, tax and royalty benefits; and implemented the construction and operation of the commercial venture. The consortium approach reduced risks, secured know-how from the stake-holders, and provided huge potential for the further development of other leases in areas such as Athabasca, Peace River and Cold Lake (Komery & Chambers, 1993).

Technology.

AOSTRA UTF developed SAGD technology for the extraction of bitumen from oil sands. The technology sharing and collaboration took place among UTF participants. UTF's staffing, committees, and reporting system were the media for technology transfer. The exchange of ideas among participants took place at the Technical Committee meetings (B. King, personal communication, Aug. 23, 2007). The impact of the SAGD development at the UTF lease has been felt both in Canada and globally. A number of projects using SAGD technology have been initiated by industry. The list of the operating plants currently using SAGD technology is given below. These plants are currently in operation and producing 414,000 bpd of bitumen. The capital investments for these projects are C$3.6 billion dollars (*Alberta Oil Sands Industries Quarterly Update*, 2009).

The first commercial use of SAGD occurred at the MacKay River lease. The start-up of this project was in 2002 (B. King, personal communication, Aug. 23, 2007).

Participants.

The government / industry collaborative approach adopted during the UTF project led to the formation of a consortium between the government and industry. The consortium's objective was to build and operate a commercial in situ SAGD project in the Athabasca region in Alberta. The members of the consortium were AOSTRA, industry participants, Syncrude, Alberta Oil Sands Equity, the Alberta Petroleum Marketing Commission and the Alberta Energy Resources Conservation Board.
The energy-efficient, high-recovery, low-maintenance and environmentally attractive SAGD process retained the interest of the industry participants in the UTF project (Komery & Chambers, 1993). In October 1995, Gibson Petroleum Company Limited was contracted by AOSTRA to be the operator of the UTF. This company was responsible for the day-to-day operation of the facility, long-term planning, and the marketing of bitumen, and chaired both the Management and Technical committees through which the participants oversaw the project (O'Rourke et al., 1997). Gibson became one-twelfth owner of the consortium in 1995, joining eight other industry participants. The Alberta Government retained a 25% share in the project (O'Rourke et al., 1994). As noted in Table 5.1, in 1997, the UTF Project was renamed the Dover Project. Its operator was the Northstar Petroleum Corporation, which owned 58.33% of the project

In addition to some existing Alberta Oil Sands lease holders, CNPC, JACOS and other multinational companies from Taiwan and Korea expressed interest in joining the UTF project because Canada is a politically stable democratic country, and Alberta's natural resources are well administrated for investment. Foreign interest sometimes can be translated into a secure supply of crude oil via the exchange of production shares with international oil companies. However, participants in the UTF Project had to be Canadian-registered corporations (Komery & Chambers, 1993).

Cost to participate.

The overall cost of the field pilot test and preparation for the commercial project was about C$145 million over a span of ten years. The funding was made up of contributions from AOSTRA, the nine industry participants, and revenue from bitumen product sales during the field pilot test. Each participant spent less than C$7 million to earn a world-wide license for the free-use rights to SAGD technology and 8.33% of AOSTRA's UTF lease as well as a license for the free-use rights to ESAGD, the technology from the AOSTRA-Shell Peace River twin horizontal well project. AOSTRA recovered its financial contribution to the project by receiving a percentage of the net revenue from product sales of the commercial project at the UTF Project lease. Also, AOSTRA's investment resulted in significant returns to the Province of Alberta in the form of royalties and taxes from future commercial oil sands operations. The industry contributions and oil production revenues fully financed the project over a 3-year period. The cost per phase in $C millions was as follows: Phase A: 2.10; Phase B-1: 3.52 (April 1, 1993: 2.75; March 31, 1994: 0.77); and Phase B-2: 1.17, amounting to a total of 6.79 (Komery & Chambers, 1993).

Benefits to participants.

The nine industry participants understood the huge potential for economic oil production by using the AOSTRA SAGD process in their oil sands leases in the

Athabasca region. These nine major oil companies retained enough leases (48%) in Athabasca to potentially produce a combined volume of some 150 billion barrels of bitumen by using the AOSTRA UTF SAGD process. The benefits to participants were as follows:

1. Worldwide license for free use of SAGD Technology
2. Worldwide license fee free use of Shell ESAGD Technology (Surface Drilled ESAGD Horizontal Well Technology)
3. Ownership of 8.33% of AOSTRA UTF lease
4. Commercial project consortium participation
5. Eligibility to become participant in the Commercial UTF Project
6. Eligibility to become commercial project operator
7. Training of company personnel on SAGD Technology

A non-participant can gain access and use rights to UTF technology in one of two ways. The first is to become a participant by purchasing a share (minimum 8 1/3 percent) of the UTF project from AOSTRA. Doing so entitles the participant to an 8 1/3 percent interest in the AOSTRA lease and the right to utilize the technology on the participant's own leases. This 8 1/3 percent share does not include the manpower costs of participants, and the benefits received through training. The other way is to purchase only the use rights for the technology from AOSTRA without purchasing a share in the AOSRA lease (O'Rourke et al., 1991).

Benefits to industry.

The UTF project increased the value of companies' oil sands leases and provided technology for companies to economically exploit their reserves (Komery & Cyr, 1998).

As the UTF Phase B project advanced, confidence in the SAGD technology grew, for the companies showed that they could use it to develop their oil sands leases. Also, by participating in the UTF project, some of the participants' staff became knowledgeable about SAGD technology and established good relationships with SAGD experts. This process facilitated the application of SAGD technology and influenced the decision to build commercial plants using the SAGD technology (B. King, personal communication, Aug. 23, 2007). The benefits are especially attractive to international oil companies, which can apply the SAGD technology in foreign countries (Komery & Chambers, 1993).

Benefits to government.

This new technology opened up 300 billion barrels of bitumen deposits that were not economically exploitable prior to the development of the UTF SAGD technology. The commercial development of this resource increased royalties to the province and provided more jobs and wealth to Albertans (Komery & Cyr, 1998).

Benefits to public.

The main benefits to the Province of Alberta are the increase in the size of the recoverable oil and gas reserves, the creation of wealth through increased employment, and increased royalty revenues from new oil and gas production (D. Komery, personal communication, May 3, 2007).

Field pilot test.

A field pilot test was part of the UTF SAGD R&D. The technology was tested in the field during all the phases of R&D, from the start of Phase 1 in 1984, until the completion in 1996. All the R&D results were field-tested, and the test results were made part of the program.

Intellectual property management.

The Department of Energy in the Province of Alberta has a valuable, major asset in the form of ownership of intellectual property in the areas of oil sands and heavy oil. This department also has use rights and / or marketing rights for technology when the department collaborates with industry in developing new technology. With the current model, the Department of Energy owns the technology that it participated in funding, markets the intellectual property, and licenses the technology. This department also maintains a technical information / data bank for use by the oil and gas industry, and administers patenting activities for the department's own projects. Ownership of this intellectual property provides the Alberta Government leverage in setting its energy policy and also a repository of data under one organization. This new technology is readily available to industry lease holders at a fair market price.

As well, the Department of Energy, as an owner of patents, has to ensure that those using a particular patented technology acquire a license to use it commercially. The approach is to convince potential licensees that they will benefit from acquiring a licence since they will receive the latest information and technology and, hence, will increase their chances of success. Thus, licenses benefit both the licensees and the licensor (Komery & Cyr, 1998). The Alberta Government and industry participants have invested jointly in oil sands research and pilot test projects during the UTF Project. Thus, the government, in cooperation with the industries, has jointly developed a technology bank and know-how. This process has helped the Alberta Government to develop new and better technologies that will enhance the economic development of Alberta's oil sands sector (Komery & Cyr, 1998).

Licensing provides commercial use rights to a technology that someone else paid to develop. The initial documents that a potential licensee wishes to see are copies of the patents in order to determine how the technology actually applies to the licensee's lease development. The transfer of know-how is also a major component if licensing; however, without the basic protection of a patent, new technology probably would not be developed. Licensing and marketing may be a shared responsibility. This possibility allows the Department of Energy to license the technology to Alberta lease holders at a fair market value and could allow the licensed company to provide the technical expertise for potential sub-licenses. License fees may be in the form of an "up-front" payment and/or a percentage of the net revenue from the project that utilizes the patented technology. The net revenue from licensee fees is usually divided among the developers (industry and government) according to the proportion of their respective investments (Komery & Cyr, 1998).

When the UTF project ended in 1997, industry took over, and the project was renamed Dover, the original industry participants each earned a working interest in the Dover property and a licence to use the SAGD technology. This license provides access to all UTF data and reports and the right to use the SAGD patents owned by AOSTRA. These use rights are fee-and royalty-free and world-wide. ARC manages the SAGD technology licenses (B. King, personal communication, Aug. 23, 2007).

By a special agreement between AOSTRA and the UTF Participants, the technology developed at the Shell AOSTRA Peace River twin-horizontal-well from surface projects is also made available to the UTF Project participants on a license fee free-use basis. These participants can use the technology from the AOSTRA-Shell Peace River (ESAGD) twin horizontal well project, have license-free use of Peace River surface SAGD technology, and obtain UTF task force reviews of the surface SAGD in Athabasca (Komery & Chambers, 1993).

Accomplishments.

The SAGD technology was successfully developed over a relatively very short period and at low cost when considered in the light of the potential recovery of an immense natural resource for a long period of time. The following are some of the UTF Project's accomplishments: Developed specialized rig; confirmed shaft and tunnel access concept; drilled 3 horizontal well pairs; higher than anticipated recovery and production rates, 2.3 SOR, >60% recovery; and total bitumen produced: 130,000 barrels, or 43,000 barrels per well pair (Komery & Chambers, 1993). The breakthrough SAGD technology is having a major impact on development of the Athabasca oil sands. This project is a prime example of how cooperation between Alberta Government and industry participants resulted in successfully developing a new technology. Moreover, this development took less than a decade and required only about C$130 million of net expenditures (Komery & Cyr, 1998).

Case conclusion.

In the mid-1970s, the industries who owned oil sands leases began operating experimental in-situ pilot test projects near Fort McMurray. Initially, only the surface mining of oil sands was practical, for 95% of the resources were too deep to mine. Cyclic steaming and steam flooding were well established technologies for conventional heavy oil recovery, and industries were trying to apply this technology to the oil sands, but with poor results. In 1979, Roger Butler et al. (D. Komery, personal communication, May 3, 2007) invented SAGD. During this same period, the Alberta Government, through AOSTRA, was looking for ways to stimulate the development of in situ oil sands recovery technology. By the mid-1980s, AOSTRA was ready to invite industry to participate in the UTF project. The industries' decision to join the project was based on the following considerations.

1. Increased shareholder value: if the new technology were successful, the bitumen resources could be 'promoted' to commercial reserves.
2. Risk reduction: participating in a project with other companies and the government significantly would reduce the financial risk of testing new technology (i.e., each company would have full access to the data and use rights by participating with only an 8.33% share). Risk would be further reduced by using a staged approach (Phase A-technology demonstration, followed by Phase B-commercial scale).
3. Skill and knowledge increase: the opportunity for staff to participate in the technical committee would provide an excellent way to transfer knowledge to the staff’s companies.
4. The participants would gain the use rights to the technology.

(B. King, personal communication, Aug. 23, 2007)

5.3 Second Case Study: AERI/ARC Core Industry Research Program

Project background.

AACI is a consortium research program managed by ARC. The consortium currently has twenty-one industry participants. Industry contributions fund about one-third of AACI's C$3 million annual operating budget. AERI and ARC each fund one-third of the remaining budget. The AACI program has been ongoing for 23 years (R. Sawatzky, personal communication, Nov. 17, 2008).

Project cost.

The annual fee for participating companies is C$105,000. The AACI program is a consortium composed of AERI (1/3 funding share), ARC (1/3 funding share) and 13 paying industry members (1/3 funding share). As well, another member provides in-kind contributions. The budget for AACI has remained static for 23 years at the C$3 million per year level (M. Godin, personal communication, Sept. 4, 2008).

R&D organization.

AACI has two committees, the Management Committee and Technical Committee, which are composed of industry members, AERI, and ARC. The Technical Committee monitors the technical progress of the program. R&D in novel areas offers significant value in the long term, particularly for recovering the remaining bitumen reserves. ARC conducts the project's laboratory and simulation work, creates ideas, develops new inventions, and presents the research to the Management Committee. The Policy and Program (P&P) Committee is responsible for long-range planning. This committee consists of senior executives of the industrial member companies and senior officers of AERI and ARC (Heidrick et al., 2006).

Technology.

In order to improve production methods in the oil and gas sector, the AACI program develops technology for the recovery of in-situ bitumen and heavy oil. The focus is on recovery methods with financial and environmental benefits. AACI is a consortium whose R&D focuses on heavy oil, improvements to SAGD, and THAI technology.

One of the key drivers for the development of AACI technologies is the desire to reduce the cost of bitumen and heavy oil recovery. Technologies developed by AACI, such as ES-SAGD, considerably reduce the amount of steam required to produce in-situ bitumen. Lower steam consumption is directly translated into reduced energy consumption and reduction in the associated emissions of greenhouse gases. Solvent processes and hybrids of thermal and solvent processes reduce greenhouse gas emission to varying degrees. Technology improvements in the area of cold production have also resulted in more efficient production with associated reductions in energy consumption and emissions of greenhouse gas. The lower steam-to-oil ratio exhibited by ES-SAGD and other hybrid approaches results in lower requirements for fresh water. Preserving water resources is a critical environmental objective, and AACI technologies play a role in achieving it. Less water usage is also directly translated into fewer water-disposal issues.

AACI provides a platform for the collaborative development of technology and a venue for technology transfer, which occurs mainly through published reports, technical conferences, discussion groups, workshops, and networking. Industry members are generally able to immediately apply the technology obtained from AACI to their operations. Technology transfer that occurs by accessibility to experts, conferences, meetings and reports is an important strength of AACI. Organizations that are not members of AACI also benefit from the AACI program. Collaboration programs are in place with universities. Non-member companies conduct significant private R&D projects with ARC, utilizing some of the same researchers that are part of the AACI program. The expertise and knowledge of ARC's research group enables private R&D projects to occur at ARC outside of the AACI program. This program also provides opportunities for ARC staff to be seconded to the field and allows staff from the member companies to participate directly in the projects as visiting engineers in the ARC laboratories (Heidrick et al., 2006).

Project participants.

In AACI, ARC is the program manager, research provider, and funder. AACI does not have multiple research providers, because of the potential for conflict of interest. The Carbonates project has multiple research providers, but in AACI, ARC is the only research provider (R. Sawatzky, personal communication, Nov. 17, 2008). In 2009, the AACI Members were Alberta Energy Research Institute, Alberta Research Council, BP Petroleum, Canadian Natural Resources Ltd, Chevron Corp, Computer Modelling Group, ConocoPhillips, Devon Canada, EnerMark, ENI, Husky Oil Operations, Imperial Oil Resources Ltd, Japan Canada Oil Sands, Marathon Oil Canada, Nexen Canada Ltd, Oilsands Quest Inc, Petro-Canada, Repsol, Schlumberger, Shell International, Statoil, Suncor Energy Inc, and Total (ARC website, June 22, 2009).

Cost to participate.

The annual fee for participating companies is C$105,000. The budget for the program is C$3 million per year. The Government's AERI and ARC provide two-thirds of the funding for the program, and the industry participants provide one-third (M. Godin, personal communication, Sept. 4, 2008).

Benefits to participants.

The participants are entitled to play a major role in developing the R&D program focused on the technology required for field applications, have direct access to the research results needed to maintain the industry's technological edge and protection of intellectual property to maximize commercialization opportunities, participate directly in defining intellectual property development, have license-fee free use of AACI technology, and have access to the results from field demonstration testing (Heidrick et al., 2006).

The knowledge received from AACI is also a critical enabling factor in the R&D and business development programs of industry members. Information from AACI is based on laboratory experiments and theoretical considerations, and complements and strengthens the field data and the experience of member companies. The AACI program provides a platform and a forum for industry to conduct collaborative R&D on common challenges. AACI conferences offer a window on industry trends and direction. AACI events facilitate the exchange of ideas among participants. Enhanced communication among companies faced with similar challenges provides opportunities to pool ideas and to benefit from economies of scale through collaborative R&D and joint industry projects. Through the collaboration of the participants in AACI, the complex process of technology development can be overcome, and also the lead time can be reduced. (Heidrick et al., 2006).

Benefits to industries.

The AACI program has a number of positive environmental impacts. The technologies developed by AACI have the potential to reduce emissions of greenhouse gases, lower requirements for water consumption, and decrease water-disposal issues. In addition, AACI's experts are leading the development of methods for the sequestration of CO2 in geological formations. AACI is recognized by industry as a critical source of technology and expertise that contributes to improved decision-making with respect to resource development. AACI has a pool of expertise in various oil and gas production sectors. This resource pool is easily accessible to the industries. AACI is a platform to jointly address current issues. AACI provides industries with opportunities for employee development and training. Industries gain new technology and understanding about processes and technologies from their interaction with AACI scientists (Heidrick et al., 2006).

Benefits to government.

Increased royalties and tax revenues are the benefits to the government (R. Sawatzky, personal communication, Nov. 17, 2008). The AACI program provides a core and long-term research program that allows ARC to maintain a nucleus of recognized experts and scientists. ARC is able to use this centre of expertise to acquire new private research contracts. The AACI program is responsible for C$2 to 3 million dollars of additional R&D contracts directly related to AACI's field of expertise (Heidrick et al., 2006).

Benefits to public.

The public benefits from the royalties, economic activities, improved technology, and employment opportunities provided by the project (R. Sawatzky, personal communication, Nov. 17, 2008).

Field pilot test.

AACI makes the decision to field test technology on a case-by-case basis (R. Sawatzky, personal communication, Nov. 17, 2008). An enhanced knowledge of field conditions allows researchers to recognize field challenges earlier than is currently possible and improves the probability of success for commercial implementation. More experience in field and commercial operations assists AACI in bridging the gap between the laboratory and field implementation. The commercial development of the SAGD technology would not have happened in a timely manner if the SAGD technology had not been demonstrated in the field. The timely field pilot test of such a technology may require a strategic investment in a demonstration facility similar to that of UTF. Pilot test data are very expensive, and companies are not willing to share the data obtained from pilot tests. The involvement of AACI in AERI-funded field trials is of great benefit (Heidrick et al., 2006).

Intellectual property management.

The current complexities of confidentiality agreements and IP ownership have made collaborative R&D more difficult than it was previously. The Government of Alberta through Alberta Advanced Education and Technology (AAET) owns the IP. ARC reports to AAET and manages the IP. Non-participants can access the technology through licensing agreements, which ARC negotiates. Technology is available to the public through licensing. The AACI program may release information to the public two or three years after an R&D project has been completed (R. Sawatzky, personal communication, Nov. 17, 2008).

Accomplishments.

The AACI program conducts R&D for the in situ recovery of bitumen and heavy oil and has contributed to the increase in bitumen production and the amount of the recoverable heavy oil reserves. The data from the Alberta Energy and Utilities Board (AEUB) and from Alberta Economic Development (AED) indicated that 74,000 bpd of increased production, worth C$410 million, could be attributed to technology improvements initiated by AACI with respect to bitumen (Heidrick et al., 2006).

As well, industry feedback indicated that additions to the reserves of heavy oil were the direct result of improved recovery technologies initiated by AACI. Average additions to the heavy oil reserves of 108 million barrels have been recognized each year since 1995, according to AEUB data. The monetary value of these additions is estimated to be C$2,489 million per year (Heidrick et al., 2006).

Bitumen's and heavy oil's monetary impact of C$2,899 million per year can be associated with the increased production and the addition to the reserves that resulted from the improved recovery technologies initiated by AACI (Heidrick et al., 2006). R&D programs such as those at AACI are part of a value chain that increases revenues and benefits the entire economy. The R&D component of the value of AACI is contributions estimated at C$35 million per year, by using publicly reported valuation parameters. The value of the AACI program amounts to a 12:1 multiple over the operating costs (Heidrick et al., 2006).

Case conclusion.

The AACI program returns significant value and is targeted at recovering one of Alberta's most important resources. Increasing the extent of bitumen recovery has substantial benefits for Alberta. Fundamental research into novel approaches to recovering bitumen is warranted and benefits both industry and the province. Industry leadership of AACI is key to its development of innovative new technologies (Heidrick et al., 2006).

5.4 Third Case Study: Weyburn CO_2 Monitoring and Storage

Project background.

In July 2000, a major research project to study the geological storage of CO2 was launched by the PTRC in Regina, Saskatchewan, in close collaboration with EnCana Resources of Calgary, Alberta. This project became known as the IEA GHG Weyburn CO2 Monitoring and Storage Project. The project's mission was to assess the technical and economic feasibility of CO2 storage in geological formations, with a focus on oil reservoirs. The success of this project has contributed significantly to the understanding of greenhouse gas management and also enhanced oil recovery. This project's overall objective was to predict and verify the ability of an oil reservoir to securely store and economically contain CO2. The method used involved a comprehensive analysis of the various process factors as well as monitoring / modelling methods intended to address the migration and fate of CO2 in a specific EOR environment. The Weyburn CO_2 monitoring and storage project was a field demonstration of carbon storage in the subsurface. The Weyburn unit was a 180 square kilometre oil field located in the southeast corner of the province of Saskatchewan in western Canada.

The Weyburn CO_2 Monitoring and Storage Project has two phases: Phase 1 and the Final Phase. The duration of Phase 1 was from 2000 to 2004, and Encana was the primary operator for Phase 1. The primary operators for the Final Phase are Encana and Apache Canada. The Final Phase is focused on technical deficiencies, and the duration is from 2005 to 2011 (Wilson & Monea, 2004). Only Phase 1 is discussed in this thesis.

Project cost.

Project cash costs totalling C$16.38 million were allocated among the project's four themes over the four-year project's life. In-kind contributions amounted to C$23 million , mostly in field support and European-Community-funded work. This work was conducted in collaboration with the North American work, but was separately funded: Theme 1: C$3.04 million; Theme 2: C$9.11 million; Theme 3: C$2.27 million; and Theme 4: C$1.95 million. Fifteen sponsors, from both government and industry, funded the project, and cash and in-kind contributions financed it (Wilson & Monea, 2004).

R&D organization.

The project was organized into eight Principal Tasks, each led by a Principal Task Leader. Each task was subdivided into a number of subtasks. Each subtask was considered as an individual project. A subtask was executed by one or more research providers. Altogether, the project had fifty subtasks. The Subtask Leaders funnelled their work through the Principal Task Leaders, who were coordinated by the Project Director. The Project Director was responsible to a Management Committee (MC) made up of representatives from the participants. The Project Director's principal role was to ensure that the development and implementation of yearly technical plans focused on meeting the project objectives. At completion, the project produced 472 deliverables, which were discussed in fifty final reports, one for each subtask. Each report summarized the outcomes of the research undertaken.

The R&D of the first phase was organized into four main themes chosen to group all subtasks in a manner corresponding to the project's main objectives. This phase's summary was organized into these same themes: Theme 1: Geological Characterization of the Geosphere and Biosphere; Theme 2: Prediction, Monitoring and Verification of CO_2 Movements; Theme 3: CO_2 Storage Capacity and Distribution Predictions and the Application of Economic Limits; Theme 4: Long-Term Risk Assessments of the Storage Site (Wilson & Monea, 2004).

Technology.

The Weyburn project's scope of work was focused on understanding the mechanisms of CO_2 distribution and containment within a reservoir into which CO_2 has been injected, and the degree to which CO_2 can be permanently sequestered. The technology developed through this R&D project can be applied in screening and selecting other CO_2 storage sites, in developing effective monitoring programs, and in designing and implementing successful CO_2 storage projects worldwide. Another objective of this project was the application of the economic realities of CO_2 capture and storage by predicting the point at which a CO_2 storage project will reach its economic limit. The application of customized economic models to the various storage cases helped in making this prediction. The main deliverable from this project was a credible assessment of the permanent containment of injected CO_2 as determined by formal risk analysis techniques, including long-term predictive reservoir simulations.

Project participants.

Encana was the primary operator and the main industry participant in Phase 1 of the Weyburn project. The project had fifteen participants from government and industry and also had twenty-four research providers and consulting organizations and about seventy technical and project personnel (R. Chalaturnyk, personal communication, Aug. 29, 2008). The Weyburn project participants were the following:

Government participants.

Alberta Energy Research Institute, European Community, Natural Resources Canada, Petroleum Technology Research Centre, Saskatchewan Industry and Resources, and United States Department of Energy.

Industry participants. British Petroleum (BP), Chevron Texaco, Dakota Gasification Co., Engineering Advancement Association of Japan, EnCana Corporation, Nexen Inc, SaskPower, Total, and TransAlta Utilities.

Canadian research providers. Alberta Research Council (ARC), Canadian Energy Research Institute (CERI), ECOMatters (ECOM), EnCana Corporation (ECC), GEDCO Inc. (GEDCO), Geological Survey of Canada (GSC), Hampson Russell (HR), J.D Mollard and Associates Ltd. (JDMA), Rakhit Petroleum Consulting Ltd. (RPCL), Saskatchewan Industry and Resources (SIR), Saskatchewan Research Council (SRC), University of Alberta (UofA), University of Calgary (UofC), University of Regina (UofR), and University of Saskatchewan (UofS).

European research providers. British Geological Survey, Britain; Bureau de Recherches Geologiques et Minieres, France; Geological Survey of Denmark and Greenland; and Istituto Nazionale di Geofisica e Vulcanologia; Quintessa Ltd.

USA research providers. Colorado School of Mines, Goldon, CO; Lawrence Berkeley National Laboratories, Berkeley, CA; Monitor Scientific Corporation International, Denver, CO; and North Dakota Geological Survey (Wilson & Monea, 2004).

Cost to participate.

The project was funded by fifteen sponsors in government and industry. This project was financed by cash and in-kind contributions. The project cash costs totalling C$16.38 million were allocated among each of the four project themes over the four-year project life. In-kind contributions amounted to another C$23 million, mostly in field support and European-Community-funded work (Wilson & Monea, 2004).

Benefits to participants.

The main benefits to the participants were leverage on R&D investment, technology sharing and networking, the opportunity to collaborate with other industries, involvement in the technology development, and expertise in carbon capture and storage technology.

Benefits to industries.

Industries are able to use the technology to contain CO2 from oil reservoirs and to apply the economic model developed through the Weyburn program.

Benefits to government.

The government gained the initiative to develop technology to reduce greenhouse gas emission, the opportunity to become a leader in developing technology to reduce greenhouse gas emission, and the opportunity to collaborate with other government organizations.

Benefits to public.

The public benefitted from the development of a technology that helps to reduce greenhouse gas emission.

Field pilot test.

Field tests were conducted at EnCana's Weyburn field and Apache's Midale field, located in southeast Saskatchewan, Canada. The project operated in conjunction with two billion-dollar commercial CO2 floods in Saskatchewan, Canada, where huge volumes of the gas are captured from an industrial source and injected to revive oil production (PTRC website, Apr. 29, 2009).

Intellectual property management.

The Weyburn project, a government / industry consortium, used two types of agreements to manage IP. The project was governed by an umbrella agreement among the major partners, and a separate subsequent research provider IP agreement is managed by PTRC. As well, an Industrial Research Provider Agreement is used to manage IP. Weyburn IP is open only to participants and will not be licensed. The project released its datasets for research work, but not until after an agreement had been completed for a specified number of years. Weyburn had no plan to sell its IP through licensing (R. Chalaturnyk, personal communication, Aug. 29, 2008).

Accomplishments.

Based on preliminary results, a natural geological setting appears to be highly suitable for long-term CO2 geological storage. The First Phase's result is the most complete, comprehensive, peer-reviewed dataset in the world for CO2 geological storage (PTRC website, Apr. 29, 2009).

Case conclusion.

Weyburn was considered to be a world-class project in terms of its organization and accomplishments. A significant range of core competencies was developed over the four-year life of the project. A great deal was learned about the concept of the geological storage of CO2. These results are significant for the development of a Design and Operating manual aimed at site assessment, project design, and field implementation of commercial CO2 geological storage projects (Wilson & Monea, 2004).

5.5 Fourth Case Study: Carbonates R&D Program

Project background.

The exploration of highly viscous heavy oil was the motivation for the Carbonates R&D project. Approximately 50% of the Alberta oil sands by area are in the form of carbonates, where the oil sands are trapped in rocks (Alvarez et al., 2008). The Carbonates program will develop technology to extract bitumen from oil sands that are trapped in rocks. The Alberta Energy Research Institute (AERI) put together the proposal and invited participants from the oil industry. The program operated for a three-year period. Carbonates could be considered as an evergreen program (Alvarez et al., 2008).

Project cost.

The cost of Carbonates was C$2.45 million per year, and each participant provided C$350,000 per year (J. Alvarez, personal communication, Oct. 29, 2008).

R&D organization.

Carbonates' R&D was managed through a steering committee. Each participant was a member. Its members voted on all decisions for the program and provided strategic input and direction to the program. The Alberta Research Council was the Program

Manager for Carbonates. Carbonates' R&D was structured by research projects. The research work was carried out according to the recommendation of ARC or the steering committee. Based on the recommendations of the steering committee, invitations were issued to research providers (J. Alvarez, personal communication, Oct. 29, 2008).

Technology.

Carbonates' R&D program developed technology to extract bitumen from oil sands that are trapped in rocks, in the form of carbonates. The carbonate formation forms a "triangle" in geographic terms across the Canadian heavy oil deposits. The carbonates require different technologies for extraction than those used for traditional heavy oil. Carbonates' R&D program developed such technologies, which are now available to non-participants through licensing agreements (Alvarez et al., 2008).

Project participants.

The Carbonates program had seven participants, including two from the Provincial Government of Alberta – the Alberta Energy Research Institute (AERI) and the Alberta Research Council (ARC). ARC, the leader and champion of the program, managed its day-to-day operations. ARC chaired the program and also was the program manager, funder, and research provider. Carbonates was a joint effort by all the participants. ARC worked with industry to come up with an R&D approach to the program. The five participants from the industry were all heavy oil producers. All seven members were involved from the beginning of the program. The research providers were not part of the program, and their participation was by invitation only. Research providers could be from within Canada or outside Canada. Carbonates had multiple research providers. Each participant was a member of the steering committee, provided directions for and strategic input into the program, provided research and funding, reviewed proposals, and prepared progress and feedback reports (R. Sawatzky, personal communication, Oct. 29, 2008).

Cost to participate.

The project expenses were divided equally among all the participants. Each participant contributed one-seventh of the project's total cost. The cost of Carbonates was C$2.45 million per year, so each participant provided C$350,000 per year. A new participant joining the project had to pay the full fee, or the amount that each participant had paid since the beginning of the program (Alvarez et al., 2008).

Benefits to participants.

For the participants, the benefits of Carbonates' R&D program were the abilities to leverage R&D, explore the oil sands, develop new technology, share the cost of technology development, share technology, gain opportunities to network, and obtain free rights to use the technology (R. Sawatzky, personal communication, Oct. 29, 2008).

Benefits to government.

The research provided advanced research opportunities to accelerate the production of bitumen from oil sands. The number of activities in the oil sands was increased. The Carbonates program enhanced the development of technology that enables the production of bitumen from oil sands. This research program also increased government royalties by increasing commercial operations. The Carbonates R&D project provided an opportunity for AERI and ARC to participate in developing and evaluating a new technology. Carbonates improved ARC`s mission and enhanced AERI's and ARC's expertise in carbonates technology (R. Sawatzky, personal communication, Oct. 29, 2008).

Field pilot test.

The Carbonates program had no field pilot test, but new technology could be tested in the field if the participants decided to do so. They could develop their own pilot tests outside the program (J. Alvarez, personal communication, Oct. 29, 2008).

Intellectual property management.

The Government of Alberta through Alberta Advanced Education and Technology (AAET) owns the intellectual property of Carbonates. ARC manages the intellectual property of Carbonates and reports to AAET. Carbonates' intellectual property consists of data from previous carbonates tests conducted in 1990, reports from the Carbonates program, and results of previous studies on Carbonates conducted by ARC. This IP is available to all the participants. Carbonates licenses technology to non-participants under licensing agreements which ARC negotiates. Technology is made available to the public through licensing. All the participants and research providers had their own background IP. All the participants were willing to share their knowledge of carbonates. Access to the background IP from the external research providers was negotiated on a case-by-case basis (R. Sawatzky, personal communication, Nov. 17, 2008).

Case conclusion.

The Carbonates program successfully completed its third year of R&D. The participants from both industry and Government were collaboratively engaged in developing the technology. All the participants were experienced in the technology and shared their experience with the other participants in the program. These factors led its success.

5.6 Fifth Case Study: Joint Implementation of Vapour Extraction

Project background.

The objective of the Joint Implementation of Vapour Extraction (JIVE) Project was to develop, demonstrate, and evaluate solvent vapour extraction (SVX) processes for enhanced oil recovery from heavy oil reservoirs in western Canada. This R&D project was started in 2006 and finished in 2009 (PTRC website, Apr 29, 2009). In 2005, only 5 to 15% of the heavy oil reserves were recovered in western Canada, and the forecasts for heavy oil production showed a reduction of 50% over the next decade unless new technologies were applied. The SVX technologies developed through JIVE can potentially increase recovery rates by 30 to 50%. In western Canada alone, such an increase translates into five to ten billion barrels of oil that otherwise would not be recovered (Kristoff et al., 2008).

Project cost.

The JIVE project was a C$40 million initiative including cash and in-kind funding (PTRC website, Apr. 29, 2009).

R&D organization.

The Petroleum Technology Research Centre (PTRC) was the manager and leader of the JIVE program. R&D was managed through a consortium. ARC and SRC were the research providers, and Sustainable Development Technology Canada (SDTC) and the Provincial Government of Saskatchewan were the two outside funders (Kristoff et al., 2008).

Technology.

The JIVE R&D program developed SVX technologies that can increase recovery rates of bitumen from heavy oil reservoirs. JIVE research consisted of laboratory studies, physical modeling, and numerical simulations. The program also had three vapour extraction field pilot test operations near Lloydminster, Saskatchewan, Canada (PTRC website, Apr. 29, 2009). As no water and heat are used in the SVX process, greenhouse gas emissions are significantly reduced during oil recovery. Compared to current steam extraction methods, SVX technology can prevent approximately 85 million tonnes of carbon dioxide from entering the atmosphere. In addition, 400 million barrels of fresh water can be saved, and 1.65 trillion cubic feet of natural gas will not be burned (per billion barrels of oil produced). JIVE also has the potential to safely store enormous quantities of CO2 in reservoirs, as the solvent is recovered, and the casing gas is not vented (PTRC website, Apr. 29, 2009). The vapour extraction process involves injecting a gaseous hydrocarbon solvent (i.e., propane, butane, methane, CO2) into a reservoir where the solvent dissolves into sludge-like oil, which becomes less viscous (or more fluid) and then drains into a lower horizontal well and is extracted (PTRC website, Apr. 29, 2009). The technology developed through the JIVE program is available to non-participants in the technology development.

Project participants.

The JIVE program had the following participants. The government participants were the Petroleum Technology Research Centre (PTRC). PTRC was the program's R&D Manager and also the owner of JIVE's intellectual property. PTRC also provided funds to the program, but was not a research provider. Industry participants included

Husky Energy, Canadian Natural Resources Limited, and Nexen Inc. The industrial participants also provided funds to the program. The research providers were Alberta Research Council and Saskatchewan Research Council. The outside funders were Sustainable Development Technology Canada (SDTC) (the Federal Government) and the Saskatchewan Government. The funders only provided funds and were not part of the program (R. Sawatzky, personal communication, Nov. 17, 2008).

Cost to participate.

The estimated cost for this project was C$40 million (cash and in-kind). SDTC contributed C$3.2 million, and PTRC contributed C$1.8 million. The three industrial participants (Husky, CNRL and Nexen) contributed C$1.8 million, C$600,000 each (Kristoff et al., 2008).

Benefits to participants.

The participants received highly leveraged funding for the development of technology and a high leverage for their R&D investments. This project provided an excellent opportunity for participants to engage in the development of a new technology. The participants could access the new technology by investing only 5% of the project's total cost (R. Sawatzky, personal communication, Nov. 17, 2008).

Benefits to government.

The Government of Saskatchewan benefited from the exploration of its heavy oil reserves and the development of a new technology. The Federal Government of Canada benefited from the development of a new technology, SVX, which is less energy-intensive than existing technologies and offers low greenhouse gas emission during extraction (Kristoff et al., 2008). The JIVE project, a field-scale experiment, provided an opportunity for ARC and SRC to be involved in a project that obtained laboratory findings in the field. ARC and SRC had the opportunity to be involved in the field pilot test projects (R. Sawatzky, personal communication, Nov. 17, 2008).

Field pilot test.

In the JIVE program, the industrial participants conducted field pilot tests separately and shared their knowledge. The three industrial participants (Husky, CNRL and Nexen) conducted separate field tests in Lloydminster, Saskatchewan, Canada. The pilot test data were shared among all the participants in the program and the research providers. The pilot test projects were estimated to cost from C$10 -20 million (Kristoff et al., 2008).

Intellectual property management.

PTRC is the owner and manager of JIVE's intellectual property, which is available to outsiders. In 2009, the plan was to manage the distribution of IP through licensing. In the JIVE program, unlike the UTF program, field-demonstrated pilot plant information is not part of the IP, which includes information from only R&D and the JIVE program. Pilot test data were shared only among the participants and are not available to outsiders or included in the licensing agreement. In the UTF program, pilot test data is part of the IP and can be accessed through a license. No active process is currently in place to manage JIVE's background IP, but the program is keeping a record of it (R. Sawatzky, personal communication, Nov 17, 2008).

Case conclusion.

The JIVE program concluded in 2009. This program accomplished its objectives because of the collaborative engagement of government and industries.

5.7 Summary

Five case studies were conducted and their data were collected. The details of the data collected were explained in this chapter. The data were collected for the pre-determined datasets, which were explained in Chapter 3. Energy agencies are adopting the collaborative research method and collaborating with industry, federal and provincial governments, universities and other research agencies. The data collected from the R&D projects will be analyzed to formulate the specifics of collaborative R&D. The details of this analysis are provided in the next chapter. The case studies conducted are the basis for the model developed in this thesis. A collaborative research approach towards R&D with government and industry participation is evident in the case studies.

Chapter 6 Intellectual Property Management

6.1 Overview

Managing intellectual property is an important part of collaboration. Technology sharing and transfer between participating organizations and other external sources occur during collaboration. Thus, the proper management of the IP related to the developed technology is vital in collaborative research. Five case studies were conducted on IP management. The IP portfolio, IP protection, licensing, pilot test data, background IP, IP for academic purposes and IP related to the improvements made to the technology are the topics included in the case studies.

6.2 Introduction to IP Management

Having a proper IP policy is important in collaborative research to avoid uncertainties over the boundaries and uses of technology assets. The participants in collaborative research share a common technology, and, thus, rules must be established to control its use. IP policies protect the technology and provide rights to use it. Dissemination of technology is possible through IP management. IP policies also establish standards for technology sharing and transfer. IP policies are established to manage the bundles of technology created through the innovation process. An IP portfolio consists of bundles of technology generated through innovations that are novel, useful, used in a tangible form, and can be managed according to the law (LES, 2003). The purpose of IP management is to develop policies to protect the technology created under IP laws and to make the technology available for others to use. Patents and trademarks are some of the means for protecting IP.

6.3 Case Studies on IP Management

Five case studies were conducted on the IP management at AOSTRA UTF SAGD, the AERI/ARC Core Industry (AACI) Research Program, the Weyburn CO2 Monitoring and Storage Project, the Carbonates R&D Program and the Joint Implementation of Vapour Extraction. These five projects were selected for the case studies on IP management for the following reasons. AOSTRA UTF was a complex project, so that IP management was important. Non-participants in the project have created a high demand for SAGD IP. This project's R&D was completed in 1997, and many licenses have been issued since then to use the technology. The IP management at the AACI program is important because the program has been ongoing for twenty-four years, and has many participants. Weyburn was an multinational R&D project with participants from various government organizations and industries. Carbonates was a new R&D program, and JIVE had individual field pilots as part of the program.

AOSTRA UTF SAGD.

The AOSTRA personnel involved in the developing of UTF technology joined the industry and shared their experience in the UTF technology development and the UTF field pilot test. The first commercial SAGD project was the Foster Creek project by the Alberta Energy Corporation in 2000. The Alberta Energy Corporation, managed by Pan Canadian, later became EnCana. The Alberta Energy Corporation never participated in the UTF Technology development, but acquired a SAGD license from ARC.

By a special agreement between AOSTRA and the UTF participants, the technology developed at the Shell AOSTRA Peace River twin horizontal wells from the surface project was made available to the UTF Project participants on a license-for-free-use basis (Komery & Chambers, 1993).

The UTF SAGD Intellectual Property Portfolio consists of patents, technical reports (1500), and operating data from the UTF field pilot test project Phase A, B, D & E. Some of the UTF field pilot test operating data have been released to the public and are available for purchase through the Energy Utility Board (EUB) (L. Forster, personal communication, Sept. 13, 2007). The SAGD Intellectual Property Portfolio is owned by the Government of Alberta. The IP is owned by the Ministry of Advanced Education and Technology, Government of Alberta, and is managed by ARC (L. Forster, personal communication, Sept. 13, 2007).

SAGD IP is protected through patents and trade secrets. The UTF SAGD patents consist of fifteen patents. The original SAGD patents are Roger Butler's patents from when Dr. Butler was working with Imperial Oil. The UTF SAGD patents are improvements to the original patents, which expired in 2001. The patents consist of improvements to the original Roger Butler patents, operating parameters, and start-up patents. UTF SAGD has one core patent and a number of peripheral patents. The core patent was intended to expire in 2009 (L. Forster, personal communication, Sept. 13, 2007). The following are some of the Underground Test Facility (UTF) Patents:

1. Steaming Process involving a Pair of Horizontal Wells Used in Heavy Oil Reservoir.
2. Directional Drilling Assembly.
3. Calometric Bitumen Cut Monitoring Method.
4. High Temperature and Pressure Separation of Bitumen and Water.

5. Differential Pressure Surveying.

6. System for Stabilization and Control of Surface SAGD Production Wells.

(Alberta Department of Energy, Oil Sands and Research Division, 1994)

R&D participants have rights concerning the use of SAGD intellectual property, such as practising rights to use the patent concepts, rights to make any improvements to the patented UTF Technology, and the right to use the license to use the technology anywhere in the world (D. Komery, personal communication, May 3, 2007). License holders have no rights to sell or sublicense the UTF SAGD technology. The license holders can inform the public (advertise) that they have a license to practise SAGD. They cannot publish the content of UTF technology, but can publish any improvements they have made to it. Sharing a license with other organizations is not permitted. In a joint venture, all the parties involved should have individual licenses. AOSTRA started the licensing of UTF technology. Now, only ARC has the authority to license it. A UTF SAGD license provides access to technical data and other information. Companies who buy a SAGD license, but were not involved in the development of the technology, have the same practising rights as the participants in the R&D (L. Forster, personal communication, Sept. 13, 2007). ARC provides training in response to the needs of a company. All organizations, especially entry-level companies, can benefit from this training. Technology transfer occurs mainly through the training and through ARC's resources (L. Forster, personal communication, Sept. 13, 2007).

The license fee was determined by AOSTRA and has never changed. Anyone can purchase UTF SAGD technology through ARC. Project-specific and global licenses are available. The licenses are available at a fair market price (L. Forster, personal communication, Sept. 13, 2007). The license fee is usually a combination of an upfront fee and a milestone fee. The milestone fee is normally negotiated with a company based on its expansion plans and when the steam injection will be used for commercial operation. Milestones can be production milestones and financial milestones. Fees are not based on a percentage of net revenue and are never linked to a company's production rate or net revenue or profit.

The UTF IP portfolio is managed under the Energy Intellectual Property Agreement between AERI and ARC. Revenues from licensing are reinvested into other heavy oil technologies used to fund new programs such as those for carbonates, and are also invested into AERI R&D programs. The participants involved in the UTF SAGD technology development do not receive any of the revenue generated by IP licensing. ARC does not have to disclose the number of licences issued or the issuing of any new licenses. What has been learned from the IP Management at UTF is being applied in the R&D projects of the Government of Alberta (L. Forster, personal communication, Sept. 13, 2007). Most of the participants in the program did not have prior knowledge about the process. The participants were willing to share their background IP with the other participants.

AERI/ARC Core Industry (AACI) Research Program.

The AACI program is managed jointly by AERI, ARC and industry. Its technology development work consists of laboratory and simulation work. Ideas are generated and developed by ARC, which presents its inventions to the program's Policy and Program Committee. It decides whether the program will proceed with an invention.

The AACI intellectual property portfolio consists of patents, technical reports and operating data (R. Sawatzky, personal communication, Nov. 17, 2008).

The AACI intellectual property portfolio is owned by the Government of Alberta. The IP is owned by the Ministry of Advanced Education and Technology, Government of Alberta and is managed by ARC (R. Sawatzky, personal communication, Nov. 17, 2008). AACI's IP is protected through patents and trade secrets. Trade secrets stay within the program and are available only to the participants in the program. Some of the trade secret may eventually made available to the public, depending on whatever the Technical Committee decides (R. Sawatzky, personal communication, Nov. 17, 2008). ARC, as the manager of the program, decides on the patentability of an idea. The costs for IP protection are borne by the government, not by the AACI program, which pays for the cost of developing the new idea (R. Sawatzky, personal communication, Nov. 17, 2008).

The participants' have worldwide royalty-free use rights to all the technologies developed by the AACI program for as long as these participants are members of the program. New members have access to all the information since the beginning of the program, but have no right to use these technologies. New members wanting to use them have to acquire a license. ARC had plans to license the new technology, but, as of 2008, no license had been issued for the AACI program. Technologies are licensed not to generate revenue, but to move technologies forward. Patents are one way to protect IP, and licensing provides the freedom to use the technology. Companies not involved in the AACI program can obtain use rights by acquiring a license. The license is non-exclusive, cannot be transferred, and cannot be shared with partners. On a joint project, all the partners should have a separate license to use the technology. An AACI member cannot partner with a non-AACI member and use the technology, unless the non-AACI member buys a license (R. Sawatzky, personal communication, Nov. 17, 2008). Transfers of technology are negotiated as part of the licensing agreement. Technology transfer occurs back and forth, or from ARC to the AACI program to participants, and from the participants to the AACI program to ARC. The companies pay for the technology transfer through the license fees.

The technology developed by the AACI program is available to the public at a fair market price. The license fee for the technology is negotiated and is not related to the net revenue, but to the amount of production. The licensing revenue is not divided among the developers or AACI participants, but is reinvested by AERI in the R&D projects of the Government of Alberta (R. Sawatzky, personal communication, Nov. 17, 2008). All the participants in the program have prior knowledge about the technology and have background IP. The industry participants are willing to share some of their knowledge with other participants in the program. Access to the background IP is negotiated on a case-by-case basis.

Weyburn CO2 Monitoring and Storage Project.

The Weyburn project developed technology for monitoring the capture and storage of CO2 within a reservoir. Fifteen participants, from government and industry, and twenty-four research providers and consulting organizations generated this technology jointly. Weyburns' Intellectual Property Portfolio consists of IP generated during Phase 1 and the Final Phase, technical reports, and operating data from Weyburn field and Midale field.

The IP of Weyburn is owned and managed by PTRC. Weyburns' IP is protected through participating agreements and trade secrets. The IP stays within the program and is available only to the participants. The Weyburn project has two types of agreements to manage IP. The IP is governed by an umbrella agreement among the major partners, and a separate subsequent research provider IP agreement. IP is managed by PTRC (R. Chalaturnyk, personal communication, Aug. 29, 2008). As of 2008, the Weyburn program committee had not yet determined the patentability options for the technology. The participants' rights on the Weyburn technology will be fully defined only after the completion of the final phase. For Phase 1, Weyburn is using an Industrial Research Provider Agreement to manage the distribution of IP for research purposes. This agreement is for industries to use the technology developed by Weyburn, for research purposes. Weyburn's IP is open only to participants and will not be licensed.

The project is planning to release the datasets for research work, but only after the completion of the Final Phase. As of 2008, Weyburn had no plan to sell its IP through licensing (R. Chalaturnyk, personal communication, Aug. 29, 2008). The participants shared their background IP with the program. The background IP was available to all the participants in the program and is protected by its IP policy. The research providers had separate agreements for sharing their background IP with the program. Agreements were made on a case-by-case basis.

Carbonates R&D Program.

Carbonates' technology was developed jointly by AERI, ARC and the industry. The technology development work consisted of laboratory and simulation work. Carbonates' Intellectual Property Portfolio consists of patents, data from previous

Carbonates tests conducted in 1990, reports, and results of first studies done by ARC. All of the above are available to the participants (R. Sawatzky, personal communication, Nov. 17, 2008).

The Ministry of Advanced Education and Technology, Government of Alberta, owns Carbonates' IP. ARC, on behalf of the Government of Alberta, is managing the IP. Carbonates' IP is protected through patents and trade secrets. The latter stay within the program and are available only to the participants. ARC decided on the patentability of the new ideas. The costs of IP protection are borne by the government, not by the program, which paid for the cost of developing the new ideas (R. Sawatzky, personal communication, Nov. 17, 2008). The participants' have royalty-free worldwide use rights to the Carbonates technology. In 2008, ARC had plans to license the technology, but had not issued a license for the Carbonates program. Companies not involved in the Carbonates program can obtain use rights by acquiring a license, which is non-exclusive, cannot be transferred, and cannot be shared with partners. On a joint project, all the partners must have a separate license. Carbonates' participants cannot partner with a non-participant and use the technology, unless the non-participant buys a license (R. Sawatzky, personal communication, Nov. 17, 2008). The transfer of technology is negotiated as part of the licensing agreement, which includes technology transfer components (R. Sawatzky, personal communication, Nov. 17, 2008). The technology developed through the AACI program is available to the public at a fair market price. The license fee for the technology is negotiated and is not related to the net revenue, but to the amount of production. The licensing revenue is not divided among the participants in the program but invested by AERI into the R&D projects of the Government of Alberta (R. Sawatzky, personal communication, Nov. 17, 2008).

All the participants in the program and the research providers had prior knowledge about the carbonates technology. ARC was not the only research provider in the Carbonates program, which had multiple research providers, including some who were not participants in the program. All the industry participants knew about Carbonates technology and were willing to share some of their knowledge with other participants in the program. All the participants in the program and the research providers had background IP and shared it with the other participants. Access to the background IP of the research providers was negotiated on a case-by-case basis (R. Sawatzky, personal communication, Nov. 17, 2008).

Joint Implementation of Vapour Extraction.

The JIVE R&D program developed SVX technologies that could increase the recovery rates of bitumen from heavy oil reservoirs. One government participant, three industry participants, and two research providers jointly developed this technology. JIVE's Intellectual Property Portfolio consists of the technical reports from R&D and the JIVE program. In this program, unlike in the UTF program, field-demonstrated pilot test information is not part of the IP. The IP of JIVE is owned and managed by PTRC. JIVE's IP is protected through participating agreements and trade secrets. The IP stays within the program and is currently available only to the participants.

In 2008, the JIVE program committee was still determining the patentability options of the technology, and participants' rights to the JIVE technology were still not fully defined because the field pilot tests had not been completed. The plan was to manage the distribution of IP through licensing, but no license had yet been issued and the details of licensing were still under development. Field pilot plant data are not part of the IP. Field test data will be shared only among the participants and will be not available to outsiders or included in the licensing agreement. The participants can share their background IP with the program. No active process is currently in place to manage background IP, but the program is keeping a record of all background IP shared with the program.

6.4 Summary of the Findings

Five case studies were conducted on IP management in open innovation at AOSTRA UTF SAGD, the AERI/ARC Core Industry (AACI) Research Program, the Weyburn CO2 Monitoring and Storage Project, the Carbonates R&D Program, and the Joint Implementation of Vapour Extraction.

UTF IP is available to non-participants in R&D through licensing because the R&D is complete. AACI is an on-going R&D program, and IP is available to the public. Weyburn would like to keep the details of its IP policy within the program and is not willing to share Weyburn's IP policy details with outsiders. Weyburn's final phase is still in progress, so the details of its IP have not been published. The Carbonates program has a fully developed IP policy in place and also has a new technology with major growth potential. This program has more technology weightage compared to that of JIVE. Thus, the IP developed through the Carbonates program is more important. The technology weightage impacts the development of IP policy. JIVE IP is shared among the three participants.

Various government and industry participants develop technology collaboratively. Thus, managing IP becomes important due to the involvement of various organizations. An innovation team consisting of twelve participants developed the UTF SAGD. In the AACI program, a team consisting of thirteen members jointly carries out innovation. Fifteen participants, from government and industry, and twenty-four research providers developed Weyburn. In the Carbonates project, the team had seven members, and JIVE had one government and three industry participants, and two research providers. All five projects either had or have government and industry participation.

The owner of IP is the leader of the innovation. In the UTF SAGD, AACI and Carbonates, the IP owner is the Government of Alberta. The Ministry of Advanced Education and Technology (AAET), Government of Alberta, owns the IP, which ARC manages. In Weyburn and JIVE, the IP is owned by PTRC. The IP created by collaborative research needs to be protected through patents and trade secrets. A R&D program first patents new technology to protect it, then tests it in the field, then implements the technology through commercial operations, and then licenses the technology to make it available for others. Patents protect the new technology not to generate revenue, but to protect the freedom to use the technology.

The participants' rights in terms of the IP are the rights available to the participants in the program and are mainly worldwide rights to use the technology without paying a royalty fee. Non- participants receive the right through licensing to use the technology, if the IP is available through licensing. The non- participants who license the technology receive the same rights as the participants, but will not have access to trade secrets, which are available only to the participants in the program.

Licensing is the method through which non-participants have access to IP. Licensing provides the rights to use the technology. In four cases, UTF SAGD, AACI, Carbonates and JIVE, licenses either have been already issued or will be issued to make the new technology available to non-participants. Weyburn has no plan to sell its IP through licensing.

Pilot test data, an important part of IP, are expensive. In the UTF, AACI, and Weyburn projects, the pilot test data are part of IP. JIVE had a field pilot, but the pilot test data are not part of the IP. In the Carbonates project, the field pilot test was not part of the innovation and, hence, is not part of IP. Like UTF SAGD, AERI and ARC are willing to share the pilot test data. However, since carbonates are a new technology and have more potential for development, industry participants are reluctant to make pilot plant data part of the program and the IP. At JIVE, participants conducted field pilot tests individually, but the pilot test data belong to the program and are part of its IP. In the Weyburn project, the pilot test data are part of the program, but are available only to the participants.

The individual participants and research providers have background IP, which they bring to a project and share with others. The participants' background IP is considered the input into the technology integration and is a technology source for open innovation. The participants' background IP is included in the IP portfolio. Access to the research providers' background IP is negotiated on a case-by-case basis. Sharing of background IP by the participants in a program is controlled. The background IP is part of their internal technology. The decision to share background IP with other participants depends on how they acquired it. The details for sharing background IP are developed by an organization before it joins a program. The organization decides which elements of the background IP will be shared. The decision not to share some background IP depends on factors such as the source of the IP, the use of the IP in other R&D program, patenting of the IP, the development of the IP through an extensive research program, and the relevance of the IP is to the program. The background IP is part of the internal technology for the organization, and not all the internal technology is shared with the other participants.

IP can be released for academic purposes, or for further research on the subject by universities and R&D organizations. Weyburn has a separate agreement in place among the participants to release IP for academic purposes. Improvements made to the original developed technology by individual organizations are not considered as part of it and are not part of the IP. Also, the data from any field tests associated with the improvements are not part of the IP.

Collaborative research changes the nature of innovation because of the collaboration with outside organizations. Various levels of interaction occur among the participants in collaboration. Its projects are complex because of the multilevel participation. Making new technology available for others to use through collaboration is an important part of collaborative research. In collaborative research, standards must be established to govern the interactions among the participants. The design of IP policies is important in collaborative research. The factors affecting the choice of IP policy strategies need to be considered carefully during the design of IP policy, which establishes the specifics of collaborative engagement during R&D and also develops policies to manage the technology developed. Through IP policies, links among (1) the

R&D participants, (2) the non-participants who would like to use the technology, and (3) the generated technology are established. In collaborative research, companies formulate IP policies so that IP will be available to the participants and outsiders. Restricting outsiders from gaining the benefits of innovation does not necessarily fit with the collaborative research model. IP policies are created not with the intention of making a profit, but to make ideas available to others for use in a controlled manner.

6.5 Summary

Having a proper IP policy is important in collaborative research to avoid uncertainties over the boundaries and uses of technology assets. The participants in collaborative research share a common technology, and, thus, rules must be established to control its use. The purpose of IP management is to develop policies to protect the technology created under IP laws and to make the technology available for others to use. In collaborative research, various government and industry participants develop the technology collaboratively. Thus, managing IP becomes important due to the involvement of various organizations. The IP portfolios in the case studies include patents, reports, and data from field tests. The owner of IP is the leader of the innovation. An R&D program first patents new technology to protect it, then tests it in the field, then implements the technology through commercial operations, and then licenses the technology to make it available for others.

Chapter 7 Analysis and Discussion of Case Studies

7.1 Overview

Analysis of the case studies was the first step in finding solutions to the problem stated in the introductory chapter. The R&D execution approach adopted in the case studies was examined in detail. The leverage on R&D investment and the current use of technology are the benchmarks for measuring success in these projects. The details of how the case studies were analyzed were explained in Chapter 3.

7.2 Case Studies Findings

R&D management.

How R&D is managed and the approach adopted by each open innovation project are analyzed in detail in this section. The R&D management style in each case study is explained below. In AOSTRA UTF SAGD, a UTF Task Force consisting of AOSTRA and industry participants managed the R&D. The R&D was managed through two committees, the Management Committee and the Technical Committee, which were formed with representation from all the participants. The R&D Management of UTF SAGD is shown in Figure 7.1.

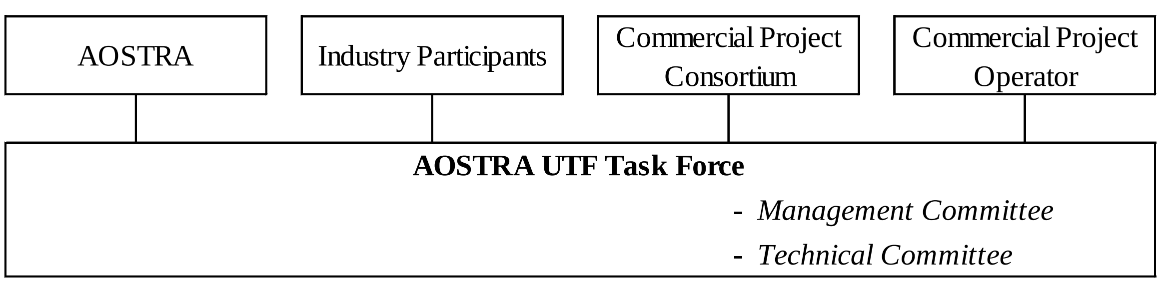


Figure 7.1 R&D Management of UTF SAGD

In AACI, the R&D is managed through two committees, the Management Committee and the Technical Committee, which are composed of industry members, AERI, and ARC. The Policy and Program (P&P) Committee is responsible for the program's long-range planning. This committee consists of members from the senior executives of the industrial member companies and senior officers of ARC and AERI. The R&D Management of AACI is shown in Figure 7.2.

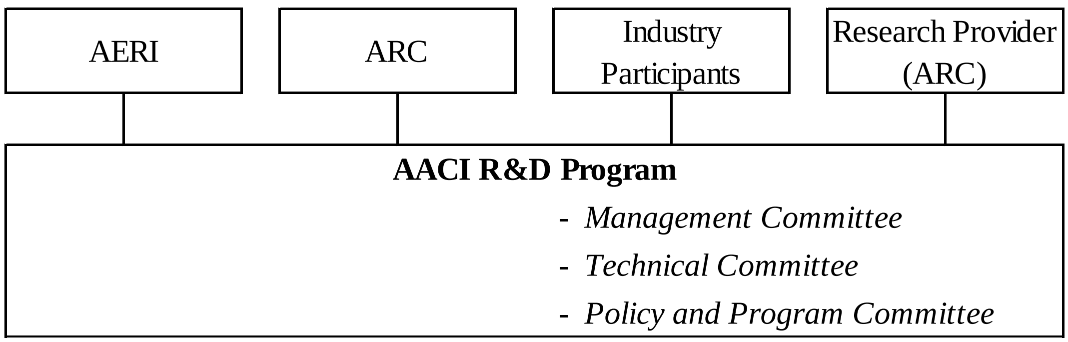


Figure 7.2 R&D Management of AACI

Weyburn was organized into eight Principal Tasks, each led by a Principal Task Leader. Each Principal Task was subdivided into a number of subtasks, each considered as an individual project. A subtask was executed by one or more research providers. The project included fifty subtasks. Subtask Leaders funnelled their work through the Principal Task Leaders, who were coordinated by the Project Director. The Project Director was responsible to a Management Committee (MC) made up of representatives of the participants. The project was organized into four main themes chosen to group all subtasks in a manner corresponding to the project's main objectives. The R&D Management of Weyburn is shown in Figure 7.3.

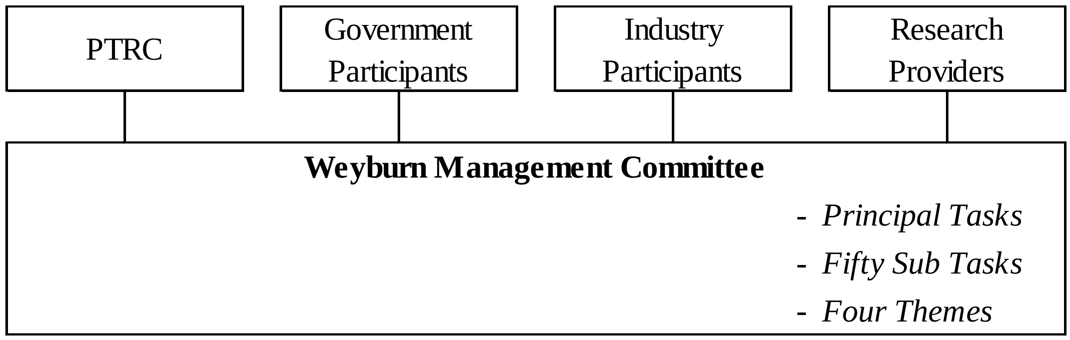


Figure 7.3 R&D Management of Weyburn

Carbonates' R&D was managed by a steering committee. Each participant had one member on the steering committee. Carbonates R&D was structured by research projects. This approach is similar to that of the Weyburn project. The R&D Management of Carbonates is shown in Figure 7.4.

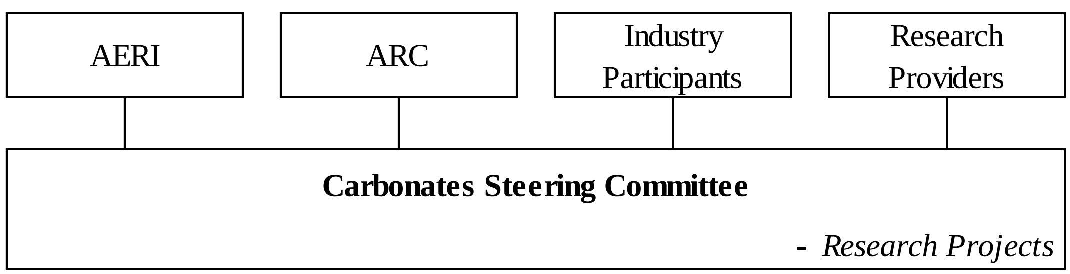


Figure 7.4 R&D Management of Carbonates

JIVE's R&D program was managed through a consortium consisting of members from all participants. ARC and SRC were research providers to the program. The R&D Management of JIVE is shown in Figure 7.5.

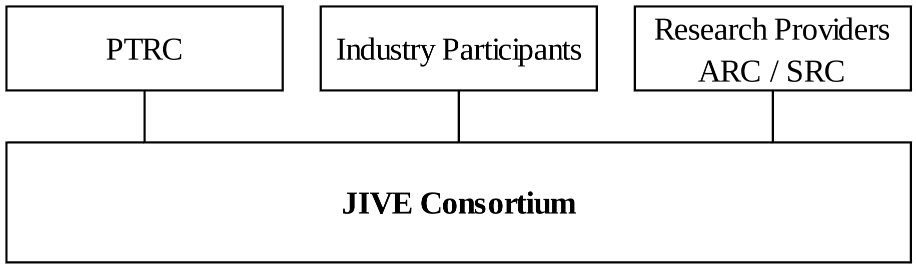
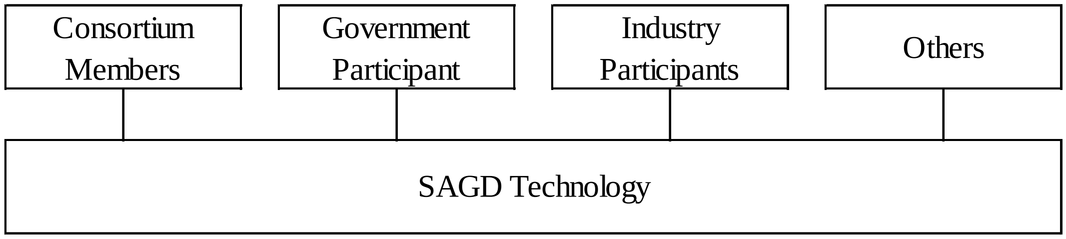


Figure 7.5 R&D Management of JIVE

All the five cases studied chose different methods to manage their Collaborative R&D project. All of them had participants from government and industry. The common element in the R&D management is that in all the cases studied, R&D was managed through committees or a consortium, an arrangement in which organizations can join together to work collaboratively.

Participants.

The participants in the projects, the government involvement, and the reasons for participating are analyzed, and the findings are presented below. AOSTRA and nine major oil companies participated in the UTF project. Energy, Mines, and Resources Canada (CANMET) participated in the UTF project's Geotechnical Program. Syncrude Canada Limited was an Associate Member of the UTF Project. Gibson Petroleum Company Limited was appointed as the Project Operator of UTF in October 1995. The UTF project formed a consortium between government and industry. The members of the consortium were AOSTRA, the UTF industry participants, Syncrude, the Alberta Oil Sands Equity, the Alberta Petroleum Marketing Commission and the Alberta Energy Resources Conservation Board. The participants in UTF SAGD are shown in Figure 7.6.



Consortium Members: *AOSTRA, Industry Participants, Syncrude, Alberta Oil Sands Equity, Alberta Petroleum Marketing Commission, Alberta Energy Resources Conservation Board*

Government Participant: *AOSTRA*

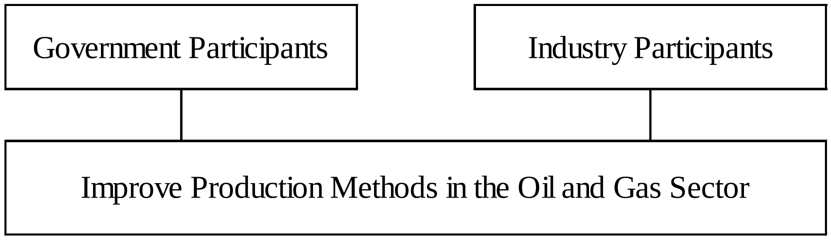
Industry Participants: *Amoco, Chevron, Conoco, CNPC, Imperial Oil, JAPEX, Mobil Oil, Petro-Canada, Shell Canada*

Others: *Syncurde (Associate Member), CANMET (UTF Geotechnical Program), Gibson Petroleum (UTF operator)*

Figure 7.6 Participants in UTF SAGD

The AACI program is a consortium composed of AERI, ARC and twenty-one industry members. ARC is the research provider for the program. The participants in the AACI program are shown in Figure 7.7.

The Weyburn Phase 1 project had fifteen participants, six from government and nine from industry: the Petroleum Technology Research Centre, Natural Resources Canada, the United States Department of Energy, the Alberta Energy Research Institute, Saskatchewan Industry and Resources, the European Commission, and nine industrial participants from Canada, the US, and Japan. The project also had twenty-four research providers and consulting organizations and about seventy technical and project personnel. The participants in Weyburn are shown in Figure 7.8.

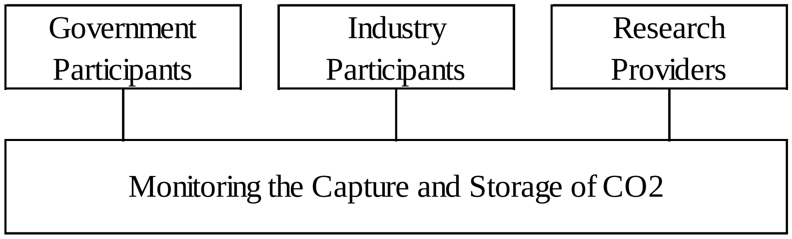


Government Participants: *Alberta Energy Research Institute, Alberta Research Council*
Industry Participants: *BP, Canadian Natural Resources Ltd., Chevron Corp., Computer Modelling Group, ConocoPhillips, Devon Canada, EnerMark, ENI, Husky Oil Operations, Imperial Oil Resources Ltd., Japan Canada Oil Sands, Marathon Oil Canada, Nexen Canada Ltd, Oilsands Quest Inc., Petro-Canada, Repsol, Schlumberger, Shell International, Statoil, Suncor Energy Inc., Total*

Figure 7.7 Participants in AACI

The Carbonates program had seven participants. Two were from the Government of Alberta: the Alberta Energy Research Institute (AERI) and the Alberta Research Council (ARC). Five participants, all heavy oil producers, were from industry. The program had research providers from either within or outside Canada. The participants in Carbonates are shown in Figure 7.9.

The Petroleum Technology Research Centre (PTRC) was the government participant in the JIVE program. The three industry participants were Husky Energy, CNRL, and Nexen Inc. The two research providers were the Alberta Research Council (ARC) and the Saskatchewan Research Council (SRC). The two outside funders were Sustainable Development Technology Canada (SDTC) (Canadian Federal Government) and the Saskatchewan Government. The participants in JIVE are shown in Figure 7.10.



Government Participants: *Alberta Energy Research Institute, European Community, Natural Resources Canada, Petroleum Technology Research Centre, Saskatchewan Industry and Resources, United States Department of Energy*

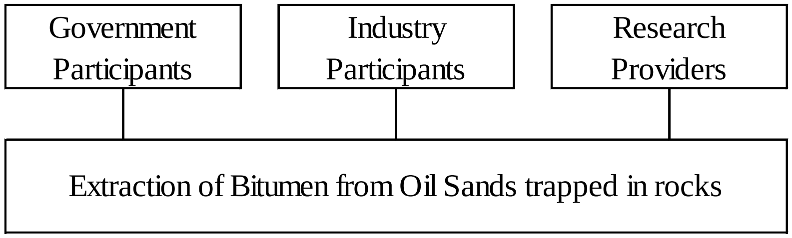
Industry Participants: *British Petroleum, Chevron Texaco, Dakota Gasification Co, Engineering Advancement Association of Japan, EnCana Corporation, Nexen Inc, SaskPower, Total, TransAlta Utilities*

Research Providers (Canada): *Alberta Research Centre, Canadian Energy Research Institute, ECOMatters, EnCana Corporation, GEDCO Inc., Geological Survey of Canada, Hampson Russell, J.D Mollard and Associates Ltd., Rakhit Petroleum Consulting Ltd., Saskatchewan Industry and Resources, Saskatchewan Research Council, University of Alberta, University of Calgary, University of Regina, University of Saskatchewan*

Research Providers (USA): *Colorado School of Mines, Lawrence Berkeley National Laboratories, Monitor Scientific Corporation International, North Dakota Geological Survey*

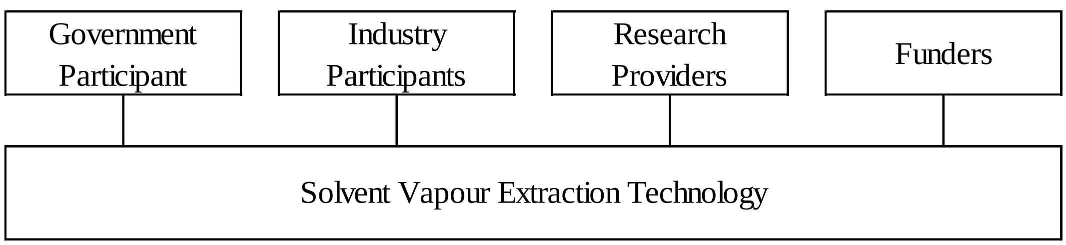
Research Providers (European Community): *British Geological Survey, Britain Bureau de Recherches Geologiques et Minieres France, Geological Survey of Denmark and Greenland, Istituto Nazionale di Geofisica e Vulcanologia, Quintessa Ltd.*

Figure 7.8 Participants in Weyburn



Participants: *Alberta Energy Research Institute, Alberta Research Council, Five Heavy Oil Producers and Research Providers*

Figure 7.9 Participants in Carbonates



Government Participant: *Petroleum Technology Research Centre*

Industry Participants: *Canadian Natural Resources Ltd., Husky Oil Operations, Nexen Canada Ltd.*

Research Providers: *Alberta Research Council, Saskatchewan Research Council*

Funders: *Sustainable Development Technology Canada, Saskatchewan Provincial Government*

Figure 7.10 Participants in JIVE

In all the five cases studied, the participants were from government and industry. All the participants contributed to the innovation process, and most joined the R&D because they understood its potential for developing new technology. Obtaining leverage on R&D investment was the main objective of all the participants.

Technology developed.

The technology developed through collaboration is the technology currently being used, the technology available for commercial operation, and the technology shared and transferred during R&D. AOSTRA UTF developed SAGD technology for the extraction of bitumen from oil sands. The AACI program develops technology to improve production methods in the oil and gas sector by enhancing the recovery of in situ bitumen and heavy oil. The Weyburn project developed technology for CO2 distribution and containment within a reservoir. Carbonates' R&D program developed technology to extract bitumen from oil sands that are trapped in rocks in the form of carbonates. The JIVE program developed solvent vapour extraction technology that might increase recovery rates of bitumen from heavy oil reservoirs. All the five cases developed new technology by using collaborative research. A collaborative interaction occurred among the participants in the technology development, and technology sharing and transfer occurred among the participants. Table 7.1 summarises the technology developed in the case studies.

Table 7.1 Technology developed in the case studies

No.	R&D project	Technology developed	Use of technology
1	AOSTRA UTF SAGD	SAGD Technology	To extract bitumen from oil sands
2	AERI/ARC Core Industry Research	Improve Production Methods in the Oil and Gas Sector	To improve bitumen production
3	Weyburn CO2 Monitoring and Storage	Capture and Storage of CO2	To capture and store CO2 from oil reservoirs to reduce GHG emissions
4	Carbonates R&D Program	Carbonates Technology	To extract bitumen from oil sands trapped in rocks
5	Joint Implementation of Vapour Extraction	Solvent Vapour Extraction Technology	To increase recovery rates of bitumen from oil reservoirs

Benefits.

The benefits received by the participants, the government, and the public are explained below. Collaborative research provides benefits to a wide range of parties. The benefits are not limited to the participants in a project, but are also available to the non-participants' organizations in the same sector, various R&D organizations, the provincial and federal governments, and the public. Table 7.2 summarizes the benefits to the participants in the five case-study projects.

Table 7.2 Summary of benefits

No.	R&D project	Benefits to participants
1	AOSTRA UTF SAGD	• worldwide license fee free use of SAGD technology and Shell ESAGD technology • ownership of 8 and 1/3% of AOSTRA UTF lease • commercial project consortium participation • eligibility to become participant in the commercial UTF project • eligibility to become commercial project operator • training of company personnel on SAGD technology
2	AERI/ARC Core Industry Research	• access to information • opportunity to do own technology development • opportunity to learn how the process works • leverage for R&D investment • industry networking • technology transfer
3	Weyburn CO2 Monitoring and Storage	• expertise in carbon capture and storage technology • application of the developed economic model • leverage for R&D investment • industry networking • technology transfer • opportunity to become a leader in developing technology to reduce greenhouse gas emissions
4	Carbonates R&D Program	• leverage of R&D • exploration of oil sands • direct research to develop technology • sharing the cost of technology development • technology transfer and sharing • opportunity and networking • free rights to use the technology
5	Joint Implementation of Vapour Extraction	• leveraged funding for the development of technology • leverage for R&D investments • opportunity to be engaged in the evolution of a new technology • access to technology by investing only 5% of the total cost

Budget.

The amount of the investments, the sources of funds, and the leverage on the R&D investments are discussed below. The total gross cost of the UTF Project from its start in 1984 to its completion in 1996 was C$145 million, with C$50 million from industry, C$15 million from product sales, and the reminder from AOSTRA. Each industry participant contributed C$6.79 million. In the AACI program, the annual fee for participating companies is C$105,000. AERI, ARC and the industry participants each contribute 1/3 of the funding share. The annual budget for the program is C$3 million. Weyburn's project cash costs totalling C$16.38 million were allocated among the four project themes over the project's four-year life. In-kind contributions amounted to C$23 million, mostly in field support and European-Community-funded work. Fifteen participants from both government and industry funded the project. Cash and in-kind contributions financed this project. The cost of Carbonates was C$2.45 million per year, and each participants provided C$350,000 per year. The project expense was divided equally among all the participants. The JIVE program's total project funding, cash and in-kind was C$40 million. SDTC contributed C$3.2 million, and PTRC contributed C$1.8 million. The three industrial participants (Husky, CNRL and Nexen) contributed C$1.8 million (C$600,000 each).

In all the case studies, the project costs were divided among the participants. The percentages of contributions from the government and industry varied in the cases. In all cases, the contribution from industry was less than C$2 million per participant, except for the UTF, where the industry contribution was C$7 million. This is an "affordable" R&D investment, and the leverage on investment is always a minimum of ten times the investment. JIVE had external funding providers, who were not part of the R&D. Carbonates received equal funding from government and industry. Table 7.3 presents a summary of the project budgets.

Field pilot tests.

This section summarizes the field pilot tests of the R&D laboratory findings, and explains how the results of the field pilot tests were shared among the participants. The UTF project was tested in the field. From the start of Phase 1 in 1984, until the completion in 1996, all the R&D results were field-tested, and the test results were made part of the program. The AACI program decides on a case-by-case basis whether its technology will be pilot-tested. Weyburn's field tests were conducted at EnCana's Weyburn field and Apache's Midale field, located in southeast Saskatchewan, Canada. The Carbonates program had no field pilot test. Technology could be tested in the field if the participants decided to develop pilot tests on their own outside the program.

Table 7.3 Summary of R&D projects' budgets

No.	R&D project	Budget	Source of funding
1	AOSTRA UTF SAGD	$145 million	Industry participants $7 million each, AOSTRA, and revenue from bitumen product sales during the prototype demonstration
2	AERI/ARC Core Industry Research	$3 million / year	AERI - 1/3, ARC - 1/3, Industry participants - 1/3
3	Weyburn CO2 Monitoring and Storage	$40 million	Fifteen participants from Government and Industry
4	Carbonates R&D Program	$2.45 million / year	Seven participants 1/7 each, C$350,000 per year each participant
5	Joint Implementation of Vapour Extraction	$40 million	SDTC C$ 3.1 million, PTRC C$1.8 million. Husky, CNRL and Nexen C$1.8 million

In the JIVE program, the industry participants conducted field pilot tests separately and shared the knowledge gained from them. In the UTF project, the participants conducted the field pilot tests together. The three industrial participants (Husky, CNRL and Nexen) conducted separate field tests in Lloydminster, Saskatchewan and then shared the test results and test data from the field. The pilot test data were shared among all the participants in the program and the research providers.

Organizations can benefit from demonstrating laboratory technology in the field. The projects in the five cases studied adopted different approaches to field pilot tests. For example, field pilot tests were not a part of the Carbonates program. JIVE included field pilot tests in its R&D program, but they were conducted individually rather than collaboratively. UTF's success was partly due to the collective implementation of field pilot tests. Weyburn used a field test as part of its R&D. AACI is planning to have more field tests as part of its R&D. Table 7.4 presents a summary of the pilot tests.

Table 7.4 Summary of pilot tests

	R&D project	**Pilot Test**
1	AOSTRA UTF SAGD	Pilot Test was part of R&D, pilot plant at UTF site in Fort McMurray
2	AERI/ARC Core Industry Research	Pilot Tests are decided on a case-by-case basis
3	Weyburn CO2 Monitoring and Storage	Pilot Test at the Encana Weyburn field
4	Carbonates R&D Program	Pilot Test was not part of R&D
5	Joint Implementation of Vapour Extraction	Three separate Pilot Tests at Lloydminster, Saskatchewan

7.3 Summary of Findings

From the case studies, it was found that government either led or is leading all these projects. Based on the case studies conducted, it is suggested that government is required as a leader for collaborative research projects. However, for a definite conclusion, more studies are required. The following conclusions were derived from the case studies. The government has

- Authority.

- Availability of funding.
- Availability of expertise.
- Government-owned resources.
- Access to external technological sources.
- The ability to inspire trust and generate interest in government-led projects.
- Knowledge of and experience in collaborating with external sources.
- Relative immunity from volatile oil prices.
- Long-term perspective and commitment towards R&D.

Multiple participants from both government and industry can develop new technology collaboratively. In collaborative research, successful innovation is achieved by the collaborative engagement of various parties. Government / industry collaboration either occurred or is occurring in all the cases studied. UTF SAGD was a government / industry collaboration. In UTF, ASOTRA represented the Provincial Government of Alberta, and nine major heavy oil producers from the industry participated. CANMET was also involved as a geotechnical consultant representing the Federal Government of Canada. In AACI, AERI and ARC represent the Provincial Government of Alberta, and twenty-one members from the industry participated. AACI is a government / industry collaborative R&D project. Weyburn was a government / industry collaboration that had Canadian, US, and European government involvement. The Canadian government was involved through AERI, NRCan, PTRC, Saskatchewan Industry and Resources. The US government was involved through the US Department of Energy, and the European government was involved through the European Community. The nine industry participants were from Canada, the US and Japan, and twenty-four research and consulting organizations were also involved. Carbonates was a government / industry collaboration with AERI and ARC representing the Provincial Government of Alberta and had five industrial participants.

In JIVE, PTRC represented the Provincial Government of Saskatchewan. There were three participants from industry. ARC and SRC were also involved in the program as research providers.

The number of participants varied in all the cases studied and depended on the requirements for the different R&D programs. The new technology was developed by the collaborative engagement of these participants. AOSTRA UTF SAGD had twelve participants, one from government and eleven from industry. AACI has fifteen participants, two from government and thirteen from industry. Weyburn had six participants from various government sectors, nine participants from the industry, and also twenty-four research providers. Carbonates had two participants from government and five from industry. JIVE had one government participant, two government research providers, and three industry participants.

Long periods of time are required to develop new technology. Through the collaboration from various sectors, this duration can be reduced, but the amount of time needed to complete R&D depends on the R&D project. UTF SAGD took eleven years to complete, from 1984 to 1996, and the R&D and was conducted in five phases. AACI has been an ongoing R&D program for twenty-four years. Weyburn’s first phase was from 2000 to 2004. The Carbonates program was for three years from 2007 to 2009. The JIVE program was for four years from 2006 to 2009. It is reasonable to assume that the collaborative nature of R&D projects reduces the time required to complete an innovation, because of the involvement of multiple parties. The government leadership also contributes to the reduced R&D period. For the case studies, a project duration of more than five years is considered as long term.

UTF participants have worldwide license fee free use of the SAGD technology. AACI participants have free use rights to the technology developed through the program, as long as they are members of the program. The use rights of participants for Weyburn technology will not be finalized until after completion of the Final Phase of the project. Carbonate's and JIVE's participants have free use rights to the developed technology. The practising rights for non-participants in R&D were managed differently in all five cases. In UTF SAGD, practising rights can be purchased through a license. In AACI, practising rights are available only to the members of the program. Weyburn was a closed program, and practising rights are available only to the participants in the program. Carbonates' practising rights can be purchased through licensing. JIVE's practising rights are available to outsiders and are purchased through licensing.

New technology was developed in all the cases studied. UTF developed the SAGD process for in situ bitumen recovery. Many operating plants and projects are currently using SAGD technology for the extraction of bitumen. The AACI program is developing methods to improve production in the oil and gas sector. AACI's R&D process is being widely used for bitumen production. Weyburn developed technology to capture and store CO2 from oil reservoirs. This technology will be used worldwide to contain CO2 from oil fields. Carbonates developed technology to extract bitumen from oil sands trapped in rocks. JIVE's program developed solvent vapour extraction technologies. JIVE's technology will increase the recovery rate of bitumen by 30 to 50%.

IP is managed through different IP policies. In UTF, IP is managed by ARC through licensing. In AACI, IP is managed by ARC through participation agreements. In Weyburn, IP is managed by PTRC. In Carbonates, IP is managed by ARC through licensing. In JIVE, IP is managed by PTRC. The case studies revealed that the IP is always managed by an entity either controlled by or associated with a government. Table 7.5 provides a summary of the findings from the case studies.

Table 7.5 Summary of case study findings

Case Study	Leader	Collaboration	No. of Participants and Period	Practising rights to participants	Practising rights to non-participants	Technology Developed	IP Management
UTF SAGD	AOSTRA	Government / Industry collaboration	11 (1986 to 1997)	Worldwide license fee free use of SAGD technology and Shell ESAGD technology	Can be purchased through license	SAGD process for in situ bitumen recovery	IP managed by ARC through license
AACI	AERI / ARC	Government / Industry collaboration	23 (ongoing for 24 years)	Free use rights to the technology, as long as they are a member	Can be achieved only by participating	Improves production methods in the oil and gas sector	IP managed by ARC through participating agreement
Weyburn	PTRC	Government / Industry collaboration	15 (2000 to 2004)	Use rights of participants is not finalized	Closed participation, available only to participants, rights to do research through research provider agreement	Monitors the Capture and Storage of CO2 from oil reservoirs	IP managed by PTRC
Carbonates	ARC	Government / Industry collaboration	7 (2007 to 2009)	Free use rights of the technology	Licenses technology to non-participants through licensing agreement	Extracts bitumen from oil sands trapped in rocks	IP managed by ARC through license
JIVE	PTRC	Government / Industry collaboration	6 (2006 to 2009)	Free use rights of the technology	IP Available to outsiders	Solvent Vapour Extraction technologies	IP managed by PTRC

7.4 Commercial Use of Developed Technology

The projects developed by using a new technology are a measure of an R&D program's success. If the technology is still in use several years after the completion of R&D, then the technology is viable. Successful R&D projects lead to increases in royalties, job opportunities, activities in the energy sector, and tax revenue. UTF SAGD's R&D and field pilot tests were completed in 1996. Tables 7.6 and 7.7 indicate where SAGD technology has been used since 1996. Table 7.6 provides the list of the operating plants using SAGD technology in 2009, and Table 7.7 provides the list of the projects that, in 2009, were planning to use SAGD technology in the future.

Table 7.6 indicates that about C$3.6 billion is being invested and about 414,000 bbl/day of bitumen are being produced. Table 7.7 indicates that about C$18.6 billion will be invested, and about 2 million bbl/day of bitumen will be produced in the future by using SAGD technology. The table also indicates that the non-participants in the UTF SAGD R&D invested about $C3 billion and that about 344,000 bbl/day of bitumen are being produced. These non-participants bought a license to use the technology. Table 7.6 shows the demand for the new technology, and its use by the non-participants, and also the revenue generated by licensing the technology. About C$0.6 billion is invested, and about 70,000 bbl/day of bitumen are produced by the participants of UTF SAGD R&D. These figures indicate the success of SAGD technology.

Table 7.6 List of the operating plants using SAGD technology in 2009

Operating Plants using SAGD Technology						
No.	**Company**	**Project**	**Phase**	**Capacity (bbl/day)**	**Start-up Period**	**Region**
1	Connacher Oil and Gas	Great Divide	Pod1	10,000	2007	Athabasca Region, Canada
2	ConocoPhillips Canada	Surmont	Phase 1	27,000	2008	Athabasca Region, Canada
3	Devon Canada	Jackfish	Phase1	35,000	2008	Athabasca Region, Canada
4	Encana	Christina Lake	Phase1A	10,000	2002	Athabasca Region, Canada
5	Encana	Christina Lake	Phase1B	8,800	2008	Athabasca Region, Canada
6	Encana	Foster Creek	Phase 1A	24,000	2001	Athabasca Region, Canada
7	Encana	Foster Creek	Debottlenecking	6,000	2003	Athabasca Region, Canada
8	Encana	Foster Creek	Phase 1C - Stage 1	10,000	2005	Athabasca Region, Canada
9	Encana	Foster Creek	Phase 1C - Stage 2	20,000	2007	Athabasca Region, Canada
10	Japan Canada Oil Sands	Hangingstone	Pilot	10,000	2002	Athabasca Region, Canada
11	MEG Energy	Christina Lake	Phase1	3,000	2008	Athabasca Region, Canada
12	Nexen	Long Lake	Phase1	72,000	2007	Athabasca Region, Canada
13	Petro-Canada (Suncor Energy)	MacKay River	Phase1	33,000	2002	Athabasca Region, Canada
14	Suncor Energy	Firebag	Phase 1	33,000	2004	Athabasca Region, Canada
15	Suncor Energy	Firebag	Phase 2	35,000	2006	Athabasca Region, Canada
16	Suncor Energy	Firebag	Cogeneration and Expansion	25,000	2007	Athabasca Region, Canada
17	Total E&P Canada	Joslyn	Phase 1	2,000	2004	Athabasca Region, Canada
18	Total E&P Canada	Joslyn	Phase 2	10,000	2006	Athabasca Region, Canada
19	BR Oil Sands (Shell)	Orion	Phase1	10,000	2008	Cold Lake Region, Canada
20	Husky Energy	Tucker	Phase 1	30,000	2006	Cold Lake Region, Canada
Total capacity of bitumen produced using SAGD technology (bbl/day)				**413,800**		
Equivalent Commercial Investment C$				**3,600,060,000**		
Number of Investors				**12**		
Number of Projects				**20**		

Source: *Alberta Oil Sands Industries Quarterly Update*, 2009

Table 7.7 List of the future projects using SAGD technology

Future Projects using SAGD Technology						
No.	**Company**	**Project**	**Phase**	**Capacity (bbl/day)**	**Start-up Period**	**Region**
1	Connacher Oil and Gas	Great Divide	Pod2, Expansion	34,000	2012	Athabasca Region, Canada
2	ConocoPhillips Canada	Surmont	Phase 2	83,000	2013	Athabasca Region, Canada
3	Devon Canada	Jackfish	Phase2	35,000	2008	Athabasca Region, Canada
4	Alberta Oil Sands	Clearwater	Pilot	2,000	2010/11	Athabasca Region, Canada
5	Alberta Oil Sands	Clearwater	Commercial Project	10,000	2012	Athabasca Region, Canada
6	Athabasca Oil Sands	Dover	Pilot	2,000	TBD	Athabasca Region, Canada
7	Athabasca Oil Sands	MacKay	Pilot	2,200	TBD	Athabasca Region, Canada
8	Canadian Natural Resources	Kirby	Phase1	45,000	TBD	Athabasca Region, Canada
9	Encana	Borealis	Phase 1, 2, 3	100,000	TBD	Athabasca Region, Canada
10	Encana	Christina Lake	Phase1C, 1D, Unnamed Expansion 1 to 5	230,000	TBD	Athabasca Region, Canada
11	Encana	Foster Creek	Phase 1D, 1E, 1F	90,000	TBD	Athabasca Region, Canada
12	Enerplus Resources	Kirby	Phase 1, 2	35,000	TBD	Athabasca Region, Canada
13	Grizzly Oil Sands	Algar Lake		10,000	TBD	Athabasca Region, Canada
14	Husky Energy	McMullen	Pilot, Phase 1	50,775	TBD	Athabasca Region, Canada
15	Husky Energy	Sunrise	Phase 2, 3, 4	150,000	TBD	Athabasca Region, Canada
16	Korea National Oil Corporation	BlackGold	Phase 1, 2	30,000	TBD	Athabasca Region, Canada
17	Laricina Energy	Germain	Pilot, Phase 1	10,600	TBD	Athabasca Region, Canada
18	Laricina Energy	Saleski	Pilot, Phase 1	11,200	TBD	Athabasca Region, Canada
19	Nexen	Long Lake South	Phase 1, 2	140,000	TBD	Athabasca Region, Canada
20	Patch International	Ells River		10,000	TBD	Athabasca Region, Canada
21	Petro-Canada (Suncor Energy)	Chard	Phase 1	40,000	TBD	Athabasca Region, Canada
22	Petro-Canada (Suncor Energy)	Lewis	Phase 1, 2	80,000	TBD	Athabasca Region, Canada
23	Petro-Canada (Suncor Energy)	MacKay River	Phase 2	40,000	TBD	Athabasca Region, Canada
24	Petro-Canada (Suncor Energy)	Meadow Creek	Phase 1, 2	80,000	TBD	Athabasca Region, Canada
25	Serrano Energy	BlackRod	Pilot	500	TBD	Athabasca Region, Canada
26	Southern Pacific Resources	STP MacKay		10,000	TBD	Athabasca Region, Canada
27	StatOilHydro Canada	KaiKos Dehseh-Leismer	Demonstration	10,000	2009	Cold Lake Region, Canada
28	StatOilHydro Canada	Leismer	Commercial, Expansion	40,000	TBD	Athabasca Region, Canada
29	StatOilHydro Canada	Corner		80,000	TBD	Athabasca Region, Canada
30	StatOilHydro Canada	Thornbury		60,000	TBD	Athabasca Region, Canada
31	StatOilHydro Canada	Hangingstone		20,000	TBD	Athabasca Region, Canada
32	StatOilHydro Canada	NorthWest Leismer		20,000	TBD	Athabasca Region, Canada
33	StatOilHydro Canada	South Leismer		20,000	TBD	Athabasca Region, Canada
34	Suncor Energy	Firebag	Phase 3, 4, 5, 6	263,500	TBD	Athabasca Region, Canada
35	SunShine Oil Sands	West Ells	Phase 1, 2, 3	65,000	TBD	Athabasca Region, Canada
36	SunShine Oil Sands	Thickwood	Phase 1, 2, 3	65,000	TBD	Athabasca Region, Canada
37	Value Creation Group	Terre de Grace	Pilot, Phase 1, 2	90,000	TBD	Athabasca Region, Canada
38	BR Oil Sands (Shell)	Orion	Phase 2	10,000	2008	Cold Lake Region, Canada
39	Canadian Natural Resources	WolfLake		5,500	TBD	Cold Lake Region, Canada
40	Husky Energy	Caribou	Demonstration	10,000	2006	Cold Lake Region, Canada
41	Koch Exploration Canada	Gemini		10,000	TBD	Cold Lake Region, Canada
42	Osum Oil Sands	Taiga		35,000	TBD	Cold Lake Region, Canada
43	PenGrowth Energy trust	Lindbergh		2,500	TBD	Cold Lake Region, Canada
44	Andora Energy	Sawn Lake	Demonstration	1,400	TBD	Peace River Region, Canada
Total capacity of future bitumen production using SAGD technology (bbl/day)				**2,139,175**		
Equivalent Commercial Investment C$				**18,610,822,500**		
Number of Investors				**26**		
Number of Projects				**44**		

Source: *Alberta Oil Sands Industries Quarterly Update*, 2009

7.5 Benefits of Joining Collaborative Research Projects

The main assets of a collaborative research project are the organizations and the people who are part of the project. Petro-Canada was a participant in UTF SAGD's R&D team whereas Encana was not. The following provides an analysis of the benefits received by both companies.

Petro-Canada invested C$7 million in its UTF SAGD R&D participation, and Encana paid C$1.2 million for a licence to practise SAGD technology. Petro-Canada and Encana were the first to build commercial operating plants using SAGD technology, soon after the completion of SAGD R&D in 1997. By 2002, Petro-Canada and Encana had plants producing 33,000 bbl/day of bitumen and 34,000 bbl/day of bitumen, respectively. In 2009, Petro-Canada and Encana had commercial operations producing 33,000 bbl/day of bitumen worth C$287 million and 78,800 bbl/day of bitumen worth C$685 million, respectively (*Alberta Oil Sands Industries Quarterly Update*, 2009). B. King (personal communication, Aug. 23, 2007) explained, "As the UTF Phase B project advanced and confidence in SAGD technology grew, it became evident to Petro-Canada that it could develop its oil sands leases with SAGD technology. Also, by participating in the UTF project, some of its staff became knowledgeable in SAGD technology and had established good relationships with other SAGD experts. This made the application of SAGD technology a little easier, and the decision to do so at MacKay River was made in 1998."

Petro-Canada was the first to build a commercial operating plant using SAGD technology. Encana was successful in using SAGD technology because this company hired the personnel who were part of the collaborative research team. Table 7.8 provides details of Petro-Canada`s and Encana`s operating plants using SAGD technology in 2009. Petro-Canada invested C$7 million and become a SAGD participant, starting its project soon after the completion of R&D. Encana bought a license to practise SAGD technology by spending C$1.2 million, and hired experts who had been part of the collaborative R&D. Figure 7.11 shows the details of the paths chose by Petro-Canada and Encana to acquire the SAGD technology. By either participating in the innovation or acquiring the developed technology and expertise through practising rights, organizations are benefiting from collaborative innovation.

Table 7.8 SAGD technology use by Petro-Canada and Encana

Petro-Canada's and Encana's Operating Plants using SAGD Technology						
No.	**Company**	**Project**	**Phase**	**Capacity (bbl/day)**	**Start-up Period**	**Region**
1	Encana	Christina Lake	Phase1A	10,000	2002	Athabasca Region, Canada
2	Encana	Christina Lake	Phase1B	8,800	2008	Athabasca Region, Canada
3	Encana	Foster Creek	Phase 1A	24,000	2001	Athabasca Region, Canada
4	Encana	Foster Creek	Debottlenecking	6,000	2003	Athabasca Region, Canada
5	Encana	Foster Creek	Phase 1C - Stage 1	10,000	2005	Athabasca Region, Canada
6	Encana	Foster Creek	Phase 1C - Stage 2	20,000	2007	Athabasca Region, Canada
Total capacity of bitumen produced by Encana using SAGD technology (bbl/day)				**78,800**		
Equivalent Commercial Investment C$				**685,560,000**		
Number of Projects				**6**		
1	Petro-Canada	MacKay River	Phase1	33,000	2002	Athabasca Region, Canada
Total capacity of bitumen produced by Petro-Canada using SAGD technology (bbl/day)				**33,000**		
Equivalent Commercial Investment C$				**287,100,000**		
Number of Projects				**1**		

Source: *Alberta Oil Sands Industries Quarterly Update*, 2009

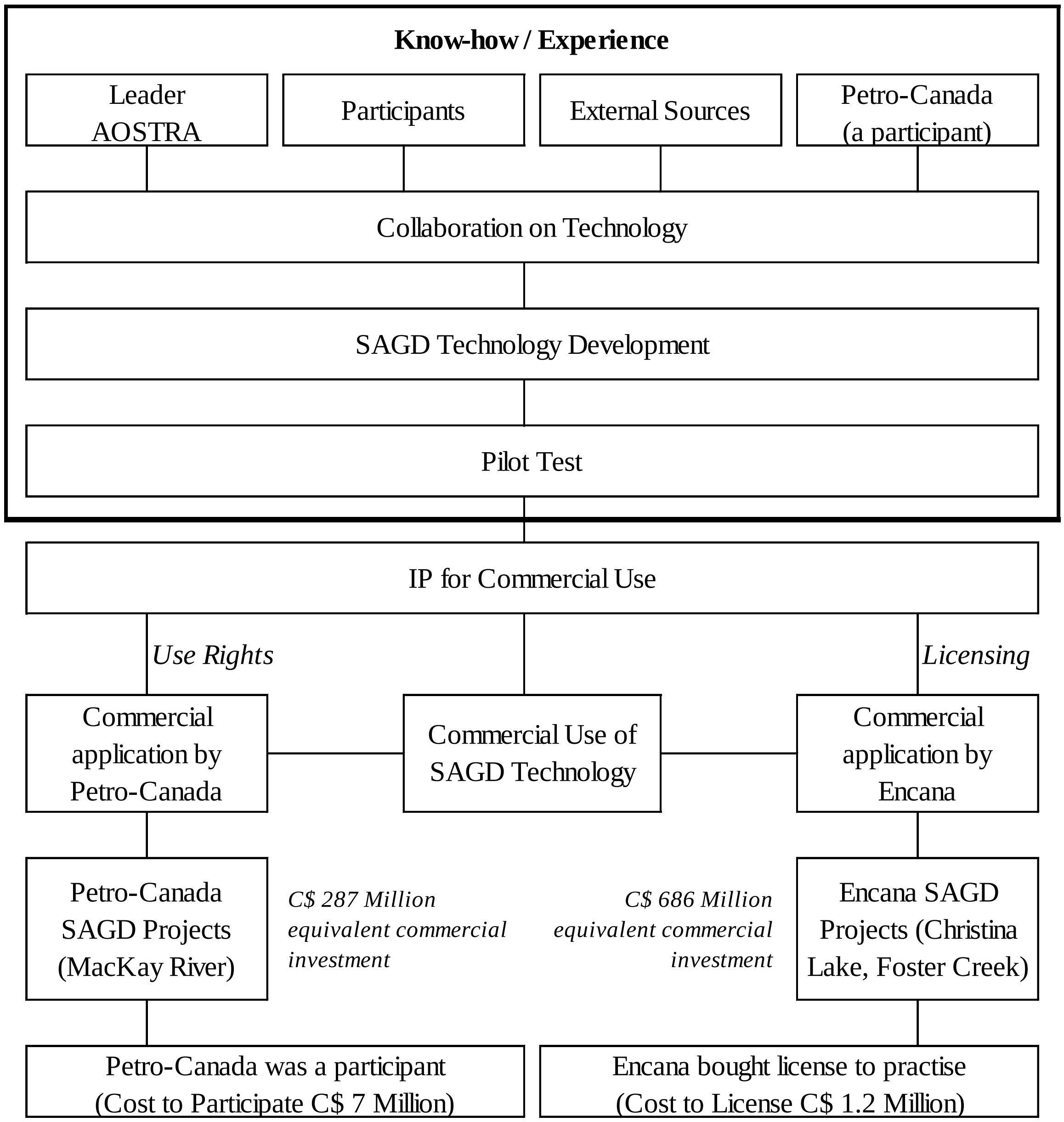


Figure 7.11 Participant and licensee of SAGD: Petro-Canada and Encana

7.6 Collaboration in the Energy Sector

The case study projects were mapped into the CRTD model. The key CRTD elements and the open innovation approaches adapted in the execution of these projects were identified. The investment in the SAGD technology demonstrates the demand for it, and also its use by participants and non-participants in R&D. The investment in this technology demonstrates the demand for technology for commercial use. The case studies demonstrate that the willingness to collaborate between government and industries and among industries increased after the beginning of UTF SAGD.

The successful completion of collaborative projects such as UTF SAGD, the AACI program, Weyburn, Carbonates and JIVE led industries and government to think more about collaboration and to realize that more could be achieved through it than by using other methods. Table 7.9 and Figures 7.12, 7.13 and 7.14 indicate the major shift that occurred in government and industry attitudes towards collaboration after the successful completion of many collaborative projects by 2009. Table 7.9 provides a summary of the perspective on collaboration in 2009. Figure 7.12 shows the trend for a government / industry collaboration to develop new technologies. Figure 7.13 shows the trend among industries to collaborate, and Figure 7.14 shows the overall trend to collaborate to conduct R&D in the energy sector. These trends were derived from the findings from the case studies.

Table 7.9 Government's and industry's willingness to collaborate in 2009

Period	Developments
2009	More and more industries willing to collaborate with government and with other industries
2009	Government-industry partnership proven to be successful and beneficial to both government and industries
2009	Collaboration proven to be a successful model for the development of technology in the energy sector

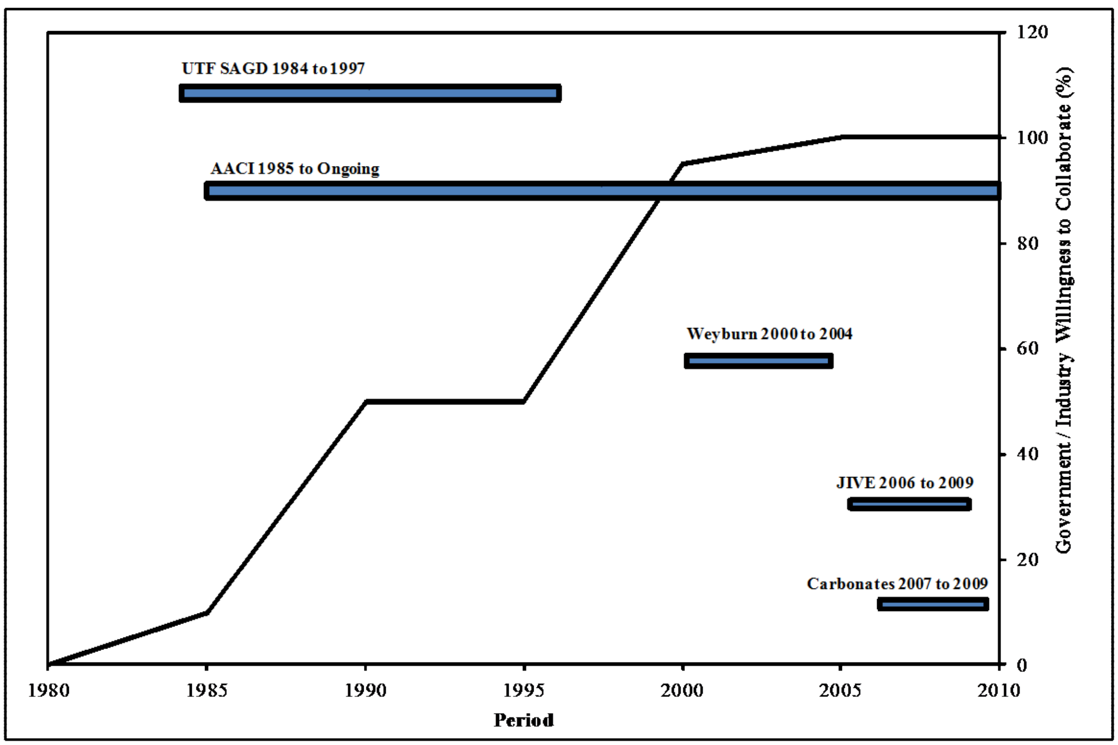


Figure 7.12 Government / Industry willingness to collaborate

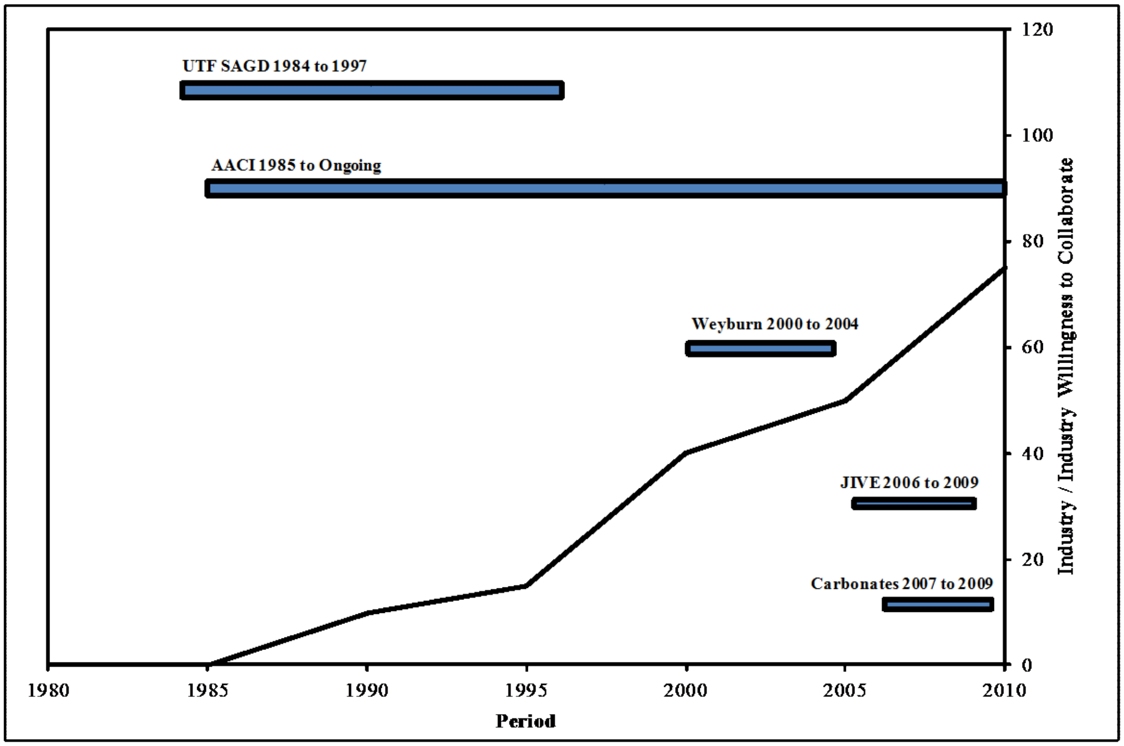


Figure 7.13 Industry / Industry willingness to collaborate

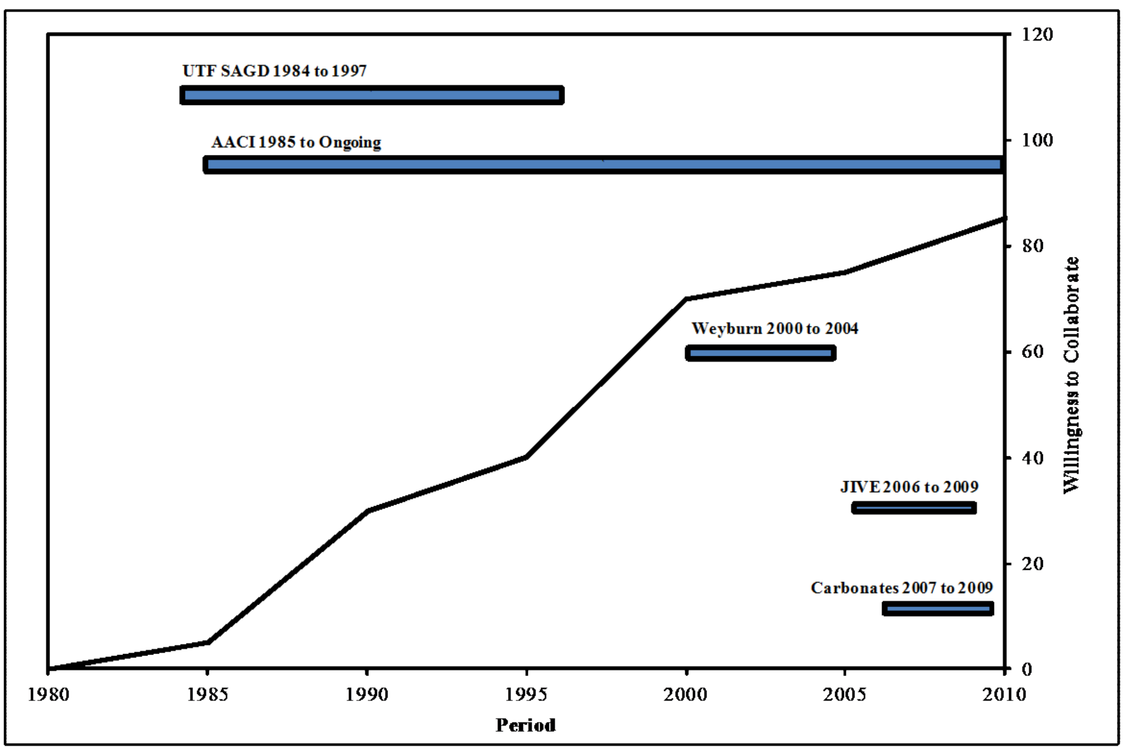


Figure 7.14 Collaboration trend for R&D in the energy sector

7.7 Summary

A detailed analysis of the data collected from the case studies was conducted in this chapter. The case study findings were divided into the categories of R&D management, participants, technology developed, benefits, budgets and field pilot tests. Findings were provided on the topics of the leader, collaboration, participants, duration of R&D, practising rights for participants, practising rights for non-participants, technology developed, and IP management.

From the case study on UTF SAGD, the following findings illustrate the success of collaborative R&D. In 2009, about C$3.6 billion was being invested, and about 414,000 bbl/day of bitumen were being produced by using UTF SAGD technology (*Alberta Oil Sands Industries Quarterly Update*, 2009). In 2009, it was estimated that another C$18.6 billion would be invested, and that 2 million bbl/day of bitumen would be produced in the future by using UTF SAGD technology (*Alberta Oil Sands Industries Quarterly Update*, 2009). By 2009, the non-participants in the UTF SAGD R&D had invested about C$3 billion, and about 344,000 bbl/day of bitumen were being produced (*Alberta Oil Sands Industries Quarterly Update*, 2009). These non-participants bought a license to use the technology. By 2009, about C$0.6 billion had been invested, and about 70,000 bbl/day of bitumen had been produced by the participants in UTF SAGD R&D (*Alberta Oil Sands Industries Quarterly Update*, 2009). Petro-Canada was able to be the first to build a commercial operating plant using SAGD, because Petro-Canada had participated in the collaborative research.

Chapter 8 Introduction to Collaborative Research and Technology Development

8.1 Overview

This chapter introduces the CRTD model and explains its evolution and necessity. An organization that has decided to conduct R&D collaboratively should be able to use this model. Not all R&D elements work in open innovation. The case studies in this thesis reveal the practical difficulties in implementing some innovation elements through open innovation and have led to the creation of a hybrid CRTD model. This chapter identifies the areas where using open innovation becomes practically impossible and explains how the CRTD model could be used instead.

From the analysis of the case studies, it is concluded that the open innovation processes cannot always be used for innovation projects in the energy sector. Some stages of innovation reject the concept of open innovation. Thus, the introduction of a new model is vital to address the findings from the case studies and to acknowledge the stages that cannot be conducted through open innovation. The knowledge that it is impossible to carry out innovation in the energy sector by depending completely on open innovation led to the creation of a new model that addresses the deficiencies identified in the open innovation model. The major difference between this new CRTD model and the open innovation model is that the CRTD model acknowledges the presence of closed innovation elements in innovation and does not attempt to carry out innovation by using only open innovation processes.

The limitations of open innovation led the author to search for an innovation process that would be possible in practice and a good fit for the energy sector, which can conduct innovation collaboratively, while also addressing this sector’s confidentiality and competition issues. Thus, a hybrid innovation model was created which is an amalgamation of open and closed innovation. This new innovation model is the deliverable of this thesis and is called the Collaborative Research and Technology Development (CRTD) model.

8.2 Open Innovation: What Does Not Work in the Energy Sector

The case studies in this thesis reveal that some open innovation activities cannot be performed in real-world applications in the energy sector.

Open innovation generally consists of the use of a complete open innovation process for technology development. However, in reality, some processes of R&D are aspects of closed innovation. The background IP, proprietary technology, and pilot test data are some examples. The CRTD model recognizes that the innovation process includes some elements of closed innovation. Collaborative innovation involves the combination of internal and external R&D sources for technology development, but not all the external R&D sources have the same role in this process. The external sources have different roles based on the participants' different levels of participation as, for example, participants, research providers, consultants, or funding providers. Open innovation groups all the external R&D sources together, whereas the CRTD model identifies their various roles in the innovation process.

The sharing of background IP, a key knowledge source in innovation, is important, but such sharing must be controlled. Closed innovation will work in this process. Background IP is the knowledge and technology acquired by an organization. It is very proprietary, and most organizations do not want to share their background IP. The participants need to understand that sharing their background IP with others helps and adds value to the innovation process and also that the background IP is protected and will not be shared further with outsiders. For these reasons, closed policies may work well for managing background IP. Effective policies for controlling and monitoring the sharing of background IP in collaborative innovations are essential. The distribution of the developed technology is also controlled and monitored, and the related IP is protected to ensure its availability to others. The participants have use rights on the technology, and non-participants' rights are controlled through licenses. Sometimes the developed technology might stay within a consortium, without being made available to the public. The CRTD model recognizes this possibility. The R&D consortium decides how the developed technology will be distributed and whether closed principles will be used during the distribution.

IP management is another area where conflicts occur with open innovation, which does not recognize the use of patents or licenses during the distribution of technology. Open innovation practitioners assume that technology can be made available to anyone who wants it without having any means of controlling it, but this assumption is not realistic. The IP will be made available to everyone in a controlled manner by using patents and licenses to control the distribution process.

Open innovation practitioners believe that companies use patents and licenses to hoard technology, so that they cannot be used in open innovation. In the CRTD model, the consortium develops an IP policy, which is used to make the technology available to others and uses patents and licenses to control the distribution process. Thus, the new technology is not freely distributed to others, as it would be in an ideal open innovation world. Competition among participants is a reality, for they are all from the same industry and are almost always competing with each other. Open innovation generally does not recognize competition but only collaboration, although even collaborating participants are still competing while they are working together for their mutual success. In the real world, individual users most often improve the newly developed technologies and do not have to report any improvements back to the consortium even though doing so would enable everyone to benefit from them. Any improvements are carried out independently and by using the closed method.

Pilot tests are part of R&D, but pilot test data are valuable and part of IP. Some pilot tests are conducted by using a closed model. Organizations might conduct their own pilot tests and not share the results with the rest of the consortium. In this case, the pilot tests may be separate from the rest of the R&D. R&D is conducted, and technology is developed by using the collaborative model whereas the technology is tested by using the closed model. The method adopted by UTF SAGD, the combined pilot test, is collaborative, and the method adopted by Carbonates, the pilot test not part of the innovation program, is closed.

8.3 CRTD: What Could Work in the Energy Sector

In CRTD, all the participants play an active role in the development of technology and are not considered as just other external knowledge sources. As Noke, Perrons, and Hughes (2008) explained, the creation of strategic alliances or non-committal relationships has emerged as a promising strategy by which oil and gas industry organizations can create discontinuous innovations. Considerable turnover occurs in high-tech alliances, but a focus on the risks of impermanence is less important than both the focus of alliances and their evolving dynamics (Hagedoorn, 2002). Participants can use the developed technology for commercial applications and make it available to other interested parties for a price (e.g. through licensing). CRTD will be applicable in situations in which organizations decide to innovate collaboratively. Moreover, either the implementation of the collaboration is controlled, or not all the elements in the innovation process can be used in open innovation. Figure 8.1 illustrates the relationship between CRTD, open and closed innovation.

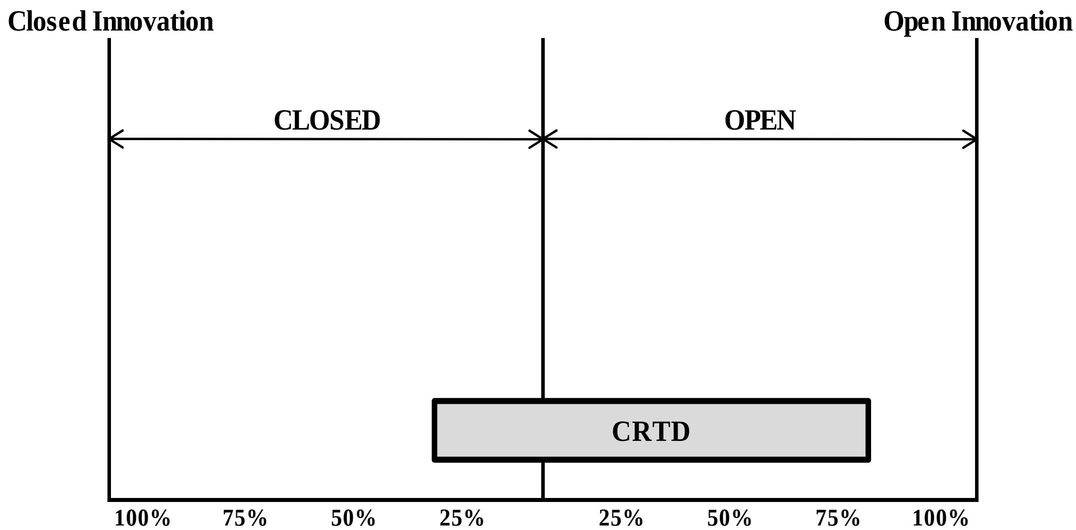


Figure 8.1 CRTD's relationship to Open and Closed Innovation

While closed innovation is 100% closed, and open innovation is 100% open, CRTD is open innovation with approximately 25% closed elements. The CRTD model was developed by using input from two sources: (1) The open innovation concept and (2) the case studies conducted for this thesis. CRTD could be considered as a modified version of open innovation developed to facilitate its practical application for technology development in the energy sector. CRTD adopts closed elements during its innovation, so it does not have complete open innovation but includes both open and closed elements.

This author recommends implementing the CRTD model as a solution for collaborative technology development in the energy sector. This model can be applied only if it meets the criteria, outlined in detail in Chapter 11. Please refer to Chapter 11 for a detailed explanation of when to use collaborative research. The CRTD model was developed for the energy sector, but could also be applied to other sectors.

8.4 Summary

The CRTD model is essentially a version of open innovation, modified for practical application in the energy sector. The CRTD model is a hybrid of open innovation and the case studies. It has elements of both open innovation and closed innovation. The processes developed in the case studies reveal that the practical application of the CRTD model is possible.

Chapter 9 The Case Studies and the CRTD Model

9.1 Overview

To meet its R&D needs, an organization should be able to decide when both to use and to apply the collaborative research model developed through this research program. This chapter provides an insight into the development of the CRTD model developed from the findings from the case studies. In this chapter, the key elements of the collaborative research model and the innovation approach of CRTD are explained. Pilot testing of technology and IP management are two important features of collaborative research and are included in this model. Different methods to conduct the pilot testing, different possible scenarios of IP management, and a recommended IP management model are discussed in this chapter. The findings from this thesis' chapters on the five case studies, IP management, and the analysis and discussion of case studies, and the introduction to collaborative research are inputs for the CRTD model discussed in this chapter.

9.2 Collaborative Research: Key Elements

Collaborative research is a process in which different parties collaborate to develop technology. The nine key elements in collaborative research are leader, participants, external sources, background IP, collaboration on technology, new technology, development, pilot test, IP management and commercial use of technology. Figure 9.1 presents the key elements of collaborative research for technology development.

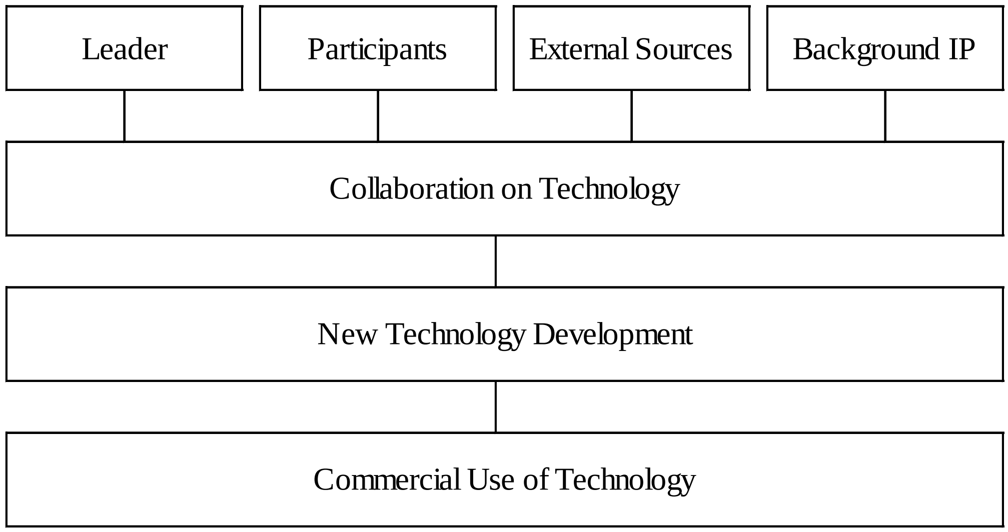


Figure 9.1 Key elements in collaborative research

Leader.

The leader identifies the problem that requires a solution and determines the need for external participants to participate in the problem-solving process. A leader who decides to pursue an innovation in collaboration with others determines the possible participants and external sources of the technology. The leader then starts inviting the participants and other external sources who can support the development of the new technology. The leader will generally be the program manager and champion for the innovation. In all the cases studied, the leader was a government organization, probably because the technology had broad, cross-company, application with large impact.

Participants.

The participants are the organizations the leader collaborates with in the development of technology. The leader normally invites the participants, who are identified from organizations willing to collaborate and to contribute to the R&D. These organizations are in need of the technology and will later want to use it for commercial operations.

External sources.

The external sources are those contributing to the collaborating effort outside the leader and participants. The external sources are generally research providers, academics, and R&D consultants. The external sources are considered as experts in the subject matter, and their contribution is an important component in the R&D.

Background IP.

Background IP is a key ingredient in the development of new technology development and is the internally generated IP that the leader and participants share with the rest of the team.

Collaboration on technology.

During this phase, the leader, participants, and external sources work together to develop new technology by using their the internal technology and background IP.

New technology development.

A new technology is generated as a result of the collaborative research.

Pilot tests.

This phase is used to demonstrate the developed technology. Pilot tests are part of R&D and may include the combined and all the participants' individual pilot tests. The data collected from these tests becomes part of the IP and can be made available to the users of the technology. In four cases, UTF, AACI (on a case-by-case basis), Weyburn, and JIVE, a pilot test was part of the innovation program, but Carbonates did not have a pilot test.

IP management.

This phase manages and issues the IP for commercial use. IP Management is based on the IP policy developed during the R&D phase. An IP Manager, who manages IP centrally, is in charge of issuing the use rights for the technology. IP management is an on-going task and is required as long as the technology is in use. Any changes made to the IP during the technology-in-use stage need to be communicated to all the users through the IP Manager.

Commercial use of technology.

In this phase, the developed technology is put into practical application. All the participants and any others who purchase a license can use the technology for commercial use. Thus, the technology has multiple users and reaches the market through multiple channels.

9.3 Collaborative Research in the Case Studies

The key collaborative research elements for technology development in the case studies are explained below.

AOSTRA UTF SAGD.

AOSTRA was the leader of the UTF SAGD project. The leader, participants and other external sources developed the UTF SAGD technology collaboratively. The new technology generated was the UTF SAGD technology for extracting bitumen from oil sands. A combined pilot test was conducted to demonstrate the technology. ARC is the IP Manager for the developed technology. In 2009, approximately twenty operating plants were using the SAGD technology, and forty-four projects were in the planning stage (*Alberta Oil Sands Industries Quarterly Update*, 2009).

AERI/ARC Core Industry (AACI) Research Program.

AERI and ARC are the leaders of the AACI program, and the participants are from mainly the oil and gas industry. All participants including the leader provide the background IP.

Weyburn CO2 Monitoring and Storage Project.

PTRC was the leader for the Weyburn program. The participants were from both government and industry, and the external sources were research providers and consultants. All participants including the leader provided the background IP. The technology generated was the new technology developed for monitoring the capture and storage of CO_2.

Carbonates R&D Program.

AERI and ARC were the leaders of the Carbonates program, which had five industrial participants. All participants including the leader provided background IP. The technology generated was the Carbonates technology for extracting bitumen from oil sands trapped in the rocks.

Joint Implementation of Vapour Extraction (JIVE).

In JIVE, PTRC was the leader. The participants from industry and the external sources were the research providers. All participants including the leader provided the background IP. Technology collaboration took place during JIVE's R&D. New technology was generated by creating solvent vapour extraction technology.

9.4 Collaborative Research: Innovation Approach

Innovation is the process of developing and marketing an idea, while collaborative research is the process of developing a technology by the collaborative engagement of various organizations, or developing a technology for commercial operations by various organizations, and making the technology available to others for commercial use for a price. The collaborative research approach in the cases studied is explained below.

AOSTRA UTF SAGD.

Ten participants developed the idea for UTF SAGD. A new technology, SAGD technology, was developed for the extraction of bitumen from oil sands. The developed SAGD technology was applied by various organizations by using pilot test plants and commercial plants. These organizations either participated in the collaborative research or bought licenses to practice the developed SAGD technology. Figure 9.2 presents the collaborative research approach in AOSTRA UTF SAGD.

AERI/ARC Core Industry (AACI) Research Program.

AACI developed its technology through the participation of two government and thirteen industry members. AACI developed various technologies for improving bitumen production. The idea is being marketed by various organizations. AACI's innovations are being put into practise by various member and non-member organizations.
Figure 9.3 presents the collaborative research approach in AACI.

Weyburn CO2 Monitoring and Storage Project.

The technology to capture and store CO2 was jointly developed by fifteen participants and twenty-four research and consulting organization. The Weyburn technology will be implemented in various oil fields to monitor the capture and storage of CO2. Figure 9.4 presents the collaborative research approach in Weyburn.

Participants: *AOSTRA, Amoco, Chevron, Conoco, CNPC, Imperial Oil, JAPEX, Petro-Canada, Shell Canada, Suncor Inc, CANMET, Syncurde*

<u>SAGD Projects</u>

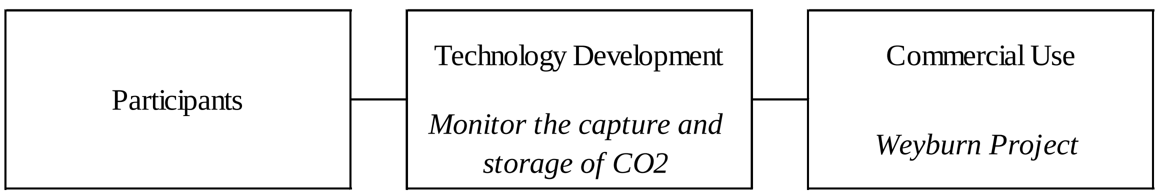
Participants	**Operating Plants**	**Current / Future Projects**
AOSTRA		
Amoco		
Chevron		
Conoco	Surmont Phase 1	Surmont Phase 2
CNPC		
Imperial Oil		
JAPEX	Hangingstone Pilot	
Petro-Canada	MacKay River Phase 1	Chard, Lewis, Meadow Creek, MacKay River 2
Shell Canada	Orion Phase 1	Orion Phase 2
Suncor Inc	Firebag 1 & 2	Firebag Phase 3,4,5,6
CANMET		
Syncrude		
Licensee	**Operating Plants**	**Current / Future Projects**
Alberta Oil Sands		Clearwater Pilot, Commercial
Andora Energy		Sawn Lake Demonstration
Athabasca Oil Sands		Dover Pilot, MacKay Pilot
Canadian Natural		Kirby Phase1, WolfLake
Connacher Oil and Gas	Great Divide Pod 1	Great Divide Pod2, Expansion
Devon Canada	Jackfish Phase 1	Jackfish Phase2
Encana	Christina Lake, Foster Creek	Borealis1,2,3, Christina Lake1C,1D, Foster Creek1D,1E,1F
Enerplus Resources		Kirby Phase 1, 2
Grizzly Oil Sands		Algar Lake
Husky Energy	Tucker Phase 1	McMullen, Sunrise 2,3,4, Caribou Demonstration
Koch Canada		Gemini
Korea National Oil		BlackGold Phase 1, 2
Laricina Energy		Germain Pilot, Phase 1, Saleski Pilot,Phase 1
MEG Energy	Christina Lake	
Nexen	Long Lake Phase 1	Long Lake South Phase 1, 2
Osum Oil Sands		Taiga
Patch International		Ells River
PenGrowth Energy		Lindbergh
Serrano Energy		BlackRod Pilot
Southern Pacific		STP MacKay
StatOilHydro Canada		KaiKos Dehseh-Leismer, Corner, Thornbury, Hangingstone, NorthWest and South Leismer
SunShine Oil Sands		West Ells Phase 1, 2, 3, Thickwood Phase 1, 2, 3
Total E&P Canada	Joslyn 1, 2	
Value Creation Group		Terre de Grace Pilot, Phase 1, 2

(Source: *Alberta Oil Sands Industries Quarterly Update*, 2009)

Figure 9.2 Collaborative research approach in AOSTRA UTF SAGD

Participants: *AERI, ARC, BP Petroleum, CNRL, Chevron Corp., CMG, ConocoPhillips, Devon Canada, EnerMark, ENI, Husky Oil Operations, Imperial Oil, Japan Canada Oil Sands, Marathon Oil Canada, Nexen Canada Ltd., Oilsands Quest Inc., Petro-Canada, Repsol, Schlumberger, Shell International, Statoil, Suncor Energy Inc., Total*

Figure 9.3 Collaborative research approach in AACI



Participants: *Petroleum Technology Research Centre, Alberta Energy Research Institute, European Community, Natural Resources Canada, Saskatchewan Industry and Resources, United States Department of Energy, British Petroleum, Chevron Texaco, Dakota Gasification Co., Engineering Advancement Association of Japan, EnCana Corporation, Nexen Inc., SaskPower, Total, TransAlta Utilities, Alberta Research Centre, Canadian Energy Research Institute, ECOMatters, EnCana Corporation, GEDCO Inc., Geological Survey of Canada, Hampson Russell, J.D Mollard and Associates Ltd., Rakhit Petroleum Consulting Ltd., Saskatchewan Industry and Resources, Saskatchewan Research Council, University of Alberta, University of Calgary, University of Regina, University of Saskatchewan, British Geological Survey, Bureau de Recherches Geologiques et Minieres, Geological Survey of Denmark and Greenland, Istituto Nazionale di Geofisicae Vulcanologia, Quintessa Ltd., Colorado School of Mines, Lawrence Berkeley National Laboratories, Monitor Scientific Corporation International, North Dakota Geological Survey*

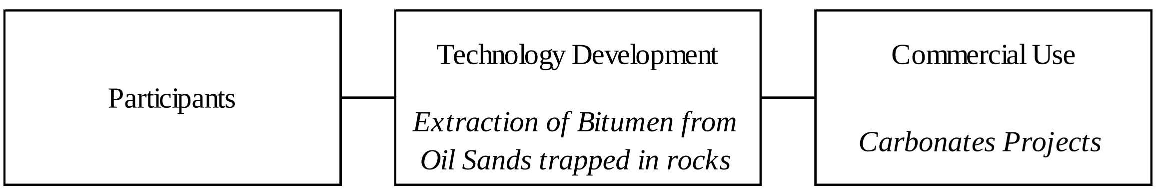
Figure 9.4 Collaborative research approach in Weyburn

Carbonates R&D Program.

The technology to extract bitumen from oil sands in the form of carbonates was developed by seven participants. The Carbonates technology will be implemented through various projects. Figure 9.5 presents the collaborative research approach in Carbonates.

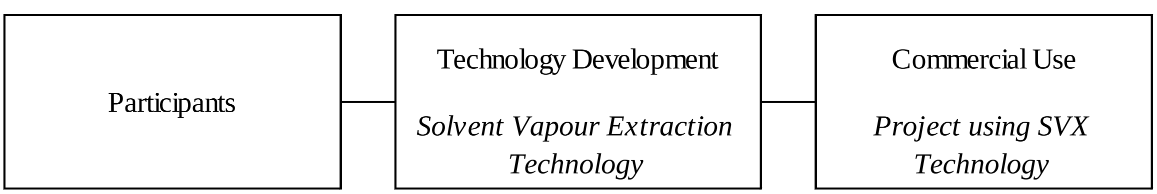
Joint Implementation of Vapour Extraction (JIVE).

Solvent vapour extraction technology was developed jointly by six participants from government and industry. The R&D was field-tested through pilot test plants, and the new technology will be applied in commercial operations. Figure 9.6 presents the collaborative research approach in JIVE.



Participants: *AERI, ARC, and Five Heavy Oil Producers*

Figure 9.5 Collaborative research approach in Carbonates



Participants: *PTRC, Husky, CNRL, Nexen Canada, ARC, SRC*

Figure 9.6 Collaborative research approach in JIVE

9.5 Technology Transfer

Organizations have to use external technological sources for technological innovation. A network of knowledge workers is created during collaborative research and enables organizations to access outside expertise and to learn about new technologies. Along with the innovation process, the best organizational practices, human resources, and business models are shared during collaborative research projects (Verhaeghe, 2002). The search for R&D participants can be global in scope. For example, in the case of UTF SAGD, CNPC and JACOS are international companies. Similarly, Weyburn is a good example of a collaborative project executed globally. Technology transfer occurs mainly through affiliations. The main sources of external technology are organizations in similar businesses, customers, knowledge repositories such as universities, external R&D, consultants, researchers, and analysts (Sherman, 1998). The business connections established during collaboration are mechanisms for technology transfer.

Through collaborative industry participation, the consortium approach to conducting research and development promises major benefits. This approach increases the likelihood of success, since numerous industry participants are represented. A consortium approach spreads know-how among consortium members and also provides an opportunity for effective technology transfer (Komery & Luhning, 1993). Technology transfer occurs throughout the innovation process. The case studies conducted demonstrated that the transfer and sharing of technology occur among organizations in collaborative research. Technology transfer occurs when the researchers and other R&D professionals from various government and industry sectors interact with each other. Industry members can apply the technology obtained through technology transfer, which also occurs through accessibility to experts, conferences, meetings and reports. The management and technical committees established to manage collaborative R&D projects are the venues for technology transfer. In the UTF SAGD project, technology transfer was an integral part of the method that AOSTRA chose to interact with industry for developing technology for the commercial development of resources.

9.6 Confidentiality

The period of maintaining confidentiality before making technology available to the public is important in collaboration. A confidentiality agreement between parties should reflect of the IP policy and is more critical and requires more priority in the collaborative R&D than in other R&D models since various parties are involved. The level of confidentiality depends on the level of participation and the elements of the innovation process. Table 9.1 shows the confidentiality level of the data for the various parties involved in R&D. During R&D, the process and all the elements remain confidential and are not shared with non-participants outside the consortium. After the completion of R&D, the team decides whether to share and when to share the IP with non-participants in the R&D. Organizations maintain different types of confidentiality levels depending on the type of organization and the nature of their businesses. Table 9.2 lists the types of organizations and their confidentiality levels.

Table 9.1 Confidentiality level of data for various parties involved in R&D

Data	Sensitivity	Shared with Participants	Shared with Non-Participants during R&D	Shared with Non-Participants after completing R&D	Shared with Non-Participants during commercial use of Technology	Shared with the Users of Technology	Shared with Public
Details of Technology developed	High	Yes	No	No	No	Yes	No
Process Details	High	Yes	No	No	No	Yes	No
Background IP	High	Yes	No	No	No	No	No
Pilot Test data	High	Yes	No	No	No	Yes	No
R&D process for technology development	High	Yes	No	No	No	No	No
R&D Management	Low	Yes	Yes	Yes	Yes	Yes	Yes
Detail s of participants	Low	Yes	Yes	Yes	Yes	Yes	Yes
R&D Budget	Medium	Yes	Yes	Yes	Yes	Yes	Yes
Source of Funding	Medium	Yes	Yes	Yes	Yes	Yes	Yes
Funds provided by each participant	Medium	Yes	No	No	No	Yes	No
IP Policy	High	Yes	No	No	No	Yes	No
Participants use rights	High	Yes	No	No	No	Yes	Yes
Licensed User's rights	High	Yes	No	No	No	Yes	No
Cost to purchase IP	Medium	Yes	No	No	No	Yes	No
Revenue generated by selling IP	Medium	No	No	No	No	No	No
Improvements made during commercial use	High	Yes	No	No	No	Yes	No

Table 9.2 Types of organizations and their confidentiality levels

Type of Organization	Confidentiality Level
Universities	Medium
R&D Consulting Firms	Medium
Government	Medium
Industry	High

The level of confidentiality decreases during a project. For example, in UTF SAGD, the confidentiality of the UTF SAGD technology decreased over time, and the technology finally became less confidential when the expiry dates of the patents approached. As time elapsed, the R&D experience became more important than the IP generated through R&D.

9.7 Competition vs. Cooperation

In collaborative R&D, the various parties involved are organizations in a similar business from the same industry and with the same interests. A certain amount of competition always exists among such participants, but since the end result after the successful completion of the R&D benefits everyone involved, they are all willing to collaborate despite being competitive. The case studies demonstrated that the participants were cooperative but also were unwilling to share certain elements of R&D. For example in the case of Carbonates, the participants wanted to conduct individual pilot tests and were not willing to share the pilot test data. R&D was conducted collaboratively, but the pilot tests were conducted individually. Please refer to Section 9.7 for the rationale behind individual and combined pilot tests.

In Carbonates, more collaborative R&D was conducted on the reservoir characterization than on the recovery technologies because the industry participants remained competitive about the latter. This example shows that an organization can be both cooperative and competitive within the same R&D program. In the energy sector, one common observation is that, if the industries have their own proprietary process, they are not inclined to share it, but are willing to share the reservoir characteristics. Organizations with a proprietary technology tend to be unwilling to share it. Competition always exists in collaboration, in which the participants are always either competitive or partially competitive.

9.8 Demonstration of Technology: Pilot Test Model

A pilot test is the method used to demonstrate in the field the technology developed in the laboratory. The pilot test data are very important and contain valuable information about the field test runs. The use of field trials is of great benefit to collaborative research participants. Knowledge of the field tests allows R&D participants to recognize problems early in the R&D process and to improve the probability of success for commercial implementation. Field pilot test tests are as important as theoretical concepts and laboratory work. Field experience and experience in pilot tests and commercial operations assist an R&D organization in bridging the gap between the laboratory and field implementation. The issues related to collaborative pilot test projects are complex. Field pilot test plants are capital-intensive, and the field pilot testing of new technologies requires investment in a demonstration facility. Pilot test data are very expensive, so companies have difficulty in acquiring the data obtained from other companies' pilot tests. Two methods of conducting pilot tests in collaborative research are explained below.

Combined Pilot Test on a Shared Technology.

In this model, the pilot test is part of the R&D. Combined pilot tests are conducted jointly by all participants. This model was adopted by UTF SAGD, in which the pilot test data were part of the IP. In this case, the non-participants who bought the IP also obtained the pilot test data.

Carrying out individual pilot tests on a shared technology and sharing the knowledge.

In the second model, the participants in R&D conduct pilot tests separately. The findings and the pilot test data are shared among all the participants, but not with outsiders who buy the IP after the completion of the R&D. Thus, if an organization is interested in the pilot test data, it should participate in the R&D. This model was adopted in the JIVE program.

The first method was used in AOSTRA UTF SAGD, and the second method was used in the JIVE program. Combined prototype demonstrations contributed to the success of the UTF SAGD project. An R&D program needs to ensure that the benefits of pilot tests are available to all the participants in the program and also to those who buy the technology through licensing. Combined pilot tests on a shared technology are recommended for the following reasons: Only one field pilot test will be necessary; the program can use its most experienced field personnel to carry out the test; all the participants collaborate; resources will be shared with all participants; and pilot plant data will be shared with all participants and made available to all the users of the technology.

Reservoir characteristics are a contributing factor in determining what type of field pilot test is suitable for the R&D. A single field pilot test is possible only when the technology developed is applied to the same reservoir. If the reservoir characteristics of each of the participants are unique, and the technology developed can be applied to all these reservoirs, then the recommended method is to conduct separate field pilot tests. Doing so will provide an opportunity to collect pilot test data on reservoirs with different characteristics.

A combined pilot test is more applicable if the process is available upfront. UTF SAGD is a good example. The SAGD process was available upfront, but had not been tested. SAGD would have worked if applied to the Athabasca in-situ. An individual pilot test is used if the technology is new or proprietary to each company and the collaborative research team develops the process. In this case, the team does not want to share the field test data with the non-participants who buy the practising rights to the technology through licensing. On a combined pilot test, the test data belong to the program and also become part of the IP developed by the program, and whoever licenses the technology will also obtain the field test data. In contrast, in individual pilot tests, the test data are not part of the IP and will not be made available to the licensors.

9.9 IP Management Model

Proper IP policies should be established in collaborative research. The specifics of the collaborative engagement among the parties need to be defined clearly. IP Management is the process of managing the IP generated during the collaborative research process. The IP becomes vital in collaborative research because of the involvement of the various participants. Technology transfer and sharing occur during collaborative research and need to be considered under IP management. The participants also bring to the collaborative R&D group their background IP. Therefore, the specifics of the collaborative engagement and IP policy need to be well defined.

The IP created by collaborative research and the technology generated by the internal and external participants through the technology integration process need to be protected through IP management. All the participants bring their own technology, called the background IP, to the collaborative R&D forum, and this technology may be shared with the other participants in the program. For example, one of the participants in Carbonates had carbonates recovery technology, which was not shared with the other participants in the program. The IP protection policy should include plans to protect this background IP. The combined pilot tests conducted on shared knowledge will also become part of the IP. Plans should also be in place to include the pilot test data in the IP policy. If the field demonstration is conducted individually and if the result of the field-testing is shared among the participants of R&D, this result will become part of the IP and will need to be protected. If not, it is owned by the individual organization.

Combined pilot tests on a shared technology.

If the pilot tests are combined and conducted by all the participants together, this test is considered as part of the R&D. The IP management will include policies to cover this field data. Based on the IP model established, the companies who purchase the IP later will obtain the benefit of obtaining the pilot test data.

Individual pilot tests on a shared technology.

In this case, the participants conduct the pilot test individually. The field test results and the findings may or may not be shared with all the participants. If shared, the pilot test data become part of the IP and need to be protected. Based on the IP model, the companies who purchase the IP later may or may not obtain this IP.

Background IP.

The participating organizations' internal and external sources may possess previous knowledge of the new technology and may have developed a similar version of it. The knowledge every organization possesses of a technology being developed is called the background IP. The know-how that every participating organization brings to the technology integration may or may not be explicitly shared with all the other participants. Please refer to the example of Carbonates provided at the beginning of this section. The IP management should have clear policies in place for managing the background IP.

Improvements to technology.

Individual participating companies may decide to make changes to the newly generated technology on their own or through other R&D projects later. These improvements are not part of the original R&D project. These participants do not have to report the improvements made to the original technology to the other participants who were involved in developing it. The plans to manage improvements to the original should be addressed in the IP policy.

9.10 IP Management Model: Different Scenarios

Technology.

1. Technology and related IP are available to only the participants in the innovation.
2. Technology and related IP are available for purchasing.
3. Technology and related IP are available by buying a licence.

4. Technology and related IP are available to only the participants in the innovation process. To obtain this technology and IP, an organization must be a member of the R&D program.

Pilot test.

1. Pilot test is not part of the R&D.
2. Combined pilot test.
    a. Pilot test data are part of R&D and are protected through IP management.
    b. Pilot test data are available to only the participants in the R&D.
    c. Pilot test data are part of the R&D and are available to the non-participants in the innovation process through licensing.
3. Individual pilot test.
    a. Individual pilot test data are not shared among participants.
    b. Individual pilot test data are shared among participants.
    c. Individual pilot test data are part of the R&D and are available to non-participants through licensing.

Background IP.

1. Background IP is shared among participants and controlled through IP policy and is available to all participants.
2. Background IP is not part of R&D and is not covered under IP policy.
3. Sharing of background IP is voluntary and is not be protected under IP policy.
4. Background IP is part of IP and is available to all participants. Non-participants also obtain the background IP when they license the technology.

Improvements to technology.

1. All participants are informed about the improvements made to original technology.
2. No need to inform participants about such improvements.
3. Improvements made to technology by individual organizations will be added to the original IP and will be made available to all participants in the original research. However, these improvements will not be available to the non-participants who buy a license.
4. The R&D manager is informed about any improvements to the original technology and makes them available to all the holders of IP, the participants of the R&D and the licence holders of IP.

9.11 Recommended IP Management Model

1. Technology and related IP are available through licensing, which helps to disseminate new technology in a controlled manner. By restricting the availability of newly developed technology only to the participants, the benefits of the innovation are received by only a small community. The technology and related IP available for licensing may be only those developed through collaboration, and licenses may not be available for the individual components such as individual pilot tests, background IP, and proprietary technology. If all the participants are licensed, both government and industry benefit. Among the cases studied, in UTF, Carbonates, and JIVE, the technology and related IP are available through licensing. In the case of AACI and Weyburn, access to technology is possible only through participation.

2. Pilot tests (combined or individual) and related data are part of R&D and are available to the participants and to the non-participants through licensing. This policy facilitates the distribution of the technology and the data produced by its application, so that they are available to both the participants and non-participants in the R&D. In UTF and JIVE, pilot test data are part of the R&D and are available to the participants and to the non-participants through licensing. AACI is considering the test data on a case-by-case basis, but they are available only to the participants. Weyburn's test data are available only to the participants, and in Carbonates, pilot tests were not part of the program.
3. Background IP is shared among participants and controlled through IP policy and is available to all participants. Background IP is important for technology development. Controlling background IP through policies facilitates its distribution in a controlled manner. The participants in all the five cases studied had background IP and shared it with their programs.
4. Improvements made to the technology by individual organizations after the completion of R&D are added to the original IP. These improvements may be shared with everyone who has the right to practise the technology: the participants in the original innovation and the non-participants who license the technology. By adding the improvements to the original IP, its distribution among all those who use the technology is guaranteed. If the technology is shared, all its users will benefit from these improvements. License holders of UTF SAGD technology have the right to make improvements to the patented UTF Technology, and they need not inform the IP manager about any improvements they make. Thus, both

the improvements made to the original IP, and the benefits of these improvements, remain within a very small community.

However, the process of managing these improvements is difficult, and the IP manager's responsibility is to ensure that they are shared among everyone who has the right to practise the technology. Individual organizations that make improvements can be allowed to sell them to the IP Manager for a reasonable price, and the IP Manager can be allowed to distribute the improvements to individual organizations who are interested in paying a fee for the improvements. Figure 9.7 shows the recommended IP model for collaborative research.

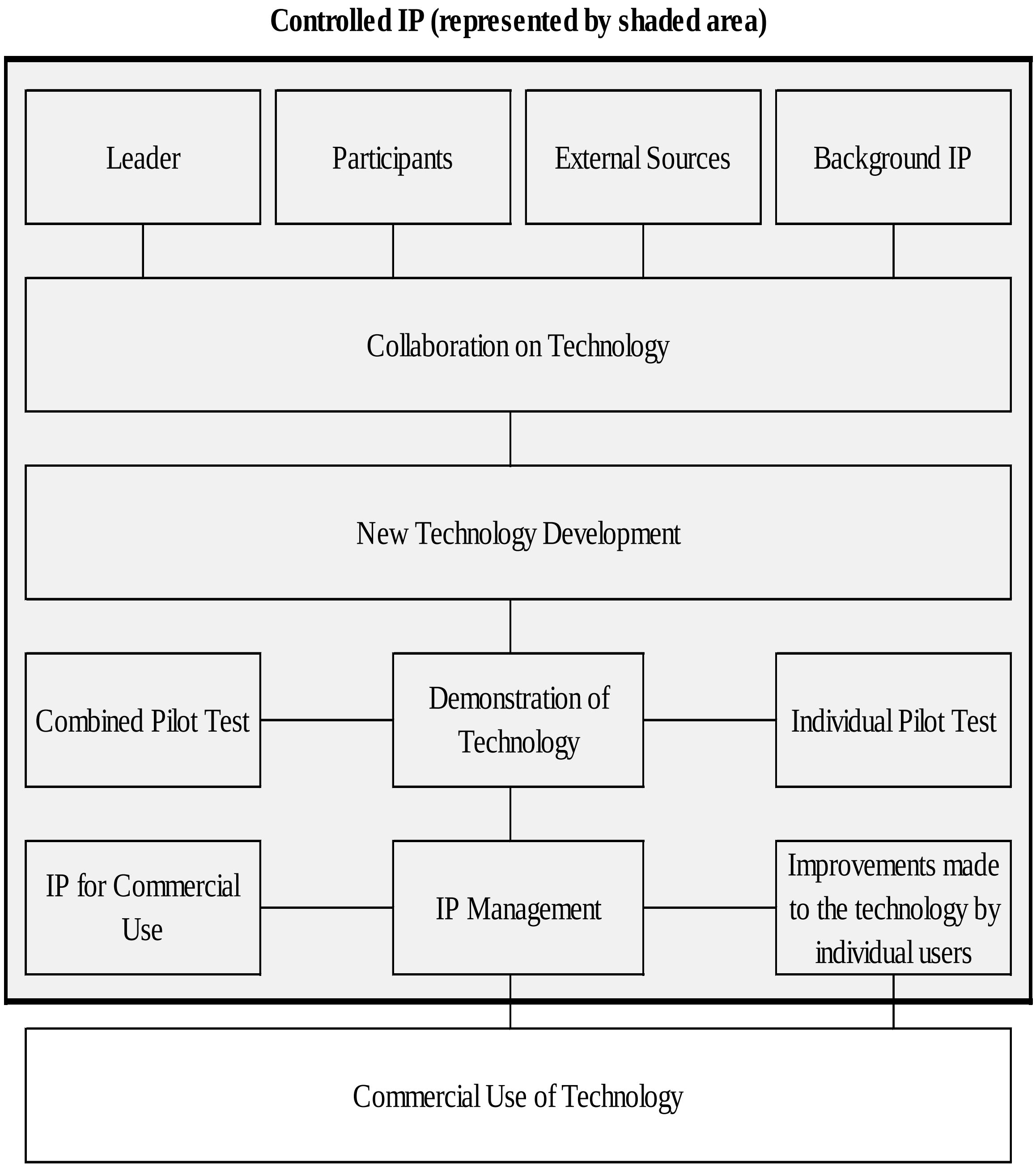


Figure 9.7 Recommended IP model for collaborative research

9.12 Summary

Collaborative research is a process in which different parties collaborate to develop technology. This chapter provided an insight into the development of the CRTD model developed from the findings of the case studies. The key collaborative research elements for technology development identified in the case studies were also explained in this chapter. Technology transfer occurs throughout the innovation process. The case studies conducted demonstrated that the transfer and sharing of technology occur among organizations in collaborative research.

The period of maintaining confidentiality before making technology available to the public is important in collaboration. The level of confidentiality depends on the level of participation and the elements of the innovation process. The confidentiality level varies, depending on the data and the type of organization. The level of confidentiality differs during the various stages of innovation. Competition always exists in collaboration, in which the participants are always either competitive or partially competitive. Since the end result after the successful completion of the R&D benefits everyone involved, they are all willing to collaborate despite being competitive.

Chapter 10 CRTD Model

10.1 Overview

The creation of new technology is a complex process. Various entities with different technological backgrounds participate in collaborative research in order to create new technology. CRTD processes, R&D phases, and the benchmark for measuring the success of a CRTD project are discussed in this chapter, which continues to discuss the CRTD model introduced in the previous chapter. The complete CRTD model is discussed in this chapter.

10.2 Technology Development

An organization that identifies a problem needing an innovative solution, has to decide whether to solve the problem either on its own or with the help of others. If the organization chooses the second alternative, collaborative research will follow. The organization that champions the innovation will be the leader. The following are the main tasks in collaborative research:

1. Identify the technology required.
2. Identify the technology that the leader can generate.
3. Identify the technology required from outside.
4. Identify the outside sources that can contribute to the technology development.
5. Devise methods to invite the outside technology sources.
6. Channel the outside technology sources to the consortium.
7. Provide a venue for the leader and outside sources to collaborate.
8. Identify the background IP of the leader and the participants.

9. Combine the background IP and the technology generated by the leader and the participants to create the new technology.

To some extent, most innovation, whether open or closed, requires information from various sources (either internal sources or sources external to the organization). Figure 10.1 provides the flow chart of the events in collaborative research.

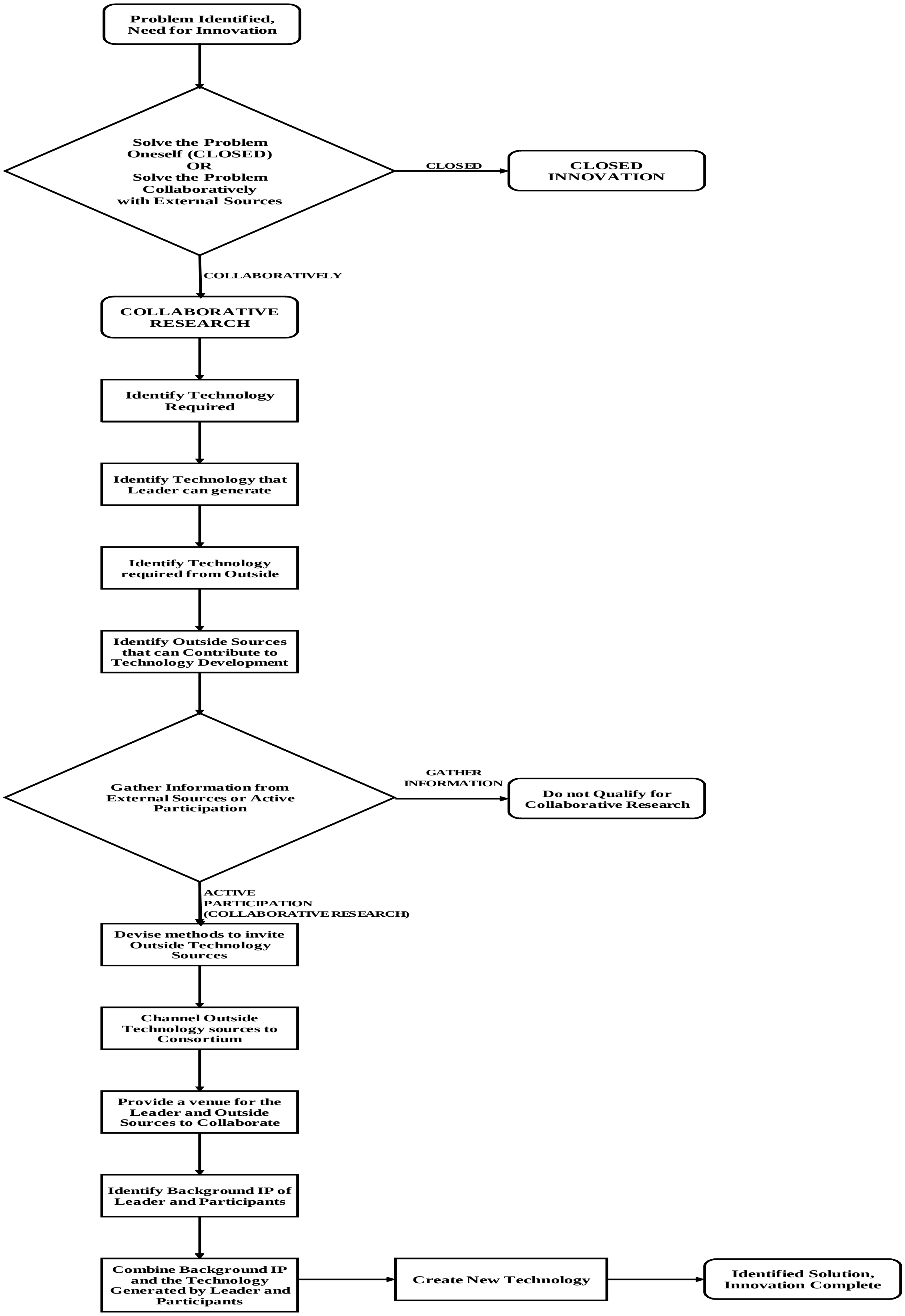


Figure 10.1 Flow chart of events in collaborative research

10.3 R&D Phases in CRTD

Organizations decide whether to conduct innovation collaboratively or on their own. If they decide on collaboration, the CRTD model can be used. Its five phases are (1) gathering technological sources, (2) developing technology, (3) demonstrating the developed technology, (4) commercializing the technology, and (5) using the technology.

The following are the key activities in the gathering technological sources phase:

1. Identifying potential participants: In the case of UTF SAGD, the participants were major oil companies who were interested in advanced technologies to extract bitumen from oil sands. AOSTRA identified the potential participants for this project.
2. Forming the CRTD team: The Weyburn collaborative research team was formed with six government and nine industry participants, and twenty-four research providers and consulting organizations and about seventy technical and project personnel.
3. Identifying the leader: The leader is identified at the beginning of the project. For example the leader for UTF SAGD was AOSTRA, and the leader for Weyburn was PTRC.
4. Securing R&D funding: R&D funds and sources were secured at the beginning of the project. For example, in UTF SAGD, the funding was made up of contributions from AOSTRA, and equal contributions of nine industry participants, and revenue from bitumen product sales during the field pilot test.
5. Developing an IP policy for the R&D phase and commercialization: IP policy for R&D and post R&D during commercialization were developed at the beginning

of the project. In the case of UTF SAGD, the IP policies were developed, and ARC was identified as the IP manager.

6. Inviting other external sources such as academics, research providers, and consultants: Weyburn invited twenty-four research providers and consulting organizations from Canada, US, and Europe to join the R&D project.

In developing technology, the following are the key activities:

1. Sharing internal technology among the participants: Sharing of internal technology may vary from project to project, and not all the internal technology is shared with other participants. This point was demonstrated in the case studies.
2. Gathering technology input from other external sources: Technological input is gathered from external sources, such as participants, research providers, consultants, and other associations developed during the project.
3. Sharing background IP among the participants and other external sources, based on the IP policy: The background IP that will be shared is controlled though IP policy. The decision to share background IP may vary from project to project.
4. Combining internal technology, background IP, and technology input from external sources to develop a new technology: Technology is developed collaboratively by combining the technology gathered from various sources.

In demonstrating the developed technology, the following are the key activities:

1. Conducting combined pilot tests on the new technology: In the case of UTF SAGD, a combined pilot test was conducted to demonstrate technology.
2. Alternatively, conducting individual pilot tests on the new technology: Individual pilot tests were conducted by the participants in the JIVE program.

3. Sharing the test data and results among the participants: In UTF SAGD, the pilot test was combined, and in JIVE, the pilot test was conducted individually. In both cases, the test data and the results were shared among the participants.

In commercializing the technology, the following are the key activities:

1. Improving the IP policy for commercialization: The IP policy for commercialization developed in phase 1 is updated prior to the release of IP for commercial use.
2. Identifying the IP manager: For UTF SAGD the IP policy was developed, and ARC was identified as the IP manager.
3. Issuing technology and IP for commercial use: IP manager controls the release of technology and IP for commercial use.

In using the technology, the following are the key activities:

1. Using the developed technology in commercial applications: In 2009, twenty operating facilities were using SAGD technology. $3.5 billion Canadian had been invested, and about 414,000 bbl/day of bitumen were being produced.
2. Making improvements to the technology: The users of the technology are free to make improvements to the acquired technology.
3. Informing the IP manager of the improvements: The IP manager shares the improvements made to the technology with the other users of the technology.
4. Sharing these improvements with the team: Individual organizations can make changes to the technology while using it. These changes need to be shared with the IP Manager, so that all the users can benefit from them.

Figure 10.2 shows the R&D phases in CRTD.

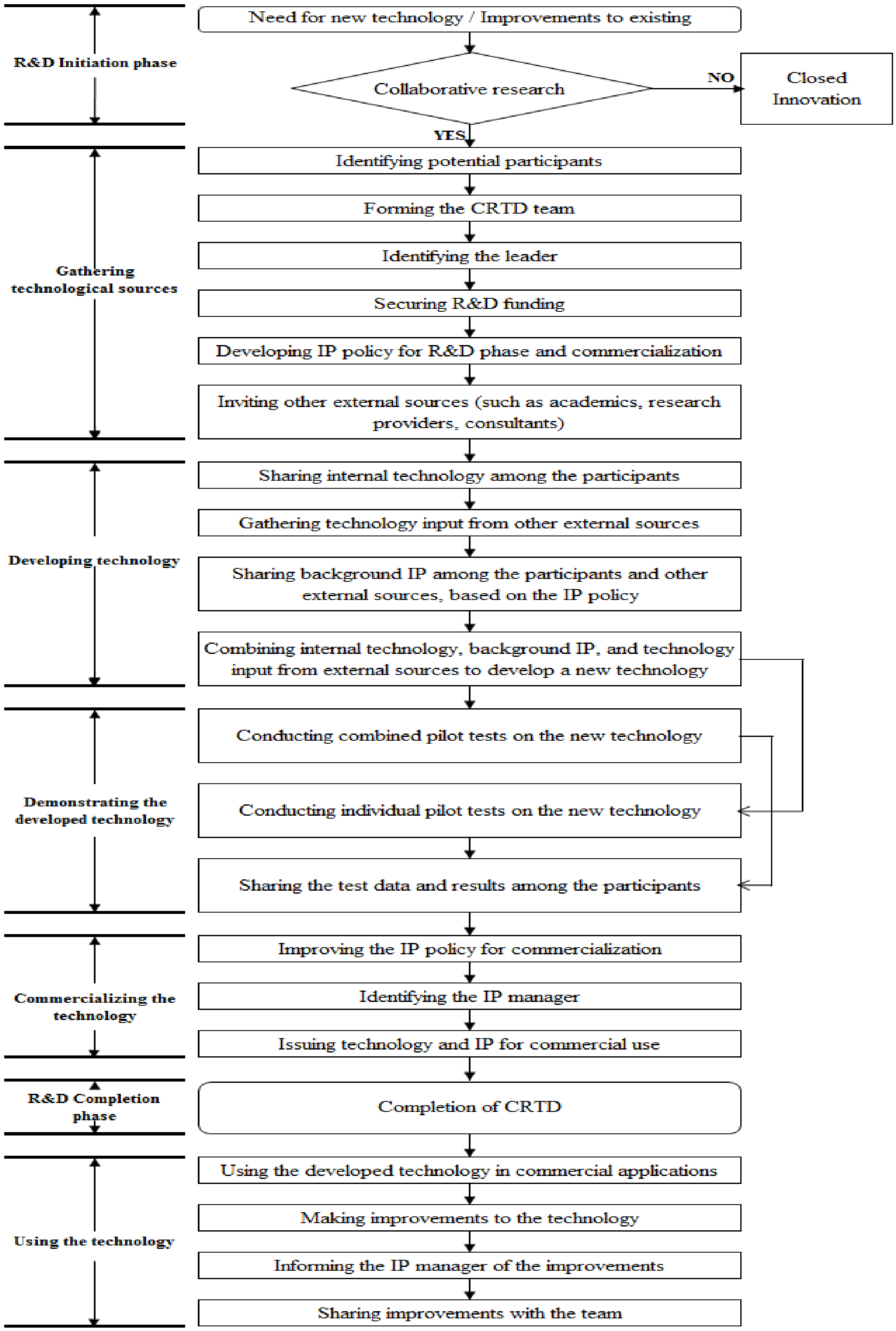


Figure 10.2 R&D phases in CRTD

10.4 CRTD Process

The developed technology will be used by the R&D participants and also by others who will purchase the use rights for the technology. The technology will be distributed in a controlled manner to ensure its use and availability to others who were not part of the R&D. Figure 10.3 shows the CRTD process.

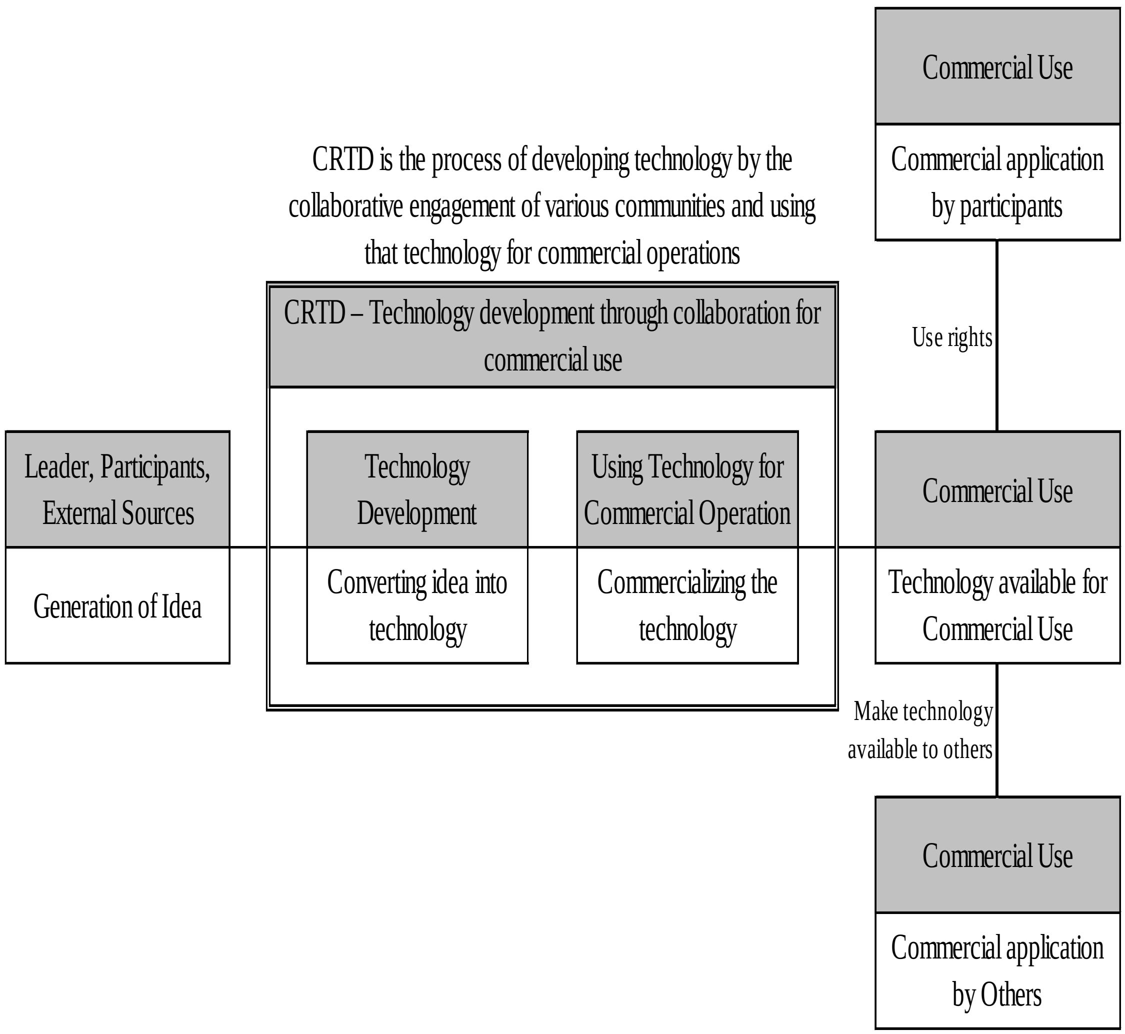


Figure 10.3 CRTD process

10.5 CRTD Model

This thesis' CRTD model consists of ten main components:

1. Leader
2. Participants
3. External Sources
4. Background IP
5. Collaboration in Developing New Technology
6. New Technology Development
7. Pilot Test
8. IP Management
9. Commercial use of Technology
10. Improvements Made to the Technology by Individual Users' During Commercial Use.

Figure 10.4 presents the main components of the CRTD model, and Table 10.1 outlines the differences between this model and open innovation.

Table 10.1 Comparison between open innovation and CRTD

Open Innovation	CRTD
Seeks knowledge from external sources	Seeks collaboration from external sources
No closed component present in open innovation	Presence of closed components in collaborative research
No provision to control IP	Controlled distribution of IP
Leader searches for external knowledge sources	Leader invites organizations that can contribute and actively participate in the development of technology
IP is made available to public	IP is controlled and interested parties can purchase use rights of IP
Background IP is not part of R&D, no sharing of background IP	Controlled sharing and use of Background IP
Technology make available in the global knowledge landscape for others to access	Technology is shared within the consortium and made available to users
No patent or licenses to control IP	Patents and licenses exist to control IP
Seek knowledge from participants during R&D	Seek collaboration from participants during R&D
Concept used for product development	Concept used for technology / process development
Existence of competition among participants is not identified	Recognition of the existence of competition among participants
100% open among participants	100% collaboration among participants
Clear distinction between technology created by internal R&D and technology received from external sources	No distinction between technology created by leader or the participants
No IP Management	IP Management exists
Improvements to the developed technology are not part of IP	Improvements during commercial use shared with all users and become part of IP
No distinction between participants and non-participants	Clear distinction between participants and non-participants

The following are the main highlights of the CRTD model.

R&D management.

A committee with representatives from all the participating members manages R&D.

Participants.

The various participants include industry participants, government participants, funding providers, research providers, and consultants. The research providers, who provide necessary support to the R&D, are not part of the innovation program and have no rights to use the technology. The funding providers, who provide financial support to the program, are part of its program, but normally do not have any use rights to the technology. The industry participants and government participants also provide funding to the program.

Technology developed.

The rights to use the technology depend on the level of participation. The technology is developed collaboratively and is used by the various participants.

Benefits.

Different groups such as the government, industry, the public, and academic organizations benefit from the technology.

Budget.

The participants and the funding providers share in the R&D budget.

Leader.

The leader initiates the program and later on invites all the other participants. The leader champions the program, but does not normally have any additional powers in the consortium.

Collaboration.

Technology is developed through collaboration.

Participating rights of the R&D participants.

Participants will have free rights to use the technology.

Participating rights of non-participants.

Non-participants can obtain the right to use the technology through licensing.

IP management.

IP management is based on the IP policy developed at the beginning of the program, prior to the start of the program. The IP policy greatly contributes to an organization's decision to join the program. An IP Manager, who manages IP centrally, is in charge of issuing the use rights for the technology. IP management is an on-going task required as long as the technology is in use. Any changes made to the IP during the technology-in-use stage need to be communicated to all the users.

Background IP.

The sharing of the background IP among the participants during R&D facilitates the successful completion of the R&D and is monitored according to the IP policy.

Improvements to developed technology.

The users of the technology are free to make changes to it. Depending on the agreement, they may or may not report to the consortium about any improvements made. The IP manager will ensure that these changes are communicated to all the users.

IP made available to others.

The IP is available not only to the participants in the R&D, but also to anyone who wants to use the technology on a controlled basis. IP is controlled through licensing as described in the IP policy.

Pilot tests.

Pilot tests may or may not be part of R&D (e.g., in Carbonates, a pilot test was not part of R&D) and includes the combined tests and all the individual pilot tests. The data collected from these tests become part of the IP and are made available to the users of the technology.

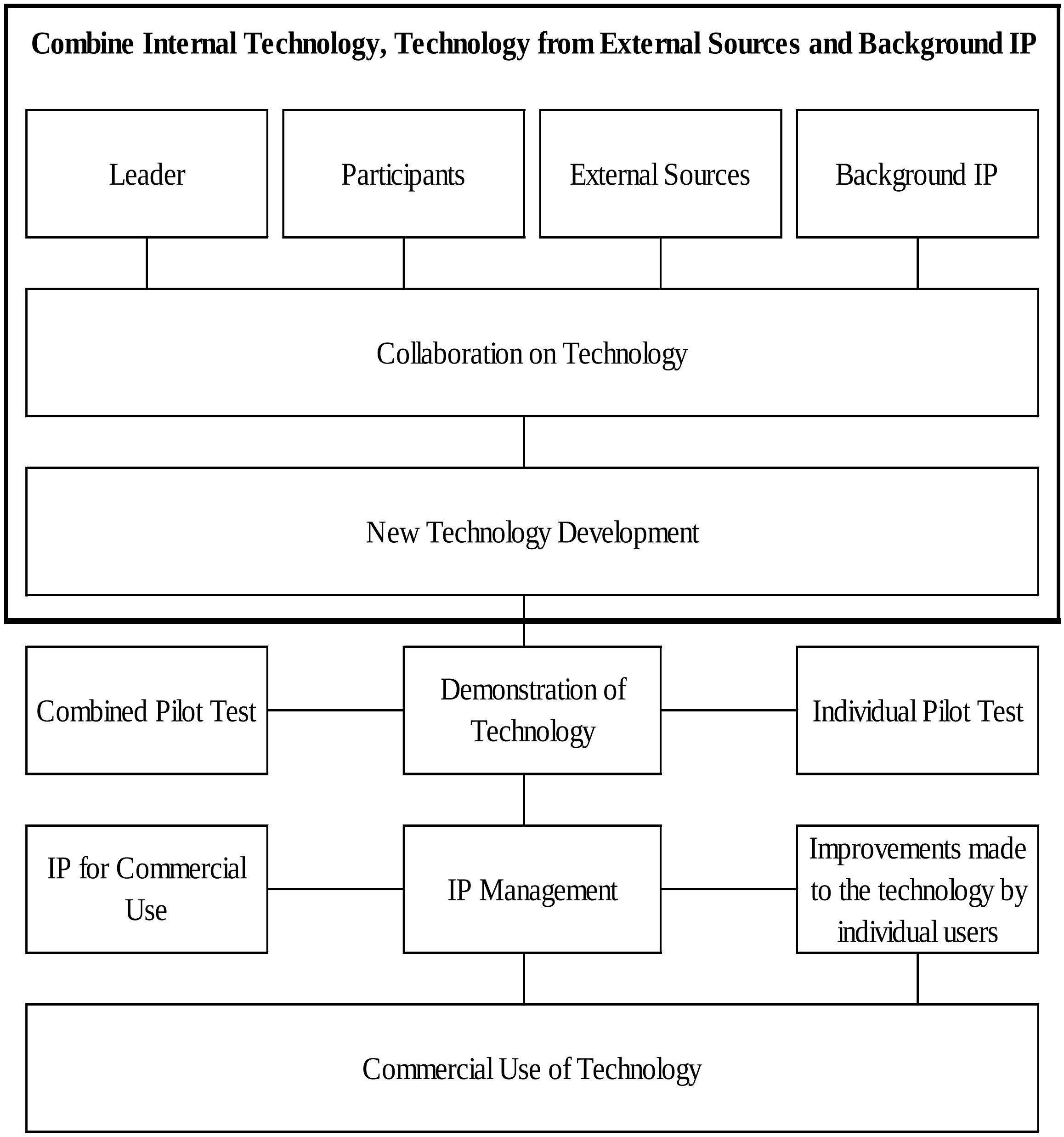


Figure 10.4 The CRTD Model

Commercial use of the developed technology.

All the participants and any others who purchase a license can use the technology. Thus, it has multiple users and reaches the market through multiple channels.

10.6 Measure of Success

The following factors contribute to the measure of success for a collaborative research project:

1. The redefinition of the R&D functions and responsibilities for collaborative research.
2. The contribution of background IP to the innovation.
3. The contribution of technology from outside sources to the innovation.
4. The extent to which the new technology is used by others for commercial operations.
5. The leverage on R&D investment.
6. The amount of revenue generated by the new technology.
7. The degree to which the R&D expenses are reduced.
8. The organization's exposure to new technology.
9. The extent to which the newly developed technology is being used.
10. The extent to which the use of collaborative research has reduced the amount of time needed for new technology development.
11. The number of new participants in the project, if it was in the same sector as that of the previous project.
12. The number of previous participants who hesitated to participate in the new project, if it was in the same sector as that of the previous project.

13. The number of staff trained in the new technology.

14. The sharing of the project costs.

15. The inclusion of pilot test in the R&D.

16. The use of an IP management policy.

Table 10.2 provides a benchmark for measuring the success of collaborative research.

Table 10.2 Benchmarks to measure the success of collaborative research

	Success Factors for Collaborative Research	Benchmarks
1	Redefine R&D for collaborative research	Redefines R&D
2	What is the contribution of background IP to the innovation?	0% to 40%
3	What is the contribution of technology from outside sources to the innovation?	2/3
4	How much of the new technology is used by others for commercial operations?	Greater than 25%
5	What is the leverage on the R&D investment?	Greater than a factor of 10
6	Is the new technology generating revenue?	Yes
7	Were the R&D expenses reduced?	Yes
8	How much of the organization is exposed to new technology?	More than 1/2
9	Is the new technology currently being used?	Yes
10	Has the period for new technology development been reduced by the introduction of collaborative research?	Reduced
11	Are the participants the same? Are there any new participants?	There are new participants along with the previous participants.
12	Did any of the previous participants hesitate to become part of the new technology development, if it was in the same sector as the previous development?	Previous participants did not hesitate to become part of new technology development.
13	How much of your staff is trained in the new technology?	Staff is trained in the new technology and have access to expertise in the new technology.
14	Is the project cost shared by all participants?	Yes, equally by all participants
15	Is field demonstration part of R&D?	Yes
16	Is there an IP management policy in place?	Yes

10.7 Summary

The steps involved in the development of technology and different R&D phases were explained in this chapter, which also provided a CRTD model that will help organizations to implement R&D collaboratively. The CRTD model discussed in this chapter was developed for the energy sector. However, organizations will be able to apply the model or the concept to other sectors as well. A flow chart of the events for the collaborative development of technology and the various R&D steps involved in collaboration was discussed in this chapter. The benchmarks to measure the CRTD model's success were also discussed.

Chapter 11 Innovation in the Energy Sector: Collaborative or Closed?

11.1 Overview

Organizations can innovate through either collaborative or closed innovation. Their innovation process differs, for the two types of innovation apply to different situations. The factors and guidelines provided in this chapter will help an organization to decide whether or not to use CRTD. This chapter also explains when and how to use CRTD and what factors influence the decision to use it. This chapter also examines whether all the participants receive a fair market share from collaborative innovation. Finally, the limitations and negative aspects of collaborative innovation are discussed.

11.2 Factors Influencing the Decision to Use CRTD

The factors influencing the decision to use CRTD are provided below. These twenty-six factors will help an organization to decide when to use CRTD.

1. **Sharing of Intellectual Property:** Before deciding to launch CRTD, an organization needs to determine its willingness to share IP.
2. **Sharing of technology:** The willingness to share developed and internal technology also determines if innovation will be CRTD.
3. **Availability of proprietary technology:** The availability of proprietary technology determines the need to seek technology from external sources.
4. **Strong technical position:** An organization's technical position determines the organization's ability to meet its need for technology. An organization in a strong technical position will not need to seek technology outside the organization.

5. **Large and complex problems:** The magnitude and complexity of problems will help an organization to determine whether it needs external support to find solutions.
6. **Need to solve the problem with the help of others:** An organization must decide whether or not to use external support and resources to solve its R&D problems and replace its inadequate technology.
7. **Need for external technology:** An organization must decide whether it needs to use external technology to satisfy its R&D needs. If external technology is needed, the organization will develop methods to identify and use external technology in its R&D.
8. **Sharing of background Intellectual property:** An organization's decision to share or not to share intellectual property also determines what type of innovation method will be used.
9. **Sharing the benefits of new technology with other industries:** An organization's decision whether or not to share the benefits of the newly developed technology with others determines the choice of innovation method.
10. **Need for new technology:** An organization's demand for new technology and how soon it is needed help the organization to choose an innovation method.
11. **Availability of recognized experts and scientists in-house:** The availability of know-how and the strength of human resources help an organization to determine whether it should seek outside expertise.

12. **Availability of R&D funds:** An organization's ability to invest in R&D influences the decision to collaborate on R&D, as the participants will share funding during CRTD.
13. **Collaborative R&D:** An organization must decide whether or not it will share its R&D efforts with others.
14. **Sharing of pilot test data:** An organization must decide whether or not it will share its pilot test data with others.
15. **Market monopoly:** An organization needs to study the market before launching R&D that will share the organization's IP with its competitors.
16. **Collaboration with other organizations:** An organization should examine how collaboration with other organizations in the same industry will affect its business.
17. **R&D culture:** R&D strategies should be based on an organization's business model. The R&D strategy will be driven by the technology demand supported by the knowledge management strategy and commercialization strategy. The R&D culture for the organization is developed from its R&D strategy and will guide the decision to use either collaborative or closed methods.
18. **Leverage on R&D investment:** An organization's business decision about the returns on R&D investment drives the decision to collaborate on R&D. An organization seeking leverage on its R&D investment will prefer to use less funding for R&D and to obtain a faster and bigger return for that investment.
19. **High competition:** The level of competition in the market determines the decision whether or not to share R&D with competitors.

20. **Competition strategy:** An organization's competition strategy is a valuable input into the decision either to share or not to share technology with others. The two cases of market monopoly and high competition are discussed above.

21. **Duration of R&D:** The duration of R&D influences the decision to use collaboration. R&D in collaborative innovation might be completed more quickly than in closed innovation.

22. **First-hand user of technology:** An organization needs to decide whether it needs to be the first-hand user of technology in order to have the advantage of being the first in the market.

23. **Dissemination of technology:** An organization needs to decide whether it wants to disseminate or hoard its technology.

24. **Establish a network with other industries, R&D organizations and government:** An organization must decide if it wants to develop a network with other organizations in the same business in order to help the organization to seek support when it is needed.

25. **Become a leader in new technology development:** An organization must decide whether it wants to become a pioneer in technology development.

26. **Access to newly developed technology:** Before participating in collaborative innovation, an organization must know whether or not it will be able to access any newly developed technology soon after the completion of R&D.

Table 11.1 contains the twenty-six factors described in this section and their relationship to collaborative and closed innovation.

Table 11.1 Factors and their relationship to collaborative and closed

No.	Sector				Influence	Factors	Influence	Sector			
	Government		Industry					Government		Industry	
	Collaborative	Closed	Collaborative	Closed				Collaborative	Closed	Collaborative	Closed
1		√		√	Not shared	Sharing of Intellectual Property	Shared	√		√	
2		√		√	Not shared	Sharing of technology	Shared	√		√	
3	√		√		Not available	Availability of proprietary technology	Available	√			√
4	√		√		Week	Strong technical position	Strong	√			√
5		√		√	Less Complex	Large and complex problems	Complex Problem	√		√	
6						Need to solve the problem with the help of others	Collaboration	√		√	
7				√	No Need	Need for external technology	Bigger Need	√		√	
8		√		√	Not shared	Sharing of background Intellectual property	Shared	√		√	
9		√		√	Not shared	Sharing the benefits of new technology with other industries	Shared	√		√	
10					No Need	Need for new technology	Bigger Need	√		√	
11	√		√		Not enough	Availability of recognized experts and scientists in-house	Available	√			√
12	√		√		Less funds available	Availability of R&D funds	Available	√			√
13	√	√		√	Less collaboration	Collaborative R&D	More collaboration	√		√	
14	√	√	√	√	Individual test	Sharing of pilot test data	Combined test	√		√	
15						Market monopoly		√			√
16	√	√		√	Less collaboration	Collaboration with other organizations	More collaboration	√		√	
17		√		√	Closed	R&D culture (Collaborative or Closed)	Collaboration	√		√	
18				√	Low leverage	Leverage on R&D investment	High leverage	√		√	
19						High competition		√			√
20			√	√		Competition strategy				√	√
21		√		√	More duration	Duration of R&D	Less duration	√		√	
22		√		√	Second hand	First-hand user of technology	First hand	√		√	
23		√		√	Slower	Dissemination of technology	Faster	√		√	
24		√		√	No network	Establish a network with other industries, R&D organizations and government	More network	√		√	
25						Become a leader in new technology development		√		√	√
26		√		√	Gradual access	Access to newly developed technology	Immediate access	√		√	

Table 11.1 was developed from the case studies. The table illustrates twenty-six factors that were identified as important during the case study research. The case study data brought to light these factors as the most influential in the process of distinguishing what leads to innovation between collaborative or closed organizational systems. Highlighting these factors and their influence sets the stage for developing the guidelines on when to use CRTD. The factors were associated with definitive patterns in businesses' approaches to collaborative innovation in all the cases. The changes that will occur in an organization based on these factors' presence and absence in their business strategy should be carefully considered. An organization should also consider how these factors can shift in importance depending on whether they are associated with industry or with government. The ranking system of these factors can be considered as a strong and reliable guideline for helping organizations to identify whether to use collaboration or closed strategies.

Table 11.1 illustrates the relationships among the factors, and the variation of their influence on businesses in the government and industry sectors. For example, intellectual property will be shared in collaborative business models, and IP will not be shared in closed innovation business models no matter what sector is involved. In both the government and the industry sectors, technology will be shared in collaborative business models, and technology will not be shared in closed innovation business models. The influence of the availability of proprietary technology on the decision to use collaborative business models can be different for the government and industry sector. The availability of proprietary technology gives an organization, a strong technical position. Industry will consider this position a technical advantage and may decide to develop the technology without external support, by adopting a closed approach. The government availability of proprietary technology can be considered as an opportunity to share and develop the technology with other partners from industry, and also can influence an organization to adopt a CRTD approach.

11.3 CRTD Innovation Guidelines

The previous section analyzed twenty-six different factors that influence the decision to use collaborative innovation. In this section, these factors are ranked depending on how strongly they influence the firm's decision to use collaborative innovation. The ranking helps to explain the level of influence of these factors.

The ranking of these factors was developed by using information from the qualitative analysis of the case studies. Table 11.2 summarizes the qualitative analysis process used to develop the ranking of the factors. The twenty-six factors and their influence level for each case study were determined. These factors were weighted for the five cases to derive the overall weighted percentage. Major contributing factors are ranked 10, which has an overall weighting of 6%, and the second major contributing factors are ranked 8, which has an overall weighting of 5%. The third contributing factors are ranked 7, which has an overall weighting of 4%, and the factors with a weighting of 3% and 2% are ranked 6 and 5, respectively.

Four factors were found to be the most influential in the decision to implement collaborative innovation processes: Sharing of intellectual property, sharing of technology, availability of proprietary technology and strong technical position. These factors are ranked ten in this factor table. An organization using CRTD should be willing to share IP and technology. An organization that possesses proprietary technology is in a strong technical position and might choose to use closed innovation, the recommended method for solving large and complex problems. Thus, it is ranked eight. The magnitude of the problem is among the top five factors to be considered in the decision to use collaborative business models. The decision to use external support or external technology is another factor influencing the decision to use collaborative business models. Sharing of background IP the benefits of the developed technology is necessary in CRTD and requires serious consideration before deciding to launch collaborative business models. The issue of sharing is also considered as a high-ranking factor influencing the decision to launch CRTD.

The weighting of the factors provided in Table 11.3 was developed based on the observations from the case studies and the judgment of the author. Various other methods are available for establishing the ranking of these factors. The conclusions reached by using the weighting of the factors are not highly sensitive to minor differences in criteria, such as differences in the order of 10%-20%. Table 11.3 provides the factors and their ranking based on their level of influence. The factors are ranked from 10 to 1 depending on their level of influence, 10 being highly influential and 1 being negligibly influential. This ranking does not mean that these factors support either collaborative or closed innovation models, but rather that these factors influence the decision about what kind of innovation will be used.

Table 11.2 Summary of qualitative analysis to develop the ranking of factors

Sl No.	FACTORS	Determining factors and their level of influence on the decision to join collaborative project: UTF SAGD – % Level of Influence	UTF SAGD – Weighted %	AACI – % Level of Influence	AACI – Weighted %	Weyburn – % Level of Influence	Weyburn – Weighted %	Carbonates – % Level of Influence	Carbonates – Weighted %	JIVE – % Level of Influence	JIVE – Weighted %	Overall Weighted Percentage	Rank determined based on Weighted Percentage
1	Sharing of intellectual property	6%	1%	6%	1%	6%	1%	6%	1%	6%	1%	6%	10
2	Sharing of technology	6%	1%	6%	1%	6%	1%	6%	1%	6%	1%	6%	10
3	Availability of proprietary technology	5%	1%	6%	1%	6%	1%	6%	1%	6%	1%	6%	10
4	Strong technical position	5%	1%	6%	1%	6%	1%	6%	1%	6%	1%	6%	10
5	Large and complex problems	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	8
6	Need to solve the problem with the help of others	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	8
7	Need for external technology	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	8
8	Sharing of background Intellectual property	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	8
9	Sharing the benefits of new technology with other industries	4%	1%	4%	1%	5%	1%	5%	1%	5%	1%	5%	8
10	Need for new technology	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
11	Availability of recognized experts and scientists in-house	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
12	Availability of R&D funds	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
13	Collaborative R&D	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
14	Sharing of pilot test data	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
15	Market monopoly	4%	1%	4%	1%	4%	1%	4%	1%	4%	1%	4%	7
16	Collaboration with other organizations	3%	1%	3%	1%	3%	1%	3%	1%	3%	1%	3%	6
17	R&D culture (Collaborative or Closed)	3%	1%	3%	1%	3%	1%	3%	1%	3%	1%	3%	6
18	Leverage on R&D investment	3%	1%	3%	1%	3%	1%	3%	1%	3%	1%	3%	6
19	High competition	3%	1%	3%	1%	3%	1%	3%	1%	3%	1%	3%	6
20	Competition strategy	3%	1%	3%	1%	3%	1%	3%	1%	3%	1%	3%	6
21	Duration of R&D	3%	1%	3%	1%	2%	0%	2%	0%	2%	0%	2%	5
22	First-hand user of technology	3%	1%	2%	0%	2%	0%	2%	0%	2%	0%	2%	5
23	Dissemination of technology	3%	1%	2%	0%	2%	0%	2%	0%	2%	0%	2%	5
24	Establish a network	2%	0%	2%	0%	2%	0%	2%	0%	2%	0%	2%	5
25	Become a leader in new technology development	2%	0%	2%	0%	2%	0%	2%	0%	2%	0%	2%	5
26	Access to newly developed technology	2%	0%	2%	0%	2%	0%	2%	0%	2%	0%	2%	5
TOTAL		100%	20%	100%	20%	100%	20%	100%	20%	100%	20%	100%	

Graphical representation of the ranking of factors

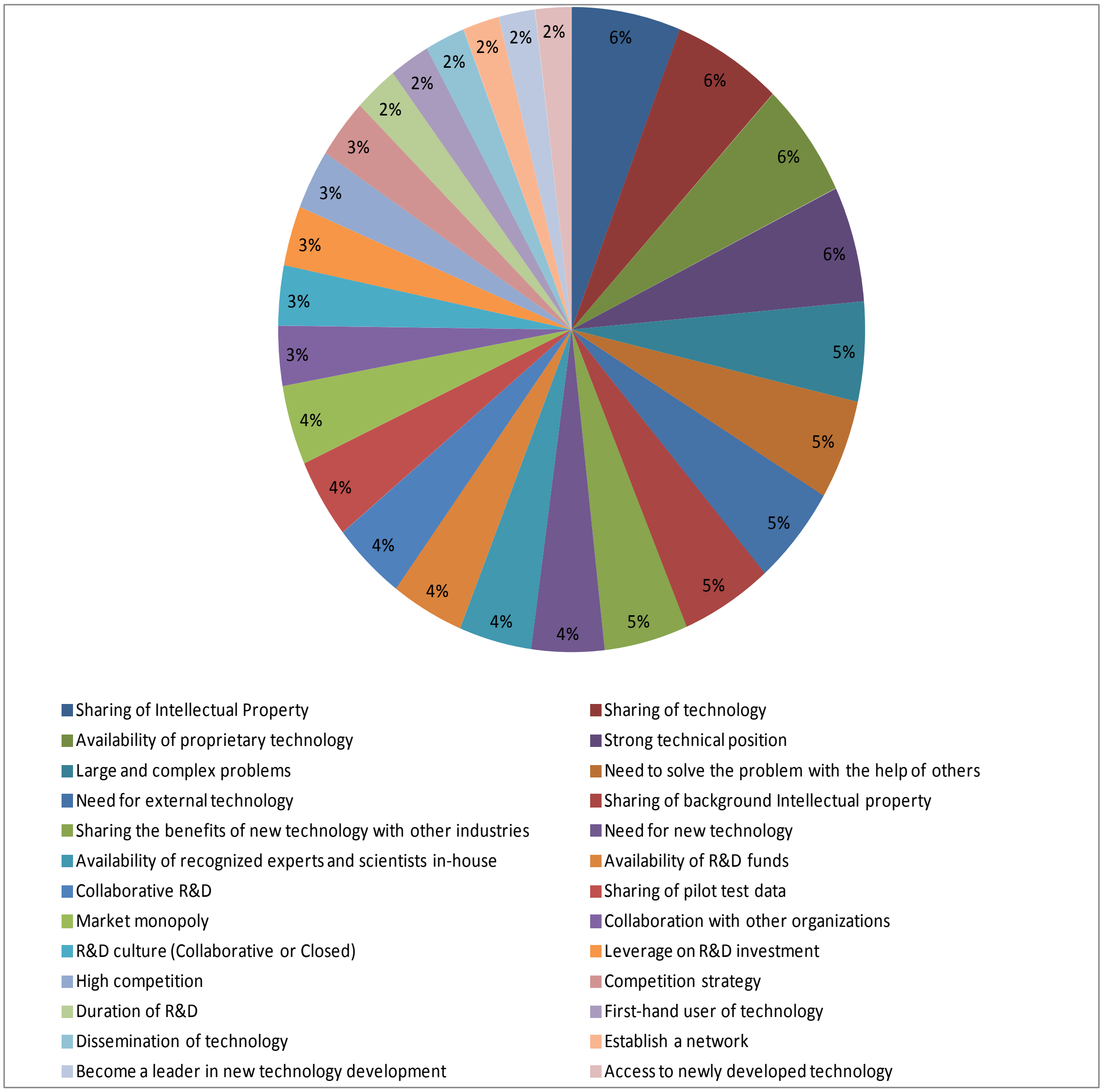


Table 11.3 The factors and level of influence in using CRTD

Sl No.	FACTORS	RANK
1	Sharing of Intellectual Property	10
2	Sharing of technology	10
3	Availability of proprietary technology	10
4	Strong technical position	10
5	Large and complex problems	8
6	Need to solve the problem with the help of others	8
7	Need for external technology	8
8	Sharing of background Intellectual property	8
9	Sharing the benefits of new technology with other industries	8
10	Need for new technology	7
11	Availability of recognized experts and scientists in-house	7
12	Availability of R&D funds	7
13	Collaborative R&D	7
14	Sharing of pilot test data	7
15	Market monopoly	7
16	Collaboration with other organizations	6
17	R&D culture (Collaborative or Closed)	6
18	Leverage on R&D investment	6
19	High competition	6
20	Competition strategy	6
21	Duration of R&D	5
22	First-hand user of technology	5
23	Dissemination of technology	5
24	Establish a network with other industries, R&D organizations and government	5
25	Become a leader in new technology development	5
26	Access to newly developed technology	5

11.4 When to Use CRTD

The following points will help an organization to decide when to use CRTD.

1. **Sharing of Intellectual Property:** If an organization is willing to share its Intellectual Property, it could choose to use CRTD.

2. **Sharing of technology:** If an organization is willing to share its own technology, it could choose to use CRTD.

3. **Unavailability of proprietary technology:** If an organization does not have proprietary technology, and wants to depend on others for it, then the organization will choose to use CRTD. On the other hand, if the organization has proprietary technology, it will prefer to use closed innovation.

4. **Weak technical position:** If an organization's technical position is weak, the organization needs the support of others for technology, and will prefer to use CRTD. In contrast, a strong technical position makes an organization technically competitive, and it will want to take advantage of its available technology and will prefer to use closed innovation. If the organization does not have proprietary technology, the organization is in a weak technical position and will then prefer CRTD because technical support is needed from others. If the organization has proprietary technology, then the organization is in a strong technical position and will prefer to use closed innovation.

5. **Large and complex problems:** If the problems facing an organization are large and complex, and the organization cannot solve them on its own, it will need to seek the support of others to develop solutions. In this situation, the organization will prefer to use CRTD.

6. **Solving the problem with the help of others:** If an organization decides to solve its problems with the help of others, it will use CRTD.

7. **Need for external technology:** If an organization needs to use technology developed by external sources to fulfill its technology demand, CRTD will help the organization to use external technologies.
8. **Sharing of background Intellectual Property:** If an organization decides to use CRTD, it may have to share its background IP with other participants during technology development. An organization using CRTD should be willing to share background IP.
9. **Sharing the benefits of new technology with other industries:** An organization using CRTD should be willing to share newly developed technology with others, including both participants and non-participants. The organization may charge a fee, perhaps in the form of license, for this sharing.
10. **Need for new technology:** CRTD may help an organization to meet the demand for new and better technology in a fast and cost-effective manner, since the new technology will be developed collaboratively by many organizations.
11. **Unavailability of recognized experts and scientists in-house:** An organization lacking the required expertise in-house to conduct R&D needs to access expertise outside the organization. CRTD provides such access.
12. **Unavailability of R&D funds:** During CRTD, R&D funds will be shared by many organizations. No single organization needs to bare all the R&D expenses. An organization without sufficient R&D funds should choose CRTD.
13. **Collaborative R&D:** An organization willing to share its R&D effort should choose CRTD.

14. **Sharing of pilot test data:** Pilot data are a very valuable set of information that enhance the collaborative process. Sharing of the pilot test data is based on a joint decision by the participants. An organization deciding to use CRTD may have to share the pilot test data if the other participants decide to do so.

15. **Market monopoly:** An organization with a market monopoly in a particular sector probably will be unwilling to share its IP with others. In such a case, the organization should not choose CRTD.

16. **Collaboration with other organizations:** If the organization is willing to share and collaborate with other organizations, it can use CRTD, which requires the sharing of information and resources.

17. **R&D culture (collaborative or closed):** Organizations with collaborative R&D cultures will seek CRTD, and organizations with closed R&D cultures will seek closed innovation.

18. **Leverage on R&D investment:** For organizations with business models driven by the leverage on their R&D investments, CRTD might be the preferred method, as the R&D investments will be comparatively low compared to those required to conduct R&D independently, and the return will be received almost immediately upon completion of R&D, as the organizations will be the first-hand users of the developed technology.

19. **High competition:** An organization facing high competition in the market will not want to share its technology with others and should choose CRTD.

The decision points provided in this section and the factors provided in Table 11.2 applied in the case of UTF SAGD. In this case, the participating organizations had oil sand leases, but did not have a process for extracting bitumen from oil sands. Therefore, the participants were willing to collaborate to develop such a process.

11.5 Collaborative Innovation in the Energy Sector

As Noke, Perrons, and Hughes (2008) wrote, case study evidence from the oil and gas industry has shown that strategic alliances can be an enabler for a discontinuous innovation process. The uniformity of the problems in this sector leads to the implementation of collaborative innovation, which has been proven successful in the energy sector. This innovation model may also be used in other sectors. Collaborative innovation might not necessarily be the best innovation approach in all circumstances. Many of the major organizations in the energy sector used to conduct their own research and development, mainly for competitive reasons. However, due to their lack of resources and desperate need for better technology, these companies began to realize that they shared many of their R&D needs with their competitors and also that they could benefit from government participation. These factors led the industries to seek to collaborate with their competitors and the government on R&D efforts.

Some of the problems causing organizations in the energy sector to use CRTD are the following:

1. Need for better technology.
2. Lack of proprietary technology.
3. Weak technical position.
4. Need for external help to solve problems.
5. Need for external technology.
6. Lack of know-how and expertise in-house.

7. Lack of R&D funds.
8. Lack of pilot test data.
9. Huge R&D investment and low return on it.
10. Lead time to complete R&D.

Some of the benefits of using CRTD are the following:

1. Access to better technologies.
2. Access to expertise.
3. Sharing of technology and resources.
4. More revenue in royalties and taxes to government.
5. More job opportunities.

Some of the organizations using methods similar to CRTD are listed in Appendix B.

11.6 Collaborative Innovation and Market Share

Technology is one of the many factors determining market share. Market conditions such as market monopoly and competition strategy are also contributing factors. The case studies demonstrated that market share can be increased during CRTD. In the case of UTF SAGD, the new technology reached customers very quickly. Between 2002 (the year of SAGD's first commercial operation) and 2009, SAGD had an operating investment of C$3.6 billion. This high amount was due to the large market share that SAGD obtained in a short period. The growth in market share was driven not only by the technology but also by the resources, such as land leases, and the ability to meet R&D expenses. Each R&D participant and licensor had a reasonable market share based on the participant's lease and the speed of commercialization. An organization that owns resources, such as a land lease, benefits from new technology, and thus the organization's market share increases.

The same situation does not necessarily occur in other sectors. The market share in CRTD depends on many factors, which differ for various types of industry sectors. Consider the case of pharmaceuticals: their market share is dominated by technology. In this type of sector, where technology has the power to increase the market share, organizations might not be interested in sharing technology with others. In a sector where technology is the dominant factor in determining market share, CRTD might not be the best approach. This conclusion is also true for the energy sector; for example, an organization using a specific process for a particular reservoir might not be interested in sharing that process with others and might not seek to use CRTD for technology development. Thus, CRTD is recommended in sectors where the market share is independent of technology.

11.7 Collaborative Innovation Limitations and Challenges

Understanding the challenges of CRTD helps organizations to decide when using it makes sense. This section explains the challenges and limitations of CRTD once a decision has made to use it.

1. **Quickest completion of R&D.** Some participants might want to complete the R&D as quickly as possible in order to use the developed technology as soon as possible. This desire might compromise the success of the R&D program and the innovation. For example, in the case of UTF, the participants seem to have wanted a completely new technology and were willing to commit the time required to

develop it. If even one of the participants had been unwilling to do so, the program might not have succeeded.

2. **Cannot guarantee the estimated return on R&D investment.** Like any other form of innovation, CRTD can also have uncertain end results. Sometimes the return on R&D investment might not be as large as estimated prior to the start of innovation.
3. **Lack of contributions from participants.** Since CRTD is a collaborative effort, all the participants need to contribute to it. A participant's lack of contribution might compromise the success of a collaborative project.
4. **Lack of a common goal.** Since organizations with different business models can be involved in CRTD, the participants might lack a common understanding. The success of CRTD lies in finding unity among the diverse business models. Failure can also occur if bad management of the program prevents clear communication of the common goal.
5. **Lack of knowledge of a new experience.** Collaborative innovation is a new experience for most organizations even if they have participated in collaborative projects. The lack of knowledge can slow down the R&D process and limit the progress of a CRTD project.
6. **Lack of best-fitting partners.** Developing partnerships that are a best fit for organizations can be difficult. Usually in CRTD, a partner is a competitor, since partnerships in CRTD are with organizations with similar interests. Developing a new technology with such a partner can be a challenge. Unfortunately, the

incompatibility of the partners may not be apparent until they have progressed well into the R&D program.

7. **Non-availability of expertise.** The success of CRTD depends on the know-how and expertise of the CRTD team. If the team cannot successfully mobilize the identified expertise in a timely manner, the program could fail.
8. **The need for constant IP management and control.** IP management and control are constantly required even after the completion of R&D. The revenue generated by selling the IP needs to be tracked, and the participants need to be informed of any changes to the IP. IP policy needs to be carefully drafted in CRTD, so that all the participants' interests are considered.
9. **Different business models.** The business models of the participants might differ and affect their motivation to innovate. Those participants with innovation as the driver of their business models will be more highly motivated to innovate than the other participants.
10. **Lack of external technology.** External technology is an important ingredient in CRTD. Finding external technological sources is often difficult. If external technology is unavailable, a CRTD project might fail.
11. **Changes required to R&D organization.** During CRTD, R&D not only creates technology but also receives it from external sources and other participants. The R&D model and structure require some major overhauling in order to receive technology. R&D should have the ability to receive, absorb, analyze and synthesize external technology. Organizations lacking their own R&D have to outsource R&D and then align the third party to the CRTD model.

12. **Commercialization of technology.** The commercialization of the developed technology is a key contributor in determining the success of CRTD, in which the developed technology enters the market through multiple channels including the participants. An organization's marketing strategy contributes to the success of CRTD. Since the participants might have different marketing strategies, the project might fail unless all the strategies are co-ordinated. For example, in the case of UTF, if one or more participants had decided to use the new technology in an operation where SAGD might not have been the right process, then this participant's capital investment in the technology would have been wasted. This outcome might have negatively affected the success of the R&D.
13. **Leadership.** Collaborative innovation always requires a leader, or an organization to act as a champion. Some organizations either will not join or will drop out from a CRTD project because of disagreements with the leader's policy and business model. As well, a leader's biases might also affect the success of a project.
14. **Residual technology.** Sometimes an organization has to leave behind well developed internal technology with the CRTD team and other participants. As a result of sharing internal technology and background IP with competitors, technology 'leftovers' may occur after the completion of R&D, and residual technology might remain with the other participants. This result cannot be controlled. Moreover, the residuals can be not only technology, but also business models, best practices, etc. If a CRTD project is not properly managed, an organization's well developed background IP could end up in the hands of competitors or strangers.

15. **Abandonment of the developed technology.** The success of CRTD lies in the commercialization of technology. Marketing is a key factor in commercialization. If the developed technology is abandoned by a participant, or not launched into market, the number of channels for getting the developed technology into the market is reduced, and the success of the innovation may be undermined.
16. **Low-key R&D.** For some organizations, R&D has a low profile in their business models, but these organizations will still participate in CRTD to reap all the benefits of a CRTD effort and to get a share of government grants. Such organizations might not fully contribute to a CRTD project.
17. **Improvements made to developed technology.** If the improvements made to the technology by individual users are not properly reported to the IP Manager, these improvements will not be shared with all the participants and all the users of the technology. In such instances, the benefits of the improvements are limited to only one user.

11.8 Is CRTD a Preferred Alternative?

The decision-making process to use CRTD is divided into six steps: The Problem / Need, Technical Position, Solution Basis, Commercialization Strategy, External Requirements, and Sharing Requirements. Figure 11.1 and Details 11.1-A to 11.1-F present the details of the decision-making process to use CRTD. Figure 11.1 provides the details of the six steps involved in the decision to use CRTD, and details of the six steps follow.

1. **Identifying the problem and need.** Solutions for complex and large problems demand the need for better technology. Better solutions can be achieved with the support of external sources. This step is represented in Detail 11.1-A.
2. **Technical Position.** An organization owning proprietary technology and deciding to use CRTD will have to decide whether it is willing to share its proprietary technology with others. A breakdown of this step is provided in Detail 11.1-B.
3. **Solution Basis.** The basis of CRTD is collaboration. Organizations cannot use CRTD without having collaboration as part of their innovation strategy. This step is presented in Detail 11.1-C.
4. **Commercialization Strategy.** Innovation is complete only if technology is introduced into the market. The marketing strategy is a key input into the decision to use CRTD. CRTD innovation is not recommended for an organization that has a market monopoly and wants to maintain it. This step is represented in Detail 11.1-D.
5. **External Requirements.** It is important to identify what is required from ‘others’, and who the ‘others’ are, in CRTD. What the organization is lacking, what information is required from others, and what external sources could provide this information need to be decided prior to using CRTD. Details of these steps are identified in 11.1-E.
6. **Sharing Requirements.** In CRTD, organizations need to share key components of innovation such as technology or IP with others. If an organization is unwilling to share these components with external organizations, then CRTD is not recommended. Details of these steps are presented in 11.1-F.

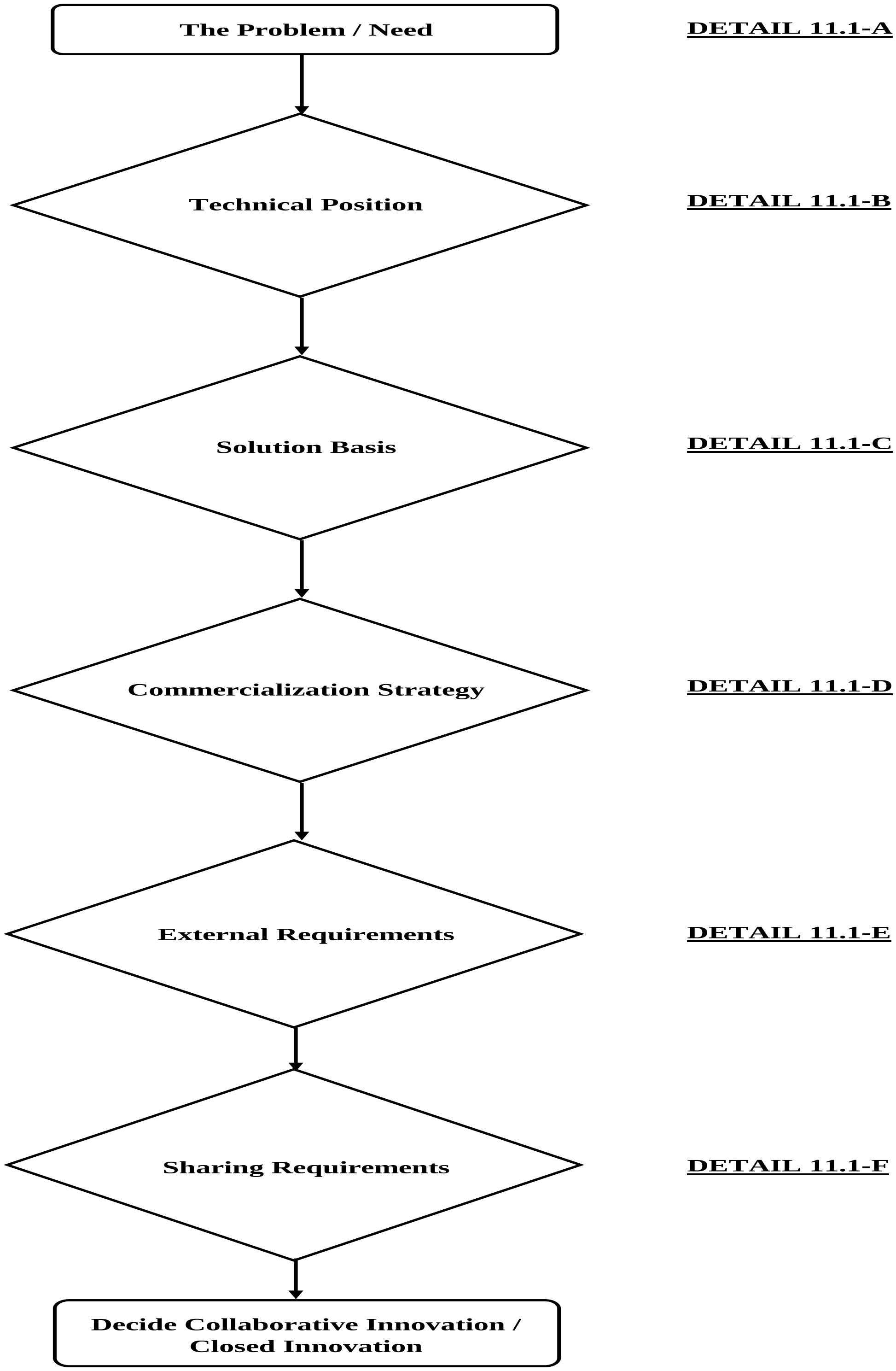
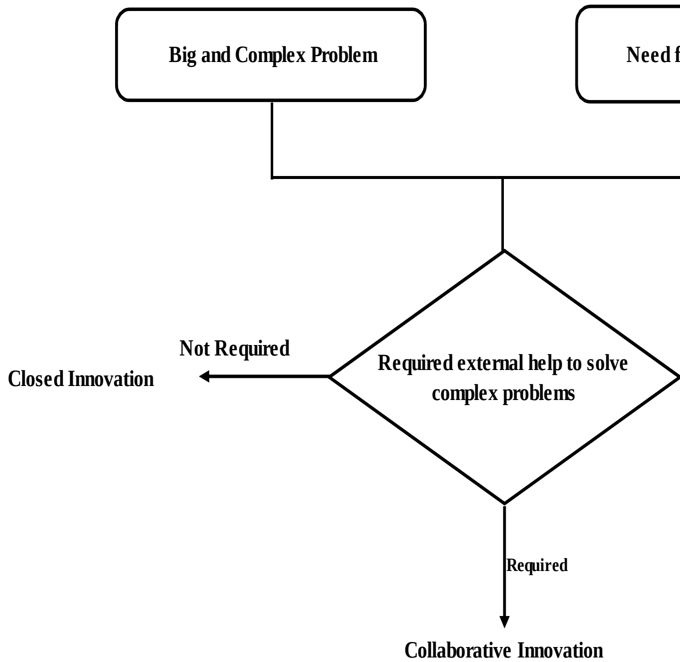
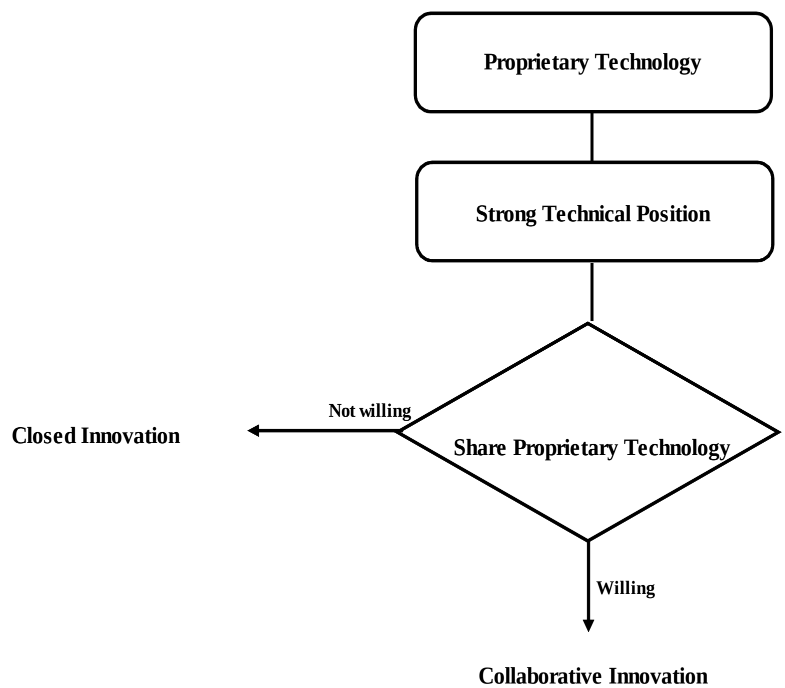


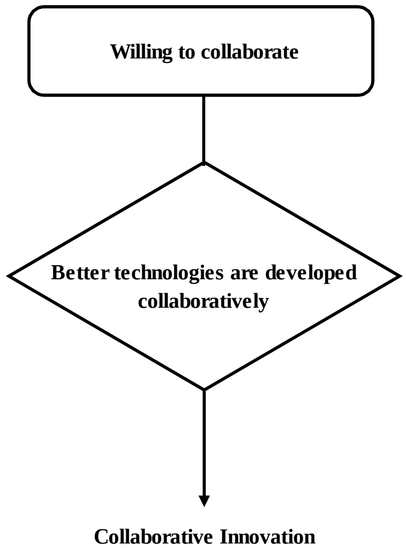
Figure 11.1 The decision-making process in CRTD



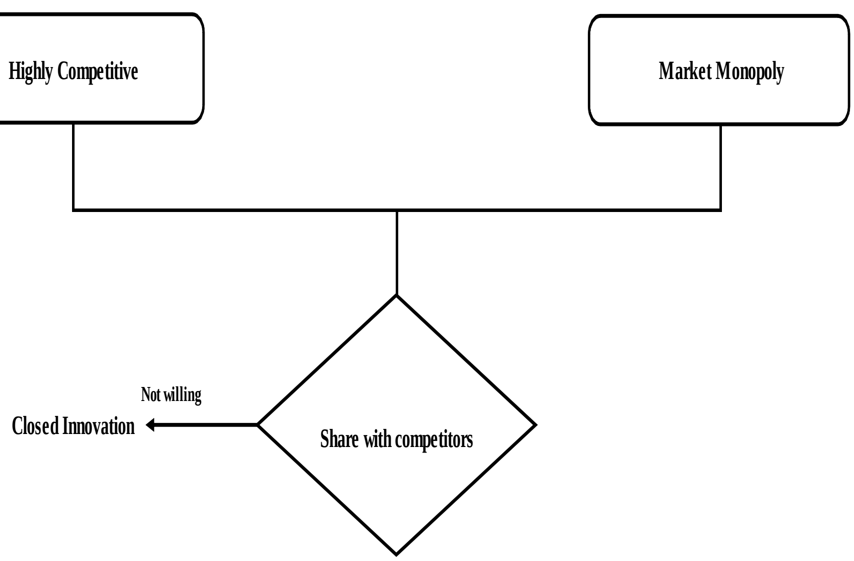
Detail 11.1 – A: Identifying the Problem and Need



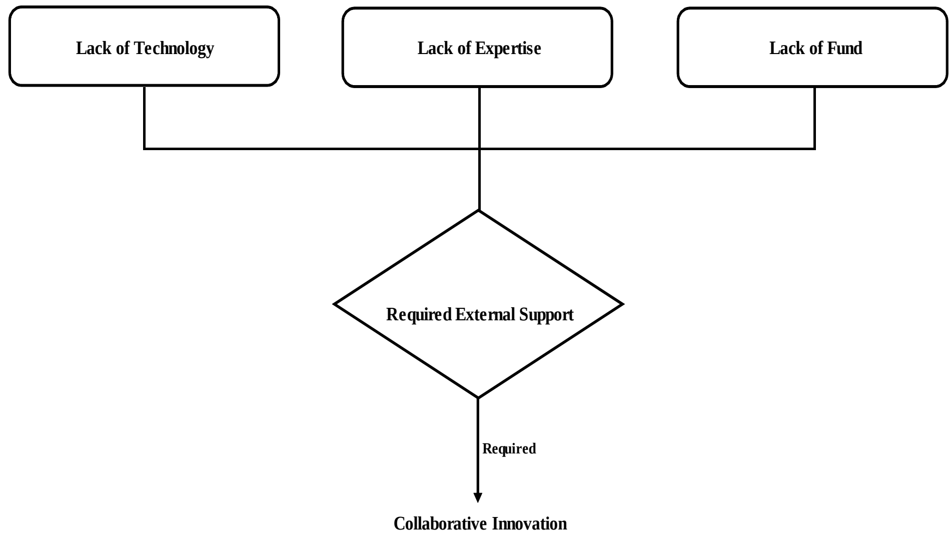
Detail 11.1 – B: Technical Position



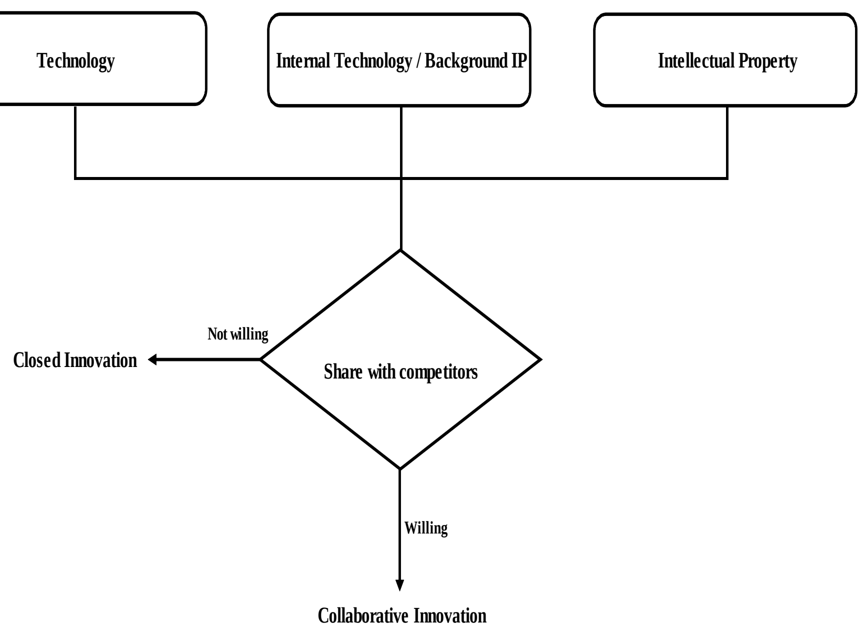
Detail 11.1 – C: Solution Basis



Detail 11.1 – D: Commercialization Strategy



Detail 11.1 – E: External Requirements



Detail 11.1 – F: Sharing Requirements

11.9 Summary

The factors affecting the use of CRTD were discussed in this chapter. Understanding their relationship with CRTD helps an organization to decide when using CRTD makes sense. This chapter explained the use of CRTD when specific conditions are met. Identifying the sectors that CRTD applies to and knowing what products and services CRTD can develop are a challenge. The guidelines provided in this chapter will help organizations to make decisions when faced with this challenge.

Chapter 12 Collaborative Research and Technology Development Conclusion

12.1 Overview

The method for executing collaborative research was explained in this thesis. This method was derived from the case studies, is applicable to the energy-related industries, and may be applicable to other industries as well. The problem identified for this research program was how and when to use collaborative research for technology development. The leader, participants and the external sources create new technology collaboratively. This process benefits the process of technology creation. Organizations' R&D culture, nature of business, competition strategy, availability of resources, revenue impact of innovation, and intellectual property are all factors contributing to the decision to use either the open or closed method to conduct innovation.

12.2 Innovation Method: Collaboration or Not?

An organization can solve a problem by using the following two approaches: Solve the problem without external help, or solve the problem with the external help of others. Without external help, an organization conducts research and development on its own. No external sources are involved in the R&D. The innovation will not be shared with others. This type of innovation generally falls under the category of closed innovation. With the external help of others, the organization solves a problem with the help of others and conducts research and development collaboratively. R&D is conducted by combining the technology contributed by various organizations and the technology available from external sources. This method of finding solutions to problems is collaborative research.

This thesis provided the following information for organizations wanting to use collaborative research: The situations and reasons that will lead an organization to use collaborative research, when to use collaborative research, and the methods for executing collaborative research. Companies want to use innovative technologies in order to build efficient facilities and to provide quality products and services to customers. Companies do not necessarily have expertise in all areas. The collaborative research method helps them to make use of the best technology and resources available.

The government is likely to receive the following benefits by leading collaborative research projects:

1. New technology developed.
2. Resources exploited.
3. Commercial development of resources increases.
4. Royalties increase.
5. Job opportunities increase.
6. People’s wealth increases.
7. Increased activities in the energy sector.
8. Increase in the amount of recoverable oil and gas.
9. Increase in tax revenue.
10. Increase in patents.
11. Presence of recognized experts and scientists.
12. Dissemination of technology.
13. Collaboration with industries and other organizations.
14. Leadership in new technology development.

15. Opportunities to field test newly developed technologies.

Industries are likely to receive the following benefits by participating in collaborative research projects:

1. Increased value for land leases.
2. Availability of new technology.
3. Accessibility to expertise.
4. Accessibility to technology.
5. New relationships with other industries, R&D organizations and government.
6. Increased value of capital assets.
7. Increase opportunities to own more facilities.
8. Increased networking and collaboration.
9. Ability to be the first users of new technology.
10. Leadership in environmentally friendly initiatives.

By participating in collaborative research projects with Canadian companies, international organizations will gain access to new technology being developed in Canada and will be able to use this technology in their own countries. Organizations often need either to create new technology or improving the existing technology. Creating new technology and improving existing technology are the underlying motives for innovation.

The need for innovation can arise from government or from industry. The following are some of the factors driving the need for innovation:

1. Exploration of resources.
2. Need for a better technology.

3. Need for environmentally friendly technology.
4. Need to reduce operating and maintenance costs.
5. Desire to become a pioneer in new technology.
6. Desire to reduce greenhouse gas emissions.
7. Desire to reduce geographical disturbance while constructing an operating facility.
8. Job creation.
9. Increased revenue.

The government generally initiates innovation if it has the potential to increase revenues and to develop resources. Industries generally join the government for innovative initiatives if the new technology will be useful in their facilities and / or if the individual organizations feel an innovation process is too big for them to tackle on their own. Sometimes, industries carry out innovation on their own, without the support of government or another organization. This type of innovation falls under the category of closed innovation. In closed innovation, organizations focus only on the knowledge created by internal R&D laboratories and pay less attention to the knowledge outside them.

In a closed innovation world, an organization has to depend exclusively on internal R&D (Chesbrough, 2003a). Industries use closed innovation due to some of the following reasons:

1. Market monopoly.
2. High competition.
3. Proprietary technology available to the industry.

4. Technically strong position.
5. Company culture oriented towards closed innovation.
6. Expertise available in-house.

Collaborative research occurs when organizations work collaboratively with the government or other organizations to find a solution. The following are some of the factors leading organizations to decide to choose collaborative research:

1. Problem too big to tackle on their own.
2. Desire to reduce the duration of R&D.
3. Ambiguous end result.
4. Availability of expertise.
5. Availability of funds.

Normally, the industries want to have government partnership because of the government's authority, regulatory approvals, and accountability, and the availability of government funds. The conclusion from the case studies conducted for this thesis is that government input is necessary for collaborative research projects and will certainly strengthen them.

Availability of Proprietary Technology

The availability of proprietary technology contributes to the decision to choose collaborative research. UTF SAGD is a good example. The availability of proprietary technology helped the leader (AOSTRA) to invite industries to participate in the program. Industries joined the program, understanding the benefits of obtaining knowledge about the SAGD technology. Industries were successful in starting commercial operations soon after the completion of the field pilot test. The government invited the industries to join the program because the government wanted to disseminate the new technology and to share its benefits with the industries. If proprietary technology is available to the government, it will prefer to choose collaborative research. However, if the proprietary technology is available to the industries, the situation might be different. The availability of proprietary technology would put the industries in a strong technical position, and they might like to conduct the innovation on their own, in a closed project. The availability of proprietary technology contributes significantly to an organization's decision to choose the collaborative or closed innovation model. Figure 12.1 represents the role of the availability of proprietary technology in the process of choosing an innovation model.

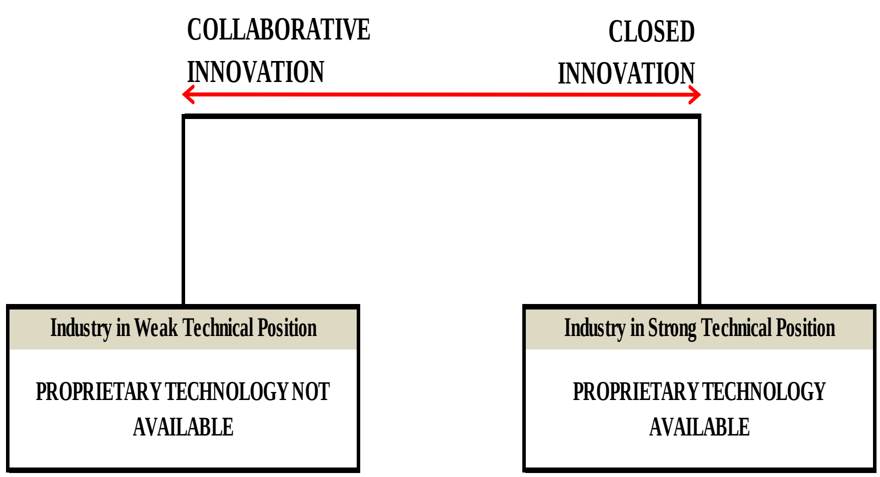


Figure 12.1 Availability of proprietary technology

Sharing of Intellectual Property

The decision to share intellectual property is a key factor in the decision to use collaborative research. Collaborative research involves the controlled sharing of intellectual property. The participants require technology from external sources and are willing to share intellectual property including background IP. IP policies are in place to control the sharing of IP. In closed innovation, no sharing of intellectual property occurs. Here the participants have their own internal technology and are not willing to share their intellectual property with others. Figure 12.2 represents the decision to share intellectual property in the process of deciding whether to use either collaborative or closed innovation.

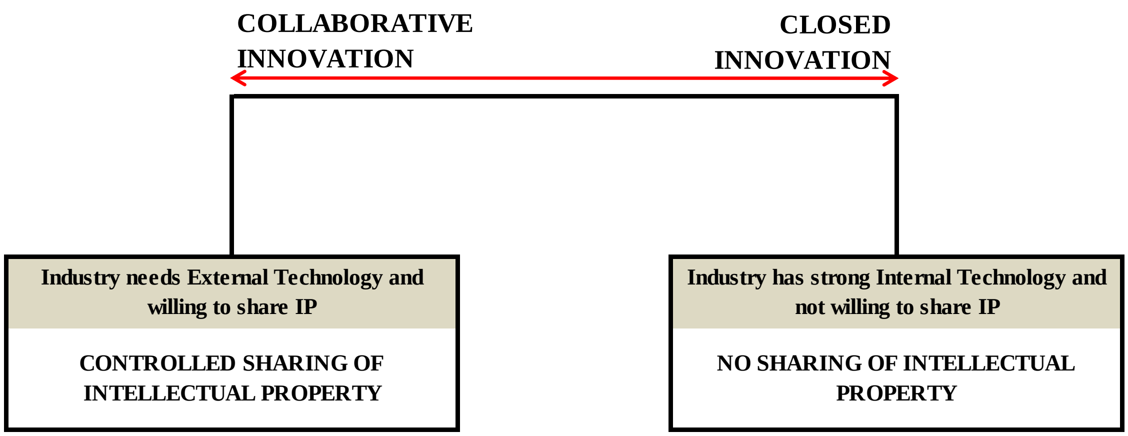


Figure 12.2 Sharing of intellectual property

12.3 Summary

The availability of proprietary technology is a major influence on an organization's decision to choose an open or closed innovation model. When the proprietary technology is available to the government, it prefers to choose collaborative research. The availability of proprietary technology puts industries in a strong technical position, so they might like to conduct an innovation on their own and to use closed innovation.

Companies do not necessarily have expertise in all areas. The collaborative research method helps them to make use of the best technology and resources available. Some of the factors that lead organizations to decide to choose collaborative research are problems too big to tackle on their own, the desire to reduce the duration of R&D,

ambiguous end results for R&D efforts, the availability of expertise, and the availability of funds.

Chapter 13 Conclusions and Future Research

13.1 Conclusions

The business environment today can be characterized as dynamic, intricate and ever-changing due to increased global competition (Makri & Lane, 2007). Thus, for many organizations, survival requires harnessing all available resources, both internal and external. Successful organizations accelerate innovation with effective strategic management solutions that meet both current and future needs.

This research was designed with the following specific purpose: to develop a technological innovation method by combining internal and external sources of technology. This purpose led to the development of a new Collaborative Research and Technology Development (CRTD) model to find solutions to complex technical problems and assist industries in using and implementing collaborative research for their R&D needs. The research provided methods to identify circumstances where collaborative research provides better economic value than other innovation methods.

Both the literature and the case studies have demonstrated that organizations do not need to have their own technology and experts in all areas when external technology and experts are available. To achieve a competitive advantage, companies should be able to use the best technology available. This thesis demonstrated that CRTD is an answer to the following questions: (1) how can the innovation process be improved, (2) how can an organization innovate effectively, and (3) how can an organization identify circumstances where the most economic value be created through collaborative research. Organizations have realized that in order to achieve success in business, they should be willing to collaborate with the available outside technology sources. The primary objective of this thesis was to determine how and when to use collaborative research. This thesis answered these questions and made recommendations.

Organizations need to choose whether they should solve problems either by themselves or with the help of others. An organization that decides to engage with others in finding solutions will conduct R&D collaboratively. The availability of proprietary technology contributes to an organization's decision to choose a form of collaborative research such as CRTD or closed innovation.

This thesis had the following specific goals:

1. Develop a technological innovation method by combining internal and external sources of technology. CRTD develops new technology by combining external, internal and technology generated by all the participants. The details of how ro develop new technology by using CRTD were explained in this thesis.
2. Develop a technological innovation model that will help organizations to find solutions to complex technical problem. The CRTD model developed in this thesis will help organizations to collaborate to find solutions to complex problems. The details of the CRTD processes were explained in this thesis.
3. Assist industries in using and implementing collaborative research for their R&D needs. The generation of new technology by using CRTD was explained in this thesis. Situations that will lead an organization to choose to use CRTD and the advantages of CRTD were explained in this thesis.
4. Identify circumstances where collaborative research provides better economic value than other innovation methods. The benefits received by various parties when adopting CRTD were explained in the thesis.

The R&D method adopted by AOSTRA in the development of UTF SAGD technology is a proven method for technological innovation. Industry joined the consortium, understanding that AOSTRA and its resources were a technology source that they could collaborate with for the development of technology in the energy sector. Industry also realized the huge potential for the use of SAGD technology in the energy sector. SAGD technology was tested in the field soon after the completion of the laboratory R&D work. The demonstration of the technology in the field was another success factor for this project. The R&D method adopted by AERI, ARC, and PTRC in AACI, Weyburn, Carbonates and JIVE in the development of technology was also successful. All these organizations decided to adopt the collaborative research method for developing new technology. This approach provides a venue for technology sharing and technology transfer, improves the R&D process, increases innovation effectiveness, and increases economic value.

In the past, organizations developed technology on their own without collaborating with external sources. The organizations in the case studies did not have to continue to innovate in this manner, since external technological sources were available. This thesis on collaborative research demonstrated with the help of case studies that the best technology can be developed and applied through collaboration by using the CRTD model. The CRTD model developed in this thesis will help industries to improve their innovation process. Industries can overcome their lack of technology by implementing CRTD. Even though this thesis focused on the energy sector, the findings and the CRTD model can be modified and applied to numerous other sectors in industry. This thesis contributes to the Engineering and Management areas of Technology Commercialization, Technology Management, Innovation Management, and Research and Development.

13.2 Lessons Learned

To use innovative processes both effectively and efficiently, an organization should be willing to collaborate. The strategic business environment, which is focused on innovation, is characterized by a collaborative model of organizational and business development, which necessitates the development of four distinct capacities: (1) the ability to recognize that a key determinant of business success and sustainability is effective innovation; (2) the ability to develop strategic collaboration practices by extending a firm's boundaries in order to glean information from external sources; (3) the ability to be open to new models of innovation, which includes willingness to accept and share technology with collaborative partners; and (4) the willingness of competitors to cooperate in achieving a common goal. To achieve such a goal, company leaders need to realize that collaborative innovation can lead to the achievements of both effective innovation and improved technology. However, many leaders of organizations do not have this understanding because they want to protect their unique practices and competitive advantages.

If the right circumstances for collaboration are present and if all the qualifying criteria provided in the thesis are met, then collaborative research should provide more benefits than closed innovation will provide to an organization. Collaborative research may not be suitable for all sectors and even for sectors where collaborative research is a good fit, such as the energy sector, appropriate analysis should be conducted to identify whether the correct business context exists for collaboration. Such analysis will facilitate the proper execution of the CRTD model as discussed in this thesis. Before proceeding on this path, companies needs to determine whether adopting CRTD is the right approach. This thesis's section on when to use CRTD provided guidelines on the factors that need to be considered for making this decision.

An organization needs to carefully consider when it should be willing to share its own or others' technology, and with whom. If a decision is made to use CRTD, identifying who has access to the technology and determining how the best technology can be created collaboratively by combining all the participants' technologies is the next major step. Identifying external sources and means of establishing collaborative methods to develop technology is a significant challenge for the organization while implementing CRTD. In the end, getting CRTD off the ground, including a search for collaborators and setting up the initial framework among collaborators, could require a significant contribution from all the players. Nonetheless, implementing CRTD has the potential to reduce the duration of R&D and therefore decrease the participant's costs over the long term.

Not all organizations have to use collaborative innovation to be successful. As well, some organizations may not understand the benefits of conducting R&D through collaboration, and lack knowledge on how to implement collaborative innovation practices in their business models. This thesis, will help to disseminate the benefits of collaborative innovation and to provide guidance and tools to help organizations determine the circumstances in which CRTD can and should be used.

13.3 Recommendations for Future Research

The CRTD model was recommended as a viable solution to achieve effective innovation and business success. The nature of a company's business and its competition strategy, available resources, and intellectual property are all factors contributing to the decision to share technology. However, collaborative research is not a good fit for all sectors and cannot be applied for developing certain types of technology. Such research clearly has links to business preferences and organizational needs. This thesis focused on only the energy sector. More research is required to determine the potential for using collaborative research in other sectors. As well, more research is needed on the possibility of splitting R&D functions to develop some technologies by using conventional R&D and to develop others by using the CRTD model. This thesis discussed five cases of collaborative research in the energy sector, but did not compare them with cases of closed innovation in this sector. This topic is recommended for future research; understanding the use of closed innovation in the energy sector will help organizations to overcome some of the challenges in deciding when to use collaborative research.

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Appendix A

Interview Questionnaires

The following is a sample of the topics on the interview questionnaires used for the case studies.

1 First Case Study: AOSTRA UTF SAGD

1.1 Participants in UTF SAGD Development

- History of UTF SAGD development
- Members from industry involved in SAGD development
- The development stage when the participants became involved
- End users of SAGD
- Members who were NOT involved in the development of SAGD, but licensed SAGD technology

1.2 Roles and Responsibilities of Participants

- Alberta Oil Sands Technology and Research Authority (AOSTRA)
- Alberta Energy Research Institute (AERI)
- Underground Test Facility (UTF) consortium
- AOSTRA s' involvement in SAGD development
- How AOSTRA managed the team of experts
- Lead role played by AOSTRA
- Modus Operandi of UTF consortium
- AOSTRA s' R&D management

1.3 Collaboration

- Involvement of members and their methods of collaborative engagement

- AOSTRA & UTF consortium
- Government – Industry collaboration
- Nine Industry participants
- Worldwide affiliations

1.4 SAGD Projects

- Twenty-Two SAGD pilot projects
- Current SAGD Projects

1.5 Costs and Benefits

- Estimated benefits for early participants
- The benefits of signing on early vs. the benefits of buying the technology later

1.6 Intellectual Property Management

- How SAGD Intellectual Property is being protected
- How the SAGD Intellectual Property is being used now
- The participants' rights concerning the SAGD Intellectual Property?

1.7 How ARC Manages SAGD Intellectual Property, Licenses and Patents

- The joint development of UTF technology by AOSTRA and Industry
- UTF assets in the form of Intellectual Property
- Ownership of SAGD Intellectual Property
- Use rights of UTF Technology
- Marketing rights of UTF Technology
- UTF Patents
- The rights of companies who bought a SAGD license, but were not involved in the development of technology

- Transfer of knowledge in licensing
- Advantages to the licensee and the licensor
- The availability of UTF technologies at a fair market price.
- License fee payment: up-front payment or percentage of the net revenue from the projects that use UTF technology.
- The use of the revenue from UTF license fees. Is it divided among the developers (industry and government) according to the proportion of their investments?

2 Second Case Study: AERI/ARC Core Industry Research Program

1. R&D management style and control
2. The participants
3. The roles and contributions of each participant
4. The leader (government or industry)
5. The benefits for participants
6. The benefits for AERI and ARC (the government)
7. Total Investment and Investment by Participants
8. Availability of the technology to others (non-participants in the R&D)
9. The management of the Intellectual Property
10. Field Pilot Test

3 Third Case Study: Weyburn CO2 Monitoring and Storage

1. The control of the R&D
2. The participants and their benefits
3. Government involvement
4. The leader

5. R&D management style and control

6. The forming of a consortium among participants

7. The control of Intellectual Property

8. The technology's availability for outsiders

4 Fourth Case Study: Carbonates R&D Program

1. R&D management style and control

2. The participants

3. The roles and contributions of each participant

4. The leader (government or industry)

5. The benefits for participants

6. The benefits for ARC (the government)

7. Total investment and investment by Participants

8. The technology's availability to others (non-participants in the R&D)

9. The management of the Intellectual Property.

10. Field Pilot Test

5 Fifth Case Study: Joint Implementation of Vapour Extraction

1. R&D management style and control

2. The participants

3. The roles and contributions of each participant

4. The leader (the government or industry)

5. The benefits for participants

6. The benefits for PTRC

7. The benefits for government

8. The benefits for ARC and SRC
9. Total investment and investment by participants
10. The technology’s availability to others (non-participants in the R&D)
11. The management of Intellectual Property
12. Field Pilot Test

Appendix B

Organizations Adopting Methods Similar to Collaborative Innovation

The following are some of the R&D organizations in Canada that have adopted an innovation model similar to collaborative innovation. The innovation methods adopted by these agencies is promoting R&D in the energy sector. Their collaborative approach to R&D is clearly visible in their visions and methods of operation. The information provided below was gathered from the organizations' websites.

1. Alberta Energy Research Institute

The Alberta Energy Research Institute (AERI) is involved in energy-related research in the province of Alberta. The AERI works collaboratively with industry and other organizations in research and technology development to promote innovation and technology. This organization promotes energy research, technology evaluation, and technology transfer in areas including oil and gas, heavy oil and oil sands, coal, electricity, and renewable and alternative energy. The AERI supports consortia and builds networks by integrating the knowledge, skills and investment potential of industry players, the federal and provincial governments, research providers and universities (AERI website, 2007)

2. Petroleum Technology Alliance Canada

Petroleum Technology Alliance Canada (PTAC) is a not-for-profit association that facilitates collaborative research and technology development to improve the financial, environmental, and safety performance of the Canadian upstream conventional oil and gas industry. PTAC's volunteer board is comprised of representatives from producers, technology suppliers, researchers, and government, and of inventors and other individuals.

The purpose of PTAC is to provide a mechanism that facilitates collaboration on R&D to the benefit of those involved. PTAC acts as a knowledge broker between those who have problems or opportunities and those who have potential R&D solutions. This organization brings stakeholders together to identify areas where R&D will make a difference and to launch specific projects to address these problems or opportunities. PTAC facilitates the transfer of commercial technologies from other industrial sectors for application in the upstream oil and gas industry. PTAC collaborates with industry to facilitate innovation, technology transfer and collaborative R&D in the Western Canadian upstream oil and gas industry. PTAC helps to facilitate R&D projects in the various technical areas and to provide a neutral forum for industry to identify opportunities, problems, and potential solutions that require research or technology development; to solicit proposals; and to launch projects (PTAC website, 2007)

3. Petroleum Research Atlantic Canada

Petroleum Research Atlantic Canada (PRAC), a federally incorporated, public-private partnership formed in 2002, fosters petroleum-related research and development throughout Atlantic Canada. PRAC works collaboratively with industry, universities and governments to promote petroleum-related research and development capacity. This organization's main objective is to increase awareness of the petroleum-related R&D activities taking place in Atlantic Canada. PRAC brings industry stakeholders together to determine research priorities related to the oil and gas industry. PRAC's excellent network of contacts and resources helps in research and development throughout this region (PRAC website, 2007)

4. National Research Council of Canada

The National Research Council (NRC), the Government of Canada's premier organization for research and development, is an agency of the Government of Canada and reports to Parliament through the Minister of Industry. The NRC collaborates with over twenty institutes and national programs, and its institutes and programs are organized into five key areas: Life Sciences, Physical Sciences, Engineering, Technology and Industry Support, and Corporate Services. The NRC is a leader in the development of an innovative, knowledge-based economy for Canada by using science and technology, and is responsible for undertaking, assisting or promoting scientific and industrial research in different fields of importance to Canada (NRC website, 2007)

5. Canadian Industry Program for Energy Conservation

The Canadian Industry Program for Energy Conservation (CIPEC) is a voluntary partnership between government and business to champion industrial energy efficiency across Canada. To promote effective voluntary action that reduces industrial energy use per unit of production, thereby improving economic performance while participating in meeting Canada’s climate-change objectives, the CIPEC facilitates a partnership between government and private industry, aiming to improve Canada’s industrial energy efficiency. The organization’s main objective is to connect industry with practical knowledge about energy-efficient technologies, best practices, and innovative concepts. The CIPEC is an open innovation engine to channel the flow of ideas, information, resources and networking among organizations committed to energy efficiency (CIPEC website, 2007)

6. Energy Council of Canada

The Energy Council of Canada (ECC), the Canadian Member Committee of the World Energy Council, is a non-profit organization with over seventy-five members from Canada's energy sector. The ECC is dedicated to enhancing the effectiveness of Canada's energy strategy and to facilitating strategic thinking, networking, and action by senior executives in the private and public sectors who have a broad interest in national, continental and global energy issues. The ECC engages a broad range of players in industry and in governments, and other stakeholders, and also establishes working relationships with one or more "think tanks" whose interests are closely aligned with those of the energy sector (ECC website, 2007)

7. Canadian Energy Research Institute

The Canadian Energy Research Institute (CERI) is an independent, non-profit research institute committed to excellence in the analysis of energy economics and related environmental policy issues in the producing, transportation, and consuming sectors. The CERI was established to provide an independent and objective source of analysis and commentary on the international and domestic energy scene. Members of the Institute are currently from Canadian government departments at the federal and provincial levels, the University of Calgary, and about one hundred energy-related companies belonging to the Institute's private sector sponsors. The CERI's multi-client studies involve the active participation of advisory committees that provide expert advice (CERI website, 2007)

8. Natural Resources Canada

Natural Resources Canada (NRCan) is one of the largest science-based departments in the Government of Canada, specializing in the sustainable development and use of natural resources, minerals and metals, forests, and earth sciences. Created by an Act of Parliament in 1994, NRCan has the main mission of ensuring the responsible development of Canada's natural resources, including energy, forests, minerals and metals. NRCan conducts innovative science in facilities across Canada to generate ideas and transfer technologies.

NRCan is the world's leading provider of innovative products, practices and technologies, and is respected worldwide for its stewardship of natural resources. This organization plays a key role in broader federal efforts to build sustainable communities, and continues, in partnership with communities, to design programs and initiatives that provide communities with the skills, knowledge and tools necessary for integrated decision-making. NRCan provides leadership on sustainable development policy and practices, investment in research and development, and commitment to knowledge, capacity building, and science and technology (NRCan website, 2007).

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