Technology Issues Table

Enhancing Technology Innovation for Mitigating Greenhouse Gas Emissions

Final

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Letter from the Table's Co-Chairs

We are pleased to present this report which describes the work of the Technology Issues Table. We believe it will make an important contribution to Canada's national effort to develop a National Implementation Strategy for Climate Change.

The observations made by the Technology Issues Table and the options presented for Ministers' consideration for a substantive and sustained investment in technology development and commercialization are essential ingredients of a national climate change response strategy. Implementation of the Table's options by provincial and federal governments will:

(i) Help to advance the development of promising environmentally-responsive technologies, and
(ii) Better position Canadian companies to reap a share of the economic benefits arising from emerging domestic and international markets.

The sustained investment will also bolster Canada's capability in innovation such that the derived benefits will be enhanced over time.

We recognize that the challenge of meeting the Kyoto target is daunting. We firmly believe that a concerted, sustained level of investment in technology development is an essential key component of Canada's climate change response strategy. Only such an investment will allow Canada to build the necessary innovation competencies to address emissions reduction in the Kyoto period and beyond, and to take advantage of associated international opportunities.

Issues and concerns have arisen in the course of our work with the Technology Issues Table that warrant special comment by the co-chairs.

Principal among these is how the contribution of technology, in the broad sense, is perceived and is integrated into the overall strategy. The mandate of the Technology Issues Table focused on technology development, that is, on the "supply side" of the equation. In contrast, the means to advance the deployment of technologies (including via regulation), of currently available technologies, has been a focus for the Sector Tables as a part of their options to reduce greenhouse gas emissions within each major sector. Clearly, this segregation of development and deployment, while necessary in the course of the work on an overall strategy, does not respect the close interplay and interdependence that exists between technology users and technology suppliers. It will be important that these facets are brought together as part of an overall innovation strategy and we therefore recommend that an integrated roll-up of technology development aspects from the Sector Tables and the Technology Issues Table be undertaken as soon as the options reports are completed.

To succeed in tackling the many challenging issues in climate change mitigation and adaptation from now to the Kyoto attainment period - and well beyond - we must underscore the importance of maintaining a national approach that combines the efforts of all levels of government, industry and the public. The strong participation and engagement in the Technology Issues Table by representatives of industry associations, by provincial and federal officials, by ENGOs and by the academic community has been exemplary and an essential feature of our Table's work. Such a national, public-private sector approach must be continued. It must be built upon federal-provincial partnerships and it must also take into proper account the particular needs and potential contributions from all regions of Canada.

It will be essential to find a balanced participation by all elements of the national fabric in the Table's options. Although it was not discussed extensively during the Table meetings, it was recognized from the outset that any national climate change strategy must recognize the need to establish partnerships between the federal and provincial governments, and between governments and the private sector. It is important that options lead to actions that enhance existing partnerships, and build them where they don't currently exist. The concept of monolithic national funds would not seem to conform to this requirement. In enunciating the options by the Table, we have tried to respect the need for this over-riding sentiment of partnership. However, it raises complex issues of implementation.

Developing quantitative *ex ante* estimates of the full impacts arising from the sizable and sustained investment we recommend has not been possible. As a consequence, it has been difficult for the Table to provide justification for each individual technology area supported by firm and reliable estimates of economic outcomes and the precise magnitude of the greenhouse gas reductions. More specific performance data and additional analysis and modeling will be needed to address these issues. This has been recognized by options from the participants at the Table's Technology Issues and Models Workshop. As co-chairs, we share the concerns of Table members that there is a risk in putting forward options that call for investments in enhancing innovation and advancing promising technologies without such analysis. While we cannot put forward a detailed analysis to defend each specific technology area, it is our firm belief that investments of the overall magnitude indicated will be required if Canada is to develop the innovative capacity to both meet the enormous challenges presented by Climate Change, and benefit from the associated international opportunities.

We must make it clear that the promising technologies described in this report are to be seen as good examples of Canada's emerging technological capability in greenhouse gas mitigation technologies. The technologies are illustrative and do not define the only technological areas of Canadian capability. We have been careful to not be seen to be 'picking winners'.

Considerable work remains to be done to identify the most advantageous promising technologies, to develop sound pathways forward for advancing their development, to assess more precisely the dimensions of emerging market opportunities for GHG mitigation technologies, and to build partnerships around present strengths and expertise. We realize that this takes time and patient effort. Above all it will require vision and leadership and we hope that this report will be able, in at least a very small way, to make some contribution to that necessity.

Clive Willis and Graham Campbell
Co-Chairs, Technology Issues Table

Foreword

This report is a summary of the observations, results and options produced by the Technology Issues Table pertaining to the development and commercialization to market-ready status of greenhouse gas mitigation technologies. The options have been developed for the consideration of federal and provincial ministers of energy and of the environment as part of the National Implementation Strategy on Climate Change.

The report deals exclusively with greenhouse gas mitigation technologies. The Science, Impacts and Adaptation Table has the responsibility to define the needs for adaptation technologies. This will be done at a later stage in their workplan. Once better information on the characteristics and priorities of potential environmental impacts emerge from the Science, Impacts and Adaptation Table, the Technology Issues Table (or its successor) can assist in identifying technologies to adapt to changing environmental conditions brought on by climate change.

Executive Summary

Action by Canada to address the significant challenge of meeting greenhouse gas reduction targets must include sustained investments in innovation to ensure that new technologies are created, developed and commercialized in the Kyoto time frame and beyond. Such investments should be directed to provide focused support for all stages of the technology innovation cycle, ranging from basic research to finding innovative new solutions based on fundamentally different approaches, to development of emerging technologies via focused research and development, and finally, to demonstration of technical and economic viability of technologies that are on the verge of commercialization.

Benefits to Canada from such investments are three-fold:

- enhanced availability of advanced technologies to help Canada and the world meet greenhouse gas reduction targets from now to the Kyoto attainment period and beyond;

- enhanced availability of technologies that contribute to other environmental benefits such as air quality and sustainable resource management; and

- enhanced commercial opportunities for Canadian companies supplying greenhouse gas mitigation technologies at home and abroad.

The Technology Issues Table has developed options pertaining to enhancing technology innovation for mitigating greenhouse gas emissions for consideration by joint provincial and federal Ministers of Energy and of the Environment. These options are based on the integration of an analysis of the emerging needs for greenhouse gas technologies in domestic and international markets, the present availability of new and emerging technological solutions, an inventory of existing measures used by governments to advance their development, and the current needs and capabilities of the Canadian innovation system related to greenhouse gas mitigation technologies. The content and coverage of the options have been enriched by the diverse background and expertise of the Table members who have been drawn from several companies and industry associations, six provincial departments, three federal departments and agencies, environmental non-governmental organizations and academia.

Elements of Canadian innovation provide the platform and the machinery to channel focused investments directed at enhancing the supply of market-ready greenhouse gas mitigation technologies. In particular, investments are critically needed in four general areas of innovation: i) in funding new basic and applied R&D to find and develop innovative new solutions; ii) in programs to support demonstration of the technical performance and economic viability of new technologies; iii) in making improvements to the business environment; and iv) in fostering the linkages between the key players in the system. It is critically important to the success of all investments that linkages between technology suppliers and technology users, between technology suppliers and technology developers in laboratories and institutes, between the academic community, industry and labs, and between Canadian technology suppliers and international markets be enhanced.

Eight Options are presented in this report which are intended to enhance the Canadian innovation system pertaining to greenhouse gas mitigation technologies. The options proposed by the Technology Issues Table[1] are listed below. They represent a total annual investment increasing from $116 million in year 1, to $535 million in year 5, and are grouped in four areas:

- **The Knowledge Infrastructure**

  1. National Climate Change Discovery Competition
  2. Enhanced Support for Basic Knowledge Generation
  3. Climate Change Technology Development Fund

- **Demonstration and Commercialization**

  4. Climate Change Technology Demonstration Program

- **Business Climate for Innovation**

  5. International Marketing
  6. Reducing Risk and Facilitating Accreditation

- **Fostering Linkages**

  7. Technology Nodes and Roadmaps
  8. Communication Forum for Technology Initiatives

A summary of the options and their recommended funding profiles is provided in a table at the end of this section (page 14).

The Table did not identify specific options to enhance the human resource base as it felt the issue would be addressed indirectly by several of the options proposed.

The options are believed to provide the optimal means to raising the competitiveness of Canadian firms, to lowering energy and carbon equivalent intensities of Canadian products with the double benefit of reducing operating costs, while supporting achievement of greenhouse gas reductions in the long-term. However, it should be emphasized that the investment levels identified by the Table reflect the level of effort thought to be necessary to achieve success, but do not commit governments or industry to making these investments.

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[1] The options are not presented in any order of priority. Rather, they are grouped according to the components of innovation and the linkages between them.

Although the recommended investment is presented for only five years, the Table believes that the investment should be sustained beyond this initial term. The Table stresses that the status quo is not an appropriate path given the magnitude of the challenge, and that concerted, sustained commitment and investment are essential.

While each option will go a significant way towards strengthening a particular element of Canada's innovation system as it relates to greenhouse gas mitigation technologies, the strength lies in the consolidation of these options and the creation of a system which provides a comprehensive approach.

Implementation of the options must include careful consideration of regional interests in the dimensions and nature of Canada's response to the climate change challenge. The investments must, therefore, be responsive and reactive to regional needs and build on regional capabilities. This calls for a horizontal governance mechanism to guide investments, combining representation from provincial and federal governments and regional development agencies. Looking ahead, the Technology Issues Table is of the view that delivery of such investments should be largely through ecxisting programs and mechanisms.

Canada has emerging strengths in technologies which offer promise to reduce greenhouse gases in Canada and abroad, and which can be added to the technology products offered today by Canadian companies. Promising technology areas that illustrate Canada's emerging capability and potential business opportunities include:

Fossil Fuel Supply Natural gas pipelines Process technologies related to energy and carbon processing efficiency Technologies to reduce or use fugitive gas emissions from fossil fuels Technologies for increasing natural gas supply	***Energy Production*** Electricity from CO_2-free/renewable sources Biomass Combustion Large Scale hydroelectricity Biomass conversion Nuclear fission Stationary gas turbines
Energy End-Use[2] Fuel Cells Buildings Transportation and transportation systems: intelligent transportation systems, advanced vehicles and fuel technology, and mass transit systems	***CO_2 Management*** Geological CO_2 management
Non-Energy GHG Emissions CO_2 from cement production Technologies to capture methane from landfills	***Enabling / Cross-Cutting Technologies*** Hydrogen Technologies Enabling Technologies - Electrotechnologies

[2] Industrial end-use process technologies were not addressed.

Methane from manure management Anaerobic digestion of municipal solid waste Nitrous Oxide from fertilizers	- Advanced materials - Catalysts - Energy Storage - Biotechnologies - Gas Technologies - Separation Technologies - Simulation and modelling System integration technologies Technologies that use less carbon intensive energy sources

These promising illustrative technologies are certainly not the only areas of opportunity. Other areas have comparable potential. Additional investment is needed to accelerate the development of these technologies and others that will follow.

The international market prospects in greenhouse gas mitigation technologies are widely believed to be very significant, fostered by the assumed aggressive growth of developing countries and by expanded engagement of more countries in the Kyoto protocol. Although much further work is needed to scope out the dimensions and timing of international markets, thirteen countries were examined in some detail:

United States	Russian Federation	China
Australia	Ukraine	India
Spain		Brazil
Czech Republic		Argentina
Poland		Thailand
Mexico		

In each case, there is a good match between the countries' needs for greenhouse gas mitigation technologies and emerging Canadian capability. It follows that directing technology development investments to areas which meet the needs of Canada, while also meeting the needs of these countries should be a priority.

The options presented are designed to provide the "technology supply side" component of the National Implementation Strategy for Climate Change. They have been designed to play a complementary role to options put forward by the various Sector Tables regarding the deployment of advanced greenhouse gas technologies within each major sector of the economy. A roll-up of the work done by the Sector Tables on needs for new technologies and approaches within the sectors, and ideas on development pathways, is recommended as further study.

Other important issues have been identified in the course of the Table's work which call for additional analysis. First, better information is needed on the dimensions and characteristics of emerging international markets for greenhouse gas technologies that expand on the observations reported here. These markets offer a potentially large future opportunity for Canadian technology suppliers. Second, this report focuses exclusively on mitigation technologies. Adaptation technologies – those designed to minimize the anticipated impacts brought on by climate change – need to be addressed. Once a better understanding of the impacts of climate change on the environment is available from the Science, Impacts and Adaptation Table, then the needs for adaptation technologies can be more fully assessed and a strategy for development of relevant technologies can be developed. Third, further work is needed to assess the anticipated technical, commercial and social benefits which are expected to arise from investments in technology development such as those recommended in this report.

Summary of Options and Funding Profiles

		Funding					
Options	Objective	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Sources**
1. National Climate Change Discovery Competition	To develop new concepts and ideas that could lead to new greenhouse gas mitigation technologies	$25M	$25M	$25M	$25M	$25M	federal
2. Enhanced Support for Basic Knowledge Generation	To enhance the knowledge base for opportunities that could have a long-term impact on greenhouse gas mitigation technologies	$5M	$5M	$5M	$5M	$5M	federal
3. Climate Change Technology Development Fund	To assist in developing technologies from concept to point of demonstration	$20M	$40M	$80M	$150M	$200M	federal: up to 50% provincial: 25% industry: 25%
4. Climate Change Technology Demonstration Program	To alleviate some portion of the financial risks involved in early domestic commercialization of greenhouse gas mitigation technologies	$60M	$90M	$150M	$240M	$300M	provincial and industry: 70% federal: 30%
5. International Marketing	To create the climate for enhanced international marketing of climate change technologies and thus achieve the second part of the Technology Table's mandate	$400K	Dependent on strategy				federal (for year 1)
6. Reducing Risk and Facilitating Accreditation	To undertake comparative analyses of the recognition of risk in the technology innovation process granted by other countries	$200K	$200K	$200K	$200K	$200K	federal and provincial

		Funding					
Options	Objective	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Sources**
7. Technology Networks and Roadmaps	To develop improved strategic understanding of technological opportunities for greenhouse gas mitigation technologies in and across industrial sectors, and between technology suppliers and technology users	$5M	$5M	$5M	$5M	$5M	federal: 60% provincial: 40%
8. Communication Forum	To ensure that decision-makers responsible for the investment of the limited resources available for technology development have the benefit of adequate knowledge and information for informed and sound decisions	$300K	$300K	$300K	$300K	$300K	federal and provincial
		$115.9M	$165.5M+	$265.5M+	$425.5M+	$535.5M+	

Chapter 1

Introduction and Context

1.1 The Kyoto Protocol

The Kyoto Protocol was established in December 1997 at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (UN FCCC) in Kyoto, Japan. Within the Kyoto Protocol, Canada has committed to reduce its greenhouse gas emissions by minus 6% relative to 1990 levels, averaged over the period 2008-2012. In real terms, this corresponds to a reduction of 20-25% for that period compared to the emission levels that would be reached if business were to proceed as usual.

The Protocol is flexible and enables signatories to meet their commitments through a customized combination of cost-effective technological solutions, new policies and yet to be clarified international mechanisms.

A practical and inclusive National Implementation Strategy on climate change is being developed under the joint auspices of federal, provincial and territorial Ministers of Energy and of Environment, and involves all levels of governments, industry, environmental groups, academia and individual Canadians.

Sixteen Issue Tables[3] were set up as part of this process to develop options for consideration by Ministers for responding to the challenges of the Kyoto Protocol.

[3] The Tables are: Agriculture and Agri-Food, Analysis and Modeling Group, Buildings, Credit for Early Action, Electricity, Enhanced Voluntary Action, Forest Sector, Industry, Kyoto Mechanisms, Municipalities, Public Education and Outreach, Science and Adaptation, Sinks, Technology, Tradeable Permits Working Group and Transportation.

1.2 The Technology Issues Table

1.2.1 Mandate and Timeframe

Since technology plays a pervasive role throughout the economy, the availability of cost-effective technologies with improved environmental performance is vital to a sustainable future for Canada. Therefore, technology development will be a fundamental element of Canada's national implementation strategy for reducing greenhouse gas (GHG) emissions. This was recognized when the Technology Issues Table was established as a component of the National Implementation Strategy.

Ensuring that Canadian companies can provide such technologies in both domestic and international markets will yield significant economic benefits to Canada. This will require concerted and sustained effort to support and stimulate the availability of technology, to enhance its commercialization and market access by Canadian companies.

The mandate of the Table was to propose ways to:

a) advance the development and commercialization of cleaner and/or innovative technologies which will contribute to the reduction of greenhouse gas emissions; and,

b) enhance the capabilities and opportunities for Canadian companies in providing environmentally-responsive technologies in domestic and international markets.

The Table's mandate, often referred to as the 'double dividend', was defined to cover the development of greenhouse gas mitigation technologies up to their first commercial introduction.

The nature of technology and its development and commercialization required the Table to take both short- and longer-term perspectives covering the Kyoto period and beyond. Some technologies are already close to market and could help reduce emissions in the Kyoto timeframe. However, the full cycle of development of new and emerging technologies can take up to many decades. The Technology Issues Table therefore focused a considerable amount of attention on means to develop the intellectual and institutional capital to ensure that technologies and systems are available to reduce emissions in the post-Kyoto timeframe. Ensuring that longer-term technology development is part of the options provided for Ministers' consideration is critical to continued reductions in greenhouse gas emissions. The Options presented in Chapter 6 will assist Ministers in making decisions about the effectiveness of current and future efforts to reduce greenhouse gas emissions and in establishing priorities for future directions of technology development to enhance economic benefits for Canadian companies.

1.2.2 Relationship with Other Tables

Given its broad horizontal mandate, the Technology Issues Table has conducted its activities in co-operation with other Tables that have complementary mandates and objectives. The mandate of the Sector Tables[4] requires them to focus on greenhouse gas reduction within their sectors to achieve their emissions reduction targets. Their work has typically included analysis of technology needs and the constraints to technology deployment within their sectors. Their emphasis is on the technology available now or in the immediate future which can be deployed to respond in the Kyoto timeframe. Moreover, the clientele of the Sector Tables is quite different from that of the Technology Issues Table. The Sector Tables were concerned with users of technology, those that actively seek the most cost effective and efficient technologies to meet their needs. In contrast, the Technology Issues Table's clientele was primarily the R&D community and technology suppliers, those that strive to develop new innovative technologies to meet the evolving needs of users as the basis of their success and competitiveness. The differences between the mandates, objectives and clientele of the Technology and Sector Tables, related to technology issues, are shown in Figure 1.

Figure 1 – The Differences Between the Technology and Sector Tables

SECTOR TABLES	TECHNOLOGY TABLE
• Meet Kyoto targets	• Kyoto targets and beyond
• Deployment • Buy & adapt existing technology	• Development and first commercialization of technology • Build Canadian Capability
• GHG reduction in Canada	• Make technologies available for GHG reduction in Canada and abroad
• Minimize economic impact of recommended GHG reduction measures	• Maximize economic opportunities for Canada
• Clientele: technology users and domestic market	• Clientele: technology suppliers and and international markets

There has also been ongoing dialogue between the Technology Issues Table and the Science, Impacts and Adaptation Table regarding technologies that assist in adapting to the impacts brought on by climate change, such as by rising sea levels and increased frequency of extreme weather events. At a later date, once the Science, Impacts and

[4] Agriculture and Agri-Food, Buildings, Electricity, Forest Sector, Industry, Transportation Tables.

Adaptation Table has identified the anticipated climate change induced impacts on the eco-system, consideration should be given to the implications for technology needs for adaptation purposes.

1.2.3 Guiding Principles and Approach

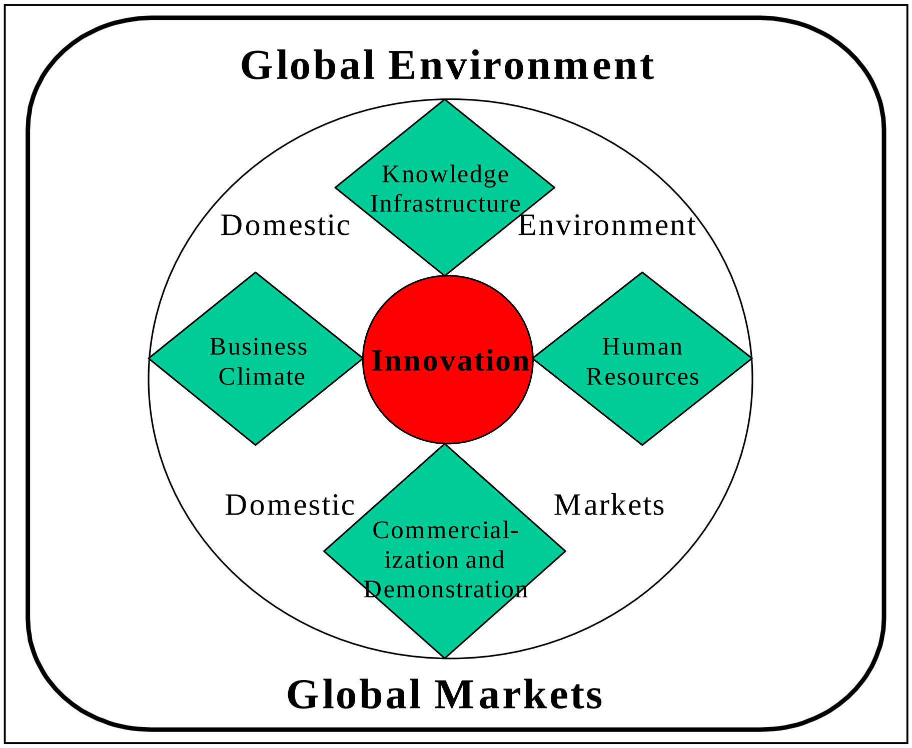
The Technology Issues Table was guided by some strong underlying principles:

- Governments at all levels in Canada must recognize the need for commitment to the climate change agenda and the need for current and sustained long-term investments in the development of greenhouse gas mitigation technologies. This commitment by governments will provide a clear signal to technology innovators and businesses that investments in technology development are supported by policies and other measures to achieve economic and environmental objectives, and which help offset the risk of investments.
- The challenge to reduce greenhouse gas emissions is substantial for Canada and the world. Leadership from governments will be an essential first step in creating a new base of intellectual capital. There will be a need to establish effective partnerships between all levels of government, industry and academia, which must respect and support the varying regional challenges and opportunities.
- Enhancements to the innovation system, in which technologies are created and brought to market, will be necessary to improve Canadian capability and the environment for development and commercialization of new, innovative, environmentally friendly technologies. The time lag between investment in innovation and eventual deployment of technologies calls for action today. Otherwise, business opportunities for the future will be missed.
- Existing programs are not currently focused to the full extent possible on the climate change challenge and can be revisited and redirected. Alignment of programs and regulations across all levels of government will be important to allow firms to better compete both nationally and in world markets.

The Technology Issues Table chose to approach its work within a national innovation framework to enhance the milieu in which climate change solutions can be developed and brought to market by Canadians. The Technology Issues Table has also attempted to shed light on the nature, effectiveness and efficiency of the Canadian innovation system to enhance GHG mitigation technology development.

Innovation provides a ‘toolkit’ of means and mechanisms to ensure sustained success in developing greenhouse gas mitigation technologies and to ensure that Canadian companies capture a share of growing markets. Innovation, by definition, is a dynamic, iterative process involving scientific discovery, applied research, development and refinement, pilot- and commercial-scale demonstration and, introduction of new technological solutions into the marketplace. It involves developing knowledge and ideas and bringing them together in the marketplace in new, creative ways. The four main components of innovation – knowledge infrastructure, commercialization and demonstration, business climate and human resources – are shown in Figure 2. Further discussion on the innovation system is provided in Chapter 5.

Figure 2 – Innovation System Model



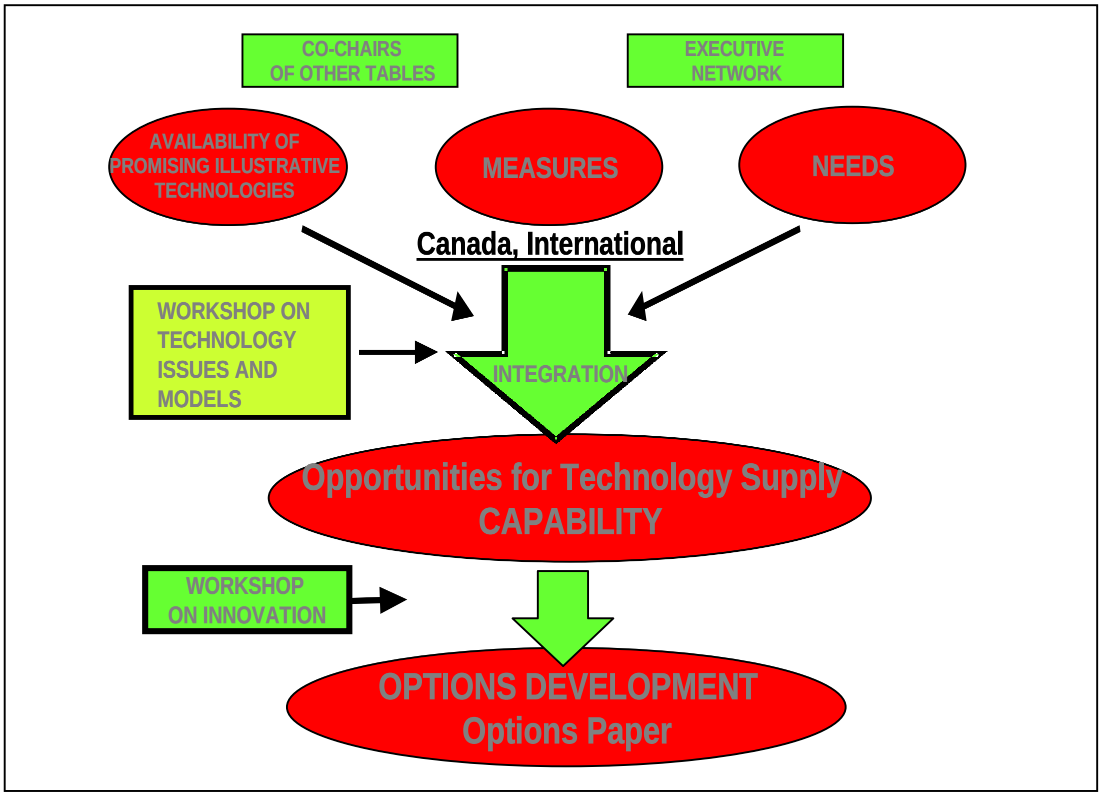
1.2.4 The Table's Workplan

The Technology Issues Table first identified *needs* for commercial greenhouse gas mitigation technology in Canada and around the world. In parallel, an inventory of the global *availability* of greenhouse gas mitigation technology was developed. The inventory was analyzed and scaled-down to represent the Canadian context. Together, the assessment of *needs* and the *Canadian availability of technologies* provided a profile of supply challenges and opportunities for Canada for greenhouse gas mitigation technologies. To complement the assessment, an inventory was developed of domestic and international *measures* that are used to advance technology innovation. Working groups, composed of members of the Technology Issues Table, guided each of the assessments on needs, availability and measures.

An integration of the three assessments by the Table provided an understanding of the efforts required to support and stimulate the availability of technology, to enhance commercialization and market access, and to enhance the innovation system in which such technologies are created and brought to market ready status. The integration also provided indications of technology areas that are appropriate for Canada to pursue.

The overall approach followed by the Technology Issues Table is illustrated in Figure 3.

Figure 3 – Technology Issues Table Workplan



The co-chairs consulted with the sector tables and also met with public and private sector representatives in several provinces, as part of the development of the executive network around the Table's deliberations. Workshops were held at two points in the process. The first workshop reviewed, in collaboration with the Analysis and Modeling Group, technology issues and approaches to modeling. The second workshop on innovation was a major event held with experts from the private and public sectors to review the results of the Table's work on technology needs and present capability and to review early ideas for the Table's options.

1.2.5 Membership

The Technology Issues Table was composed of technology and research managers, technology developers and experts in innovation from all regions of the country. The 25 plus members were selected to provide cross-sectoral representation from federal and provincial governments, academic institutions, industry and industry associations, and environmental non-governmental organizations. A list of members is provided in Appendix 1.

Chapter 2

Greenhouse Gas Mitigation Technologies - Domains of Domestic Needs

Technology is pervasive. It is all around us and fulfills a multitude of needs that generally make 'life easier' and/or more fulfilling. Technology is used by all individuals and in all businesses. The term, used loosely, is commonly understood to refer to products, systems, services and processes.

In a broader sense, the term technology refers to a component of society's base of knowledge, to the concepts and ideas that lead to products and services. As such, technologies have been around, in one form or another, for thousands of years. They have increased in sophistication since ancient civilizations used them to draw water, transport goods, etc. However, it is only since the Industrial Revolution that the world has seen an explosion of technologies. This has led to an increasing dependence by society on them, which will continue to grow in the future.

Society will continue to require - and demand - technologies that meet their needs for heat, power, transportation, housing, food, and goods and services of all kinds, but in a greenhouse gas constrained world, technologies will also have to reduce the greenhouse gas emissions current practices give rise to. All sectors of the economy are impacted by technology, and all sectors will require different technology solutions to respond to the climate change challenge. This is true in Canada and around the world.

The challenge of developing and commercializing new technologies brings opportunities for Canadian companies to capture a share of what will be a growing market. There are many emerging technologies that can help meet the climate change challenge and Canada must take action to ensure it captures a proportionate share of rapidly expanding markets.

Given the long-term nature of the challenge - and the time lag from conception to market acceptance and deployment of technologies - it is important to include technologies that can meet near-, mid- and long-term needs. Technologies have to be considered that could help Canada meet the emissions reduction commitment it made in Kyoto, but more importantly, that lay the groundwork for transformational technologies which will have a dramatic impact on emissions in the post-Kyoto period. The latter is crucial as more stringent emission reduction goals are likely to be set in the future. Canada must act now to develop better and fundamentally different ways of producing, delivering and using energy and other greenhouse gas emitting services in the future.

The Technology Issues Table did not, and could not, identify every technology need and the corresponding technological solution. Such inclusiveness would have been an immense task given the sheer size of the inventory of technologies, and would have represented an exercise that went beyond the time and resource limits of the Table. It would also have been duplicative of the work of the Sector Tables.

The approach taken by the Technology Issues Table was to focus on the challenge itself by 'defining the target' for which a technological solution could be directed, rather than focus directly on currently available technological solutions.

To evaluate the domestic needs for climate friendly technologies, the Technology Issues Table commissioned a study. The methodology used is found in Appendix 2. Via a survey questionnaire, and a review of the current literature and Foundation Papers of the Sector Tables, the Table assembled a broad view of domains of domestic needs for GHG mitigation technologies. The Table members, experts themselves in their fields, undertook a concerted effort to refine and generalize the domains of needs. They synthesized them according to six categories defined by areas of use or by type of technology. These categories, shown below, are carried forward throughout subsequent analyses:

- Fossil Fuel Supply;
- Energy Production;
- Energy End-Use;
- CO_2 Management;
- GHG Emissions from Non-Energy Activities; and
- Enabling/Cross Cutting Technologies.

The list of needs, which formed the basis for the Table's subsequent work, is found in Table 1.

To position Canada to respond technologically to the challenge of climate change up to the Kyoto timeframe and beyond, it was necessary to anticipate future needs that recognized different ways of providing energy and other services in the future. R&D, by its very nature, takes time and must anticipate future needs. R&D investments must begin early in order to foster Canadian capacity to succeed in future economies, to develop the technologies themselves, to introduce them to existing processes or societies, and to advance the infrastructure necessary to support such innovative approaches. In the energy field, this could require a different mix of primary energy sources than are in use today. For example, in the future, Canada could have an energy economy with a strong contribution from renewable energy sources (beyond large hydro-electricity), or an economy based on large-scale production and use of hydrogen as an energy carrier.

Table 1 – Needs Defined by the Technology Issues Table Members[5]

Fossil Fuel Supply • To develop clean, efficient pipeline and gathering systems • To increase the energy and carbon efficient processing (exploration, natural gas, oil, refining, oil sands recovery and upgrading, gas from coal, gas to liquid fuels, coal) • To reduce or utilize fugitive gas emissions • To respond to the growing demand for natural gas
Energy Production • To increase electricity supply from CO_2-free/neutral sources • To efficiently convert primary fossil fuels to electricity, and biomass to fuels/chemicals • To switch to lower carbon fossil fuels • To efficiently convert primary energy sources to carbon free fuels
Energy End-Use • To have clean, efficient buildings and municipalities • To have more efficient transportation systems and better traffic management systems
CO_2 Management • To manage emissions from large point sources
GHG Emissions from Non-Energy Activties • To decreased emissions of CO_2, CH_4 and N_2O from, for example, cement production, landfills and fertilizer applications
Cross-Cutting/Enabling Technologies • To develop less carbon intensive energy sources • To better apply enabling technologies • To improve energy and resource efficiency

[5] The needs for industrial processes were not covered.

A review of needs requires considerable time, but it is the crucial first step to address any challenge. A good way of identifying future technological needs for greenhouse gas mitigation technologies is through technology "roadmap" exercises. Roadmaps are a forecasting, foresighting and planning tool that helps identify critical technological products and services and their market opportunities from three to ten (or more) years into the future. They involve all stakeholders and often take two-three years to develop. They are discussed further in Chapter 6.

Example of a "Visioning" Exercise

The Energy Technology Futures Project is a major NRCan policy research effort that is designed to move us beyond our current time frame and focus to develop possible pictures of Canada's energy system three to five decades into the future. The fundamental intent of the project is to addresses the main public policy issue in the climate change debate i.e., altering the fundamental relationship between economic growth and increasing GHG emissions. The secondary objective of the project is to improve NRCan's longer-term S&T planning capabilities. The project will develop four scenarios of the future that examine the potential role of energy related technologies in resolving long-term climate change issues. These scenarios will outline the technologies that Canada could be using in the way we live, work and travel. Each scenario will also examine the energy mix, and the role of fossil fuels and other energy forms necessary to meet the energy needs of that scenario, and will identify key technologies that could have a major impact on future GHG emissions.

Chapter 3

Canadian Capability to Respond to the Need for Future Greenhouse Gas Mitigation Technologies

Using the description of needs identified in Table 1, the Technology Issues Table surveyed the availability of technologies and compiled a manageable grouping of promising illustrative technologies where current and future Canadian capacity could be used to fulfill the needs. The Table consulted with experts and associations across the country and referenced a comprehensive list of more than 1300 very specific existing, emerging and future global technologies that could be used to reduce emissions of greenhouse gases. Appendix 3 contains the comprehensive list.

The technologies of interest, which ultimately have the best potential to achieve the 'double dividend' for Canada, have four characteristics. First, they have good greenhouse gas reduction potential, in one or more of four ways:

- reduce the energy intensity of energy-using activities (increase efficiency);
- increase the use of low carbon, or zero carbon, fuels;
- capture, transport, use or store CO_2 once it has been produced; and/or
- reduce emissions of greenhouse gases from non-energy activities.

Second, their development can be advanced by existing Canadian capability in research and development organizations and in firms, or where the Canadian potential exists to develop these capabilities. Third, the technologies respond, primarily, to strong emerging domestic needs and, secondarily, to international needs, thus providing a large market base. Finally, the technologies are not yet economically viable, and therefore require research, development and demonstration assistance.

To be more specific, the Technology Issues Table used the following criteria to identify promising technologies:

1. strong Canadian capacity exists to develop the technologies, and the technology responds to both a Canadian and an international need[6]. These are considered the best opportunities for Canadian firms;

2. the technology responds to a Canadian and an international need where Canadian capacity does not currently exist, but where there are benefits in, and opportunity for, developing the capacity. These are considered interesting opportunities that should be examined further;

3. strong Canadian capacity exists to develop the technologies, and the technologies fulfill a Canadian need only. These are considered

[6] International needs are treated in Chapter 4

interesting opportunities, but are limited in scope due to the small size of the Canadian market.

The technologies that respond to a domestic need are a common feature in the above three criteria. The Technology Issues Table did not consider those technologies that:

4. fulfill an international need but not a Canadian one, even though some Canadian expertise exists.

5. fulfill an international need only, for which Canadian capacity is weak and not considered worth strengthening.

Figure 4 shows this selection criteria.

The basis for not identifying certain technologies was the recognition that there is weak Canadian-base upon which to compete with entrenched interests of technology suppliers in the countries needing the technology.

Figure 4 – Selection Criteria Used to Identify Promising Illustrative Technologies[7]

Opportunities Considered	Rating of Opportunities	Canadian Capacity	Canadian Need	International Need
Opportunities of Interest	1. Best	✔	✔	✔
	2. Interesting†	✘	✔	✔
	3. Interesting but limited	✔	✔	✘
Opportunities Excluded	4. Weak	✔	✘	✔
	5. Weak	✘	✘	✔

†*This category is particularly interesting if the international capacity is week*

[7] Not all Table members agreed with the selection criteria. Some members felt that international opportunities should be pursued regardless of the existence of a domestic need or a strong Canadian capacity to fulfill the need.

3.1 Promising Illustrative Technologies

Using the selection criteria, the Technology Issues Table identified 25 groupings of promising illustrative GHG mitigation technologies that need further R&D and commercialization efforts. They are found in Tables 2A-2F. The mitigation technologies cited are illustrative of the potential that exists. They should not be interpreted as *the* definitive list of technologies to abate greenhouse gas emissions. The technologies cited are at various stages of development, but are all believed to provide significant domestic opportunities if barriers to their advancement can be overcome.

For each of the promising illustrative technologies, short profiles were produced. A synopsis of each is found in Appendix 4. Information is provided on:

- the features of the technology or challenge;
- technological overview and status;
- estimated timeframe to market readiness;
- Canadian research and supply capabilities;
- market potential;
- barriers to innovation;
- measures that could overcome the barriers and enhance innovation; and
- estimated amount of funding required for research, development and demonstration of the technologies

The profiles identify significant opportunities for Canada to develop and commercialize a number of promising technologies that fulfill a need to reduce greenhouse gas emissions.

Table 2A – Promising Illustrative Technologies – Fossil Fuel Supply

Technologies to reduce leaks from natural gas pipelines
Process technologies related to energy and carbon processing efficiency
Technologies to reduce or use fugitive gas emissions from fossil fuels
Technologies for increasing natural gas supply

In the ***fossil fuel supply*** *area*, the industry is already well-engaged in tackling the technology challenges that they face. Technologies are being developed to suit Canadian geology, environmental requirements and reservoir and fluid characteristics. There is a good co-ordinated effort by producers, service companies, funding alliances and facilitating organizations, such as the Petroleum Technology Alliance of Canada, to develop technologies to suit domestic and potential export needs. In many cases, investments are made to adapt technologies from foreign sources. Both tracks often open up opportunities for service companies to market these technologies abroad to handle similar operating conditions.

The promising areas include technologies to limit emissions from operation of natural gas pipelines, to increase the efficiency of recovery and processing of heavy oil and bitumen, and down-hole oil-water separation. Technological opportunities in these areas require investments to advance their development to the market-ready stage, or funding for pilot testing to refine the technology to match Canadian operating and reservoir conditions.

In addition, the Table identified the need for technologies to increase natural gas supply, from both conventional and non-conventional sources. Recent trends in the demand for natural gas for residential, commercial and power generation purposes suggest that long-term supply could become an issue, testing the limits of conventional sources and calling for investments to increase supply in the long-term from non-conventional sources such as coal-beds and gas hydrates. More fundamental research effort is required to meet this need.

Further information on fossil fuel supply is found on pages 33 to 42 of Appendix 4.

Table 2B – Promising Illustrative Technologies – Energy Production

Electricity from CO_2-free/renewable sources
Biomass combustion
Biomass conversion
Large scale hydroelectricity
Nuclear fission
Stationary gas turbines

Energy production is an area where the innovation challenges are quite varied and are specific to the technology itself. For example, renewable energy forms such as biomass combustion and small hydro-electricity are well known technologies that have been well exploited over the years. However, innovation continues to respond to changing needs. Other so-called ‘non-conventional’ renewable energy sources such as solar and wind are not yet widely deployed across the country and need further research to lower costs, improve efficiency and ensure integration into existing infrastructures. They could also benefit from demonstration and commercialization to provide technical and performance data to potential users.

Large-scale hydroelectricity is a well proven technology that supplies more than half of Canada’s electricity. Nonetheless, innovation is needed for large-scale hydroelectricity-related technologies in order to develop a better understanding of migration of CO_2 and CH_4 emissions from reservoirs, create more optimal energy storage and more efficient high voltage transmission infrastructures, etc.

Nuclear fission is a technology that produces energy without the emission of greenhouse gases and Canada has world class capability in heavy water system technology. There are, however, concerns associated with it related to high costs, safety, the management of waste products, and perhaps even proliferation of nuclear arms. To overcome the concerns and challenges, continuing innovation is required to facilitate life-extension of today’s systems by developing advanced materials, reducing the cost of systems, and demonstrating the effectiveness of waste and fissile material management methods. The long life cycle of an individual plant (40 to 100 years) demands long term commitment to achieve refinement and improvement of nuclear power systems.

See pages 45 to 61 in Appendix 4 for further information on energy production technologies.

Table 2C – Promising Illustrative Technologies -Energy End-Use

Fuel cells (Stationary and Transportation) Energy efficient building technologies Transportation and transportation systems: intelligent transportation systems, advanced vehicles and fuel technology, and mass transit systems

Energy End-Use represents a diverse collection of technologies. The Table limited its analysis to fuel cells, and buildings and transportation technologies. It did not delve into the details of industrial process technologies. These are too numerous and the Table assumed that they will be dealt with by the Sector Tables.

Fuel cells require more research in all components in order to lower the initial costs and improve performance. The cost of reforming fuels also needs to be lower, and these need to be evaluated in the context of full life-cycle carbon dioxide emissions. In addition, demonstrations of the technology should be undertaken, and the distribution infrastructure for new fuels needs to be established.

There are several new and improved practices and technologies for future buildings already under development. These should be pursued. Actions to influence building design, construction and refurbishment are high leverage activities that provide long-term benefits because of the long lifetimes of buildings. Demonstrations of building technologies have been particularly effective in the past, and should continue.

Technology will play a key role in Canada's ability to reduce greenhouse gas emissions from transportation. To date, new technologies have been instrumental in improving energy efficiencies in several key areas. For example, fuel economies in light duty vehicles, aviation and trucking have improved considerably as a result of more efficient engines, improved design and new, lighter-weight materials. Canada has been playing an important leadership role in many new transportation technologies. Nevertheless, ongoing innovation, research, development, and demonstration will be crucial to achieving GHG reductions. Some of the key technologies for continued research and development include: improvements in car and truck design, engines and materials; fuel cells for road, rail and marine use; production, distribution and use of alternate fuels, such as natural gas and cellulosic ethanol; Intelligent Transportation Systems (ITS); urban transit systems and vehicles (buses, commuter rail, subways); safety issues related to new vehicle designs, materials and fuels; and, transportation systems and links to urban design and land use.

Further information on energy end-use technologies is found on pages 65 to 71 in Appendix 4.

Table 2D – Promising Illustrative Technologies – CO_2 Management

Geological CO_2 management[8]

CO_2 Management is an exciting, newly emerging area of greenhouse gas mitigation technologies that enable capture of CO_2 from stationary sources, and use, transport and sequestration in geological formations. Value-added uses of the CO_2 include enhanced oil recovery and enhanced natural gas recovery from coal beds. Geological 'sinks' for CO_2 include deep confined and unconfined saline aquifers, depleted oil and gas reservoirs, deep coal beds and the oceans. Although enhanced oil recovery is fairly advanced along the development pathway, several CO_2 management technologies are still in their infancy; for example, the enhancement of methane production using CO_2 while sequestering the injected CO_2 in deep coal beds. Canada has particular strengths in this area, particularly in CO_2 capture and geological sequestration technologies.

Page 78 in Appendix 4 contains the profile for CO_2 management technologies.

Table 2E - Promising Illustrative Technologies – GHG Emissions from Non-Energy Sources

Technologies to reduce CO_2 from cement production
Technologies to capture methane from landfills
Technologies to reduce methane from manure management
Anaerobic digestion of municipal solid waste
Technologies to reduce nitrous oxide from fertilizers

Reducing ***greenhouse gas emissions from non-energy sources*** represent challenges in many sectors. The Table has focused on technologies in the cement and agriculture industries. In order to reduce greenhouse gas emissions from cement use, supplementary cementing materials, such as fly ash from coal burning plants and blast furnace slags from steel plants can be used in place of cement in the manufacture of concrete, but need to be further demonstrated. In the agricultural industry, new technologies and management practices to reduce nitrous oxide emissions from fertilizer application is a short-term sequestration option. In addition, livestock manure can be anaerobically digested to capture methane emissions as a fuel. Municipalities also provide opportunities to reduce emissions by capturing methane from landfills and also using it as a fuel. As with the cement industry, many of the technologies are fairly well advanced, but need demonstration successes before they will be implemented on a wide scale.

[8] Biosphere management of CO_2 (i.e. natural sinks) were not considered. It was assumed that they would be sufficiently addressed by the Forest Sector, Agriculture and Agri-Food, and Sinks Tables.

See pages 81-93 in Appendix 4 for more information on technologies to reduce greenhouse gas emissions from non-energy sources.

Table 2F – Promising Illustrative Technologies – Enabling / Cross Cutting Technologies

Hydrogen technologies
Enabling technologies
Electrotechnologies
Advanced materials
Catalysts
Energy Storage
Biotechnologies
Gas Technologies
Separation Technologies
Simulation and modelling
System integration technologies
Technologies that use less carbon intensive energy sources

Cross-cutting and enabling technologies may not have direct greenhouse gas mitigation potential, but they have the potential to make an extremely important contribution to reductions in all sectors. Technologies such as catalysts, membrane-based separations technologies, and sensors and controls provide the underpinnings or the backbone that allow many of the above mentioned technologies to function efficiently and effectively. Rapid advances in information technologies translate into continuous improvement of enabling technologies. Technologies that cut-across several sectors, such as gas technologies, electrotechnologies, and biotechnologies offer opportunities to make fundamental changes to current approaches. For example, electrotechnologies can be used more efficiently than other technologies in recycling, manufacturing and recovery processes. Biotechnologies have the potential to replace many chemical processes in use today. Hydrogen technologies and technologies that use less carbon intensive energy sources (e.g. natural gas) are also included in this category. All require considerable continuous innovation.

Further information on enabling/cross-cutting technologies is found on pages 96-125 in Appendix 4.

Many of the promising illustrative technologies cited have benefited, over the years, from both public and private support. Past objectives for developing the technologies have not necessarily been climate change related, but because of the past effort, the current innovation infrastructure already provides the underpinnings to enhance Canadian capabilities and opportunities. The machinery is in place. The competency exists. However, neither are resourced sufficiently, nor focused and aligned to the scope of the challenge of >*Kyoto and beyond*=.

The options proposed in Chapter 6 are designed to enhance the development and demonstration of the promising illustrative technologies, and to foster new ideas and concepts that could lead to future technologies that reduce greenhouse gas emissions.

Chapter 4

A Perspective on International Market Conditions for GHG Mitigation Technologies and Their Relationship to Domestic Needs

To respond to the second part of the Technology Issues Table's mandate, a perspective on the international market opportunities for greenhouse gas mitigation technologies was needed since it is generally accepted that international markets provide larger opportunities than the domestic one.

The selection criteria shown in Figure 4 (Chapter 3) indicates, however, that the Technology Issues Table's interest resided in those technologies that fulfill needs in both domestic and international markets. While Canada can expect to capture some of the market, it will face stiff competition as other countries aggressively strive for market share. By concentrating on technologies that fulfill both a domestic and an international need, Canadian companies will be capitalizing on their strengths and building on to domestic successes. They will find niche opportunities.

It is important to note that the existence of international technology needs do not necessarily – or easily – translate into international market opportunities for Canadian companies. Several factors, both general and country-specific, may constrain Canadian technology suppliers' ability to fulfill the needs. Such factors include, but are not limited to:

- limited access to capital;
- high cost of capital in developing countries;
- international trade and market barriers such as import duties;
- insufficient intellectual property protection regimes;
- product incompatibility outside Canada;
- high transaction costs associated with specific transfer pathways (e.g. licensing, franchising, joint venture);
- lack of reliable international data and information on technology and market characteristics;
- non-existent or small Canadian presence in a country;
- strong competition from domestic suppliers, and from suppliers from other nations;
- limited technical and institutional capacity in developing countries to evaluate and select appropriate technologies; and
- subsidized or otherwise controlled prices for energy or other services.

There are two other important considerations to bear in mind when accessing international markets. First, technologies typically need to be modified to suit local conditions. This raises costs and lengthens the time it takes to penetrate a market. Second, achieving success in export markets takes time to understand foreign markets and their business and social practices, to cultivate contacts, and to learn the nuances of international transactions. This in turn requires persistence and a considerable amount of cash flow to sustain the effort until revenue starts flowing.

4.1 International Market Needs Assessment

Notwithstanding the constraints, the international market potential for greenhouse gas mitigation technologies is believed large enough to warrant a company taking the risk of attempting foreign market entry. To gain an appreciation of international market characteristics, the Table commissioned a broad assessment of international technology needs.

An assessment of this kind can only scratch the surface. The assessment was much more general than the one for domestic needs, but it provided some indications of areas of opportunity. Clearly further market research and intelligence must be undertaken for each country and region of interest. For Canada to better position itself, further study should begin now.

Following a compilation of baseline data on greenhouse gas emissions and a forecast of future emissions for all countries where data were available, the study assessed market dynamics and the scale of need in each country. The latter included commitments under the Kyoto Protocol and the evolution of the existing market for environmental goods and services. A literature review provided additional information. An integration of the data then provided a broad assessment of international technology needs. The detailed methodology used for the assessment is in Appendix 5 and a summary of international technology needs (for environmental goods and services) is in Appendix 6.

Some of the features and characteristics of overall international market potential for greenhouse gas mitigation technologies are presented in Table 3.

In general, in the near-term, OECD countries provide the best opportunities for export sales. Most OECD countries have committed to reducing greenhouse gas emissions, they are in a better position to pay for the new services, they have business and fiscal rules similar to Canada's, they have the human and physical infrastructure to accept and adapt the technologies, and they often have compatible codes and standards.

Transitional and developing countries, with their trend of increasing population and economic development, represent potentially large market opportunities in the mid- to longer-term. It is important to note that the drivers in developing countries for technologies are not often environmental ones. Their needs usually stem from social and economic considerations. This is not to say that opportunities do not exist today for greenhouse gas mitigation technologies. Indeed, Canadian companies are already capitalizing on opportunities in several countries given that greenhouse gas mitigation technologies meet several objectives.

Table 3 – International Market Potential for Greenhouse Gas Mitigation Technologies

Market Category	Features
1. Highly likely large market potential in the short term	• Liberalized markets • Existence of full cost pricing or movement to full cost pricing of energy services • Existence of regulatory and incentive mechanisms to promote generation and consumption of greener power • Established regulatory framework to enforce environmental legislation • Existing, generally open trading relationships between Canada and target markets
2. Emerging market potential over the short to medium-term	• Liberalized markets • Signals of movement towards full cost pricing of energy services • Secondary training relationships between Canada and target markets • Existing signatory to the Kyoto Protocol • Potential candidate for subject to CDM/JI projects
3. Major market potential in the medium to longer-term	• Large population • Large population growth rate • One of critical countries to emergence of a CDM/JI framework • Vast unmet energy requirements • Demonstration of some potential to energy market liberalization
4. Limited market potential	• Consumer of small percentage of world energy • Large domestic reserve of fossil fuels • Not part of tier A or B of Canadian trading relationships • Move to greenhouse gas reduction will be driven by development of system requirements primarily • Per capita demand-growth in electricity consumption beginning to drop

4.2 Detailed Country Assessments

To get a better glimpse of the opportunities in selected countries, the Technology Issues Table chose 13 countries for further examination. They were chosen to represent a cross-section of OECD, developing and transition countries. They are:

United States	Brazil
Australia	Spain
Russian Federation	Ukraine
Poland	Czech Republic
China	Argentina
India	Thailand
Mexico	

An overview of each country assessed is in Appendix 7A, and a more complete description is in Appendix 7B.

Examples of Canadian Companies Active Abroad

Super E(tm) House Program

The Super E(tm) House Program is an initiative of the CANMET Energy Technology Centre (CETC) to improve the volume, profitability and sustainability of sales of Canadian energy-efficient housing systems, products and services in export markets, currently focusing on Japan. Successful partnerships are being formed between Canadian housing exporters and Japanese builders to build top quality energy-efficient housing with high Canadian product and service content across Japan. After one year of commercial operation, the program now has ten Japanese builder and six Canadian exporter member companies. One of the Canadian companies is K. Ito and Associates, a Vancouver-based housing export company that, with its Japanese client, designed and produced the first Super E(tm) House. K. Ito and Associates is a nine-person engineering/architectural firm that consolidates and ships housing packages to the Japanese market. Since completion of this initial project eight months ago, K. Ito and Associates has shipped ten more Super E(tm) House packages and continues to receive more orders and interest. Each house has a Canadian value-added content of more than $100,000.

AECL

Atomic Energy of Canada Limited (AECL) is a leading international vendor of nuclear power reactors. AECL sells CANDU® power reactors, MAPLE research reactors and the MACSTOR advanced spent fuel storage system. AECL engages in a wide range of R&D activities and provides nuclear engineering products and services to customers world-wide in nuclear and related industries.

The technology supporting these systems was developed and first deployed in Canada. This expertise was then applied to the export market. Six CANDU reactors are now operational in the Republic of Korea, Argentina and Romania. Two CANDU reactors are under construction in China. Many other Canadian companies are involved in uranium mining and processing, fuel manufacture, and reactor and balance of plant component supply. The total investment represented by each plant is of the order of $2 billion.

4.3 Relationship Between Domestic and International Opportunities

The Technology Issues Table was interested in those technologies that have intersecting domestic and international needs and for which there is innovation capacity in Canada (see the promising illustrative technologies in Chapter 3). Appendix 8 shows that there are several technologies that overlap.

Areas where there are considerable overlapping needs between domestic and international markets are in the energy production and energy end-use areas. These are among the good candidates for export as strong Canadian capability exists to support the sales, services and evolution of the technologies. Other areas, however, should not be discounted given such a preliminary analysis. Examples of technologies that respond to intersections of domestic and international needs are shown in Table 4.

The development of cross-cutting and enabling technologies is fundamental for all greenhouse gas mitigation technologies, even though they are not shown as an intersecting need simply because they are often overlooked in international studies.

The Table believes that international opportunities are worth pursuing, and recognizes that they need to be further elaborated. A first step would involve gathering additional market intelligence, and developing a comprehensive strategy to support Canadian firms in their efforts to access foreign markets for greenhouse gas mitigation technologies. One of the options in Chapter 6 addresses this issue.

Table 4 – Examples of Technologies That Respond to Both Domestic and International Needs

Fossil Fuel Supply	Energy efficiency improvement for refining Coal bed methane recovery technologies Technologies to reduce fugitive gas emissions
Energy Production	Power plant rehabilitation and efficiency Transmission and distribution rehabilitation and upgrades Technologies that allow switching to lower carbon fuels Combined cycle natural gas plants Biomass cogeneration and gasification Large hydroelectricity Small hydro Nuclear fission Wind energy Photovoltaics (Grid connected and off grid) Advanced biomass Fuel cells Solar-thermal power Integrated combined cycle
Energy End-use	More efficient lighting, heating, ventilation and air conditioning appliances Improved industrial processes Improved district energy Improved vehicle fuel efficiency Alternative fuels for transportation Efficient boilers Variable speed motors Mass transport with higher efficiency Fuel cell and electric vehicles Building technologies
Carbon Dioxide Management	Increased carbon sequestering, through both natural 'sinks' and through capture, use and storage in geological formations
Non-energy Related Sources	Methane recovery from landfills Manure management Improved livestock feed

Chapter 5

Canadian Innovation Capability for Greenhouse Gas Mitigation

Greenhouse gas mitigation technologies are found in several areas and lines of research. Often examined in isolation in the past, they must now receive dedicated, focused attention.

In Chapter 2 we identified domestic needs to support meeting Kyoto greenhouse gas mitigation objectives and beyond. Chapter 3 examined promising illustrative technologies to respond to the need. Finally in Chapter 4, evidence was provided for a strong market potential for greenhouse gas mitigation technologies. It is evident that the nation must focus more attention on ensuring that it can respond to the greenhouse gas technology requirements. Efforts must be co-ordinated and partnerships need to be enhanced.

It is well known that the cycle of technology development for a new conventional technology typically takes a decade or more. Given the risk and time factors involved, there will be a need for sustained national investment. If Canada is to avoid economic losses and to derive substantial economic benefits from GHG technologies, strong and determined steps need to be taken now to support and help position Canadian firms. Other countries are already maneuvering to position their companies for expanding markets.

The cross-cutting and comprehensive challenges require a dynamic systems approach. A national effort building on Canada's innovation framework would help Canada achieve its short- and longer-term climate change objectives, and also help strengthen economic performance. It could also provide other collateral benefits, including better air quality.

This chapter explores the features and requirements needed to strengthen the Canadian innovation systems as they pertain to greenhouse gas mitigation technologies.

5.1 Enhancing Innovation

Innovation is a system-based activity that draws together the factors necessary to develop and commercialize new products and services. It focuses upon improving the economic output of a nation's or a region's capabilities to meet agreed objectives. Refer to Figure 2 in Chapter 1 for a general innovation system model. Innovation tuned to greenhouse gas mitigation will help solve the broad horizontal challenge of climate change, and will provide potential positive economic impact.

The Technology Issues Table examined the capacity of Canada's innovation system to advance the development of technologies to assist in lowering Canada's greenhouse gas emissions in the Kyoto period and beyond, to access international markets for GHG mitigation technologies, and to contribute to the First Ministers' commitment that no

Canadian region will be adversely impacted by Kyoto. The latter will be achieved by being sensitive and adaptable to regional requirements and capabilities.

Figure 5 depicts a perspective of an innovation system specifically tuned to enhance technologies for greenhouse gas mitigation. It provides a view of the Canadian context, and highlights the linkages in the system.

Firms must be the central players in the innovation system. They must interact with each other, and operate within the context of domestic and international markets.

Typically, technology supply firms are small- and medium-sized enterprises. The strong technology using firms tend to be at the large end of the size-spectrum. Whether small or large, firms make use of technologies in every part of their business, but are preoccupied with profitability. The challenge for the technology suppliers is to develop products and services for the technology users that are effective in leading to reductions in greenhouse gas emissions, while at the same time, helping to satisfy needs for improved performance, process improvement, reduced impacts on other environmental aspects, etc.

The main components of the innovation system to support the activities of the firms – the central innovators in the system – are:

Knowledge Infrastructure activities generate and/or apply knowledge. The three most common forms of activities are basic and applied research, development of technologies and engineering design. Knowledge infrastructure also includes making knowledge available through libraries, information clearing houses, publishing houses, journals and periodical, electronic media, etc.

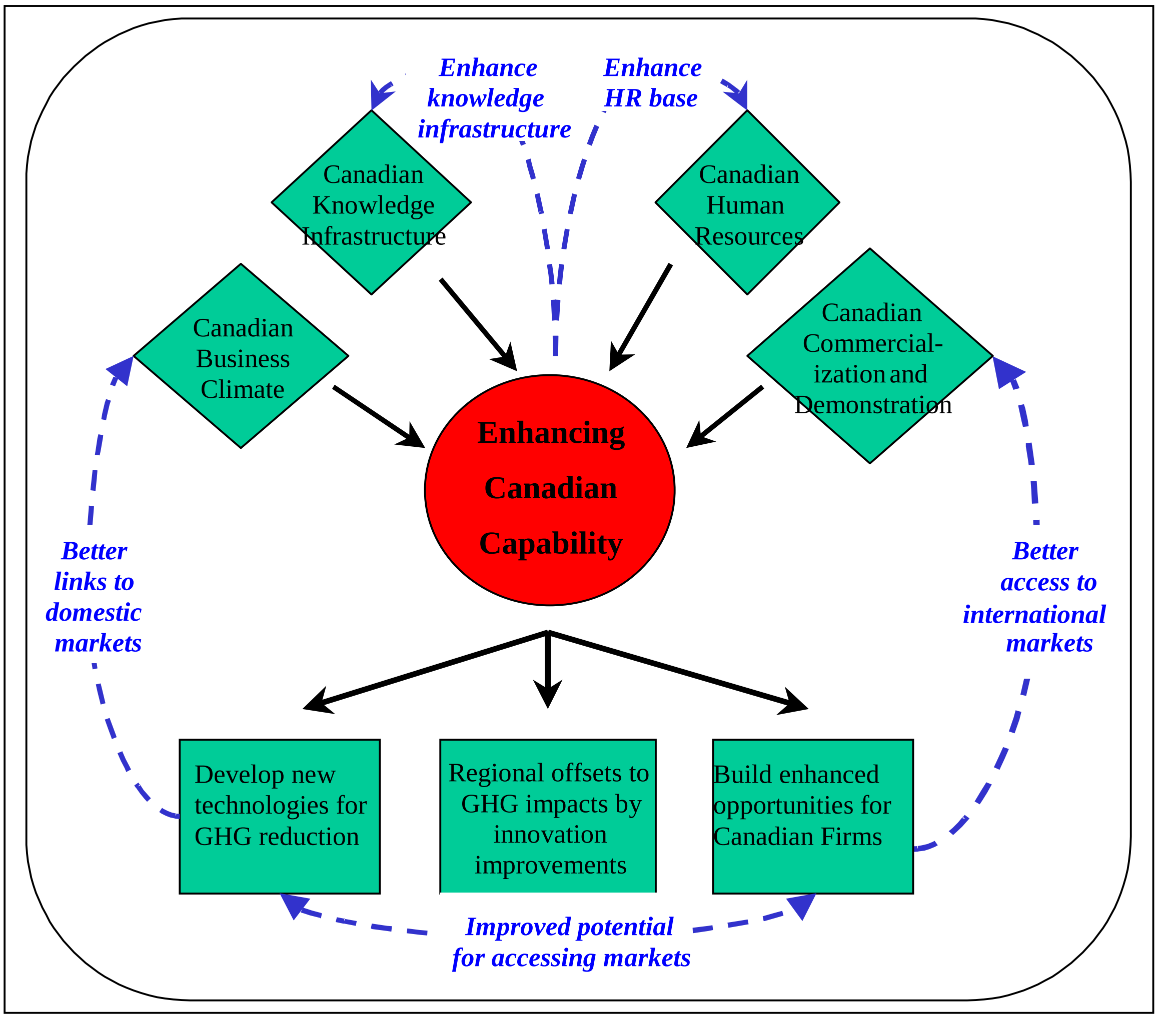
Demonstration and Commercialization[9] are needed to establish a position for emerging technologies. Demonstration of successful technical operation and economic viability is an essential component of innovation for emerging technologies. Technology is most readily accepted after it has proved itself through actual performance, in a variety of conditions, and has been confirmed by a third party.

Business Climate provides the context for profit and brings products to market. It refers to the business services and support required to develop and adopt new technologies. Business climate focuses on the critical link between the firm and the market place. The players involved include technology suppliers, technology users, market intermediaries, and marketing, sales and distribution agents. Business climate can include economic instruments such as grants, subsidies and incentives, taxation, regulations, and other measures that provide direct and indirect support to industry.

[9] The Table interpreted the word commercialization to mean 'first commercialization', that is, up to the market entry stage. It did not interpret it to involve any deployment-type activities.

Human Resources provide the analytical capability, creativity and curiosity necessary for solutions. Education and training policies need to cover a range of skills, from household-level contractors to advanced basic research.

Figure 5 – Greenhouse Gas Technology Innovation in a Canadian Context – What Needs to be Accomplished.



Effective innovation requires efficient linkages within and between the various components of the innovation system to allow firms to interact satisfactorily with the marketplace. It is important that the knowledge infrastructure optimize the use of the Canadian knowledge base and the innovation infrastructure. It is important that Canadian firms are well linked to that knowledge infrastructure so that they can draw knowledge inputs, and that components of the knowledge infrastructure reflect current and future industrial needs.

Although the axis of such an innovation system must be the firms operating in the context of domestic and international markets, all players, including governments, have a role in improving the system. Governments must provide leadership for building the excellence of the knowledge and human resource infrastructures, in disseminating information, and in setting a regulatory system that supports a positive business climate. Governments must also provide clear and understandable signals on levels to which GHGs will be reduced, and need to provide support to build and enhance linkages, particularly where significant gaps are present. They need to play an assistive role with the private sector in balancing the risk benefit ratio factors against national and regional objectives.

The governmental role traditionally is expressed through programs, policies and regulations, which can be grouped together under the generic concept of innovation measures. By means of a consultant's study, the Table reviewed existing policy, programs and regulations which foster innovation for greenhouse gas mitigation technologies. The objectives of the study were to provide a broad sampling of existing federal and provincial measures, to describe the features of those measures cited, to identify gaps in technology innovation, and to identify measures applied outside of Canada that might fill some of these gaps. The methodology used for the study is in Appendix 9.

A total of 166 domestic measures were identified and are listed in Appendix 10. To benchmark these measures against those of other countries, the Table commissioned an overview examination of international measures used to promote the development of mitigation technologies complementary to those used in Canada. These are found in Appendix 11.

Governments also have other responsibilities related to greenhouse gas mitigation. The long-term nature of technology development dictates that they have to provide clear market signals. Clearly, market pull today for greenhouse gas mitigation technologies is less than what it would be if greenhouse gas emission targets were part of the business culture. In the eventuality that industrial greenhouse gas emissions are someday controlled through mechanisms that price emissions – whether a tax or trading system – the need for greenhouse gas mitigation technologies will expand.

5.2 Benefits of Technology Innovation

There are well documented benefits to innovation. While it is too early to provide documented benefits for an innovation approach for greenhouse gas mitigation technologies, some general benefits are worth noting.

- Innovation reduces the cost of production of goods and services over the long-term.
- Economic growth in industrialized countries is being driven by knowledge based industries. Large and sustained investments in climate change technology development will be a major component in a knowledge-based economy in the next millennium.

- By pursuing innovation in greenhouse gas technology as an economic engine over the Kyoto period, any potential negative economic consequence can be minimized.
- As climate change technologies are developed and deployed, they provide multiple benefits to Canadian societies which impacts on the quality of life of Canadians. These multiple benefits include emergence of clean industries, improved air quality and reduced impacts on health.
- New technologies, particularly enabling technologies, have spill-over effects in the economy.

5.3 Current Requirements to Enhance the Innovation System for Greenhouse Gas Mitigation Technologies

Having examined the features and benefits of innovation in general, the Table charted the requirements to enhance innovation for greenhouse gas mitigation technologies. Table 5 provides a summary of the identified and necessary requirements.

Table 5 –Requirements for the Canadian Innovation Systems for GHG Mitigation Technologies

Knowledge Infrastructure requires:

- enhanced research focused on mitigation technologies;
- stronger linkages between universities, industry and government; and
- integrated consideration for all components of the innovation system up front, including financial support post the R&D phase.

There has been a decline in public science and technology investments over the last decade, even though industry investment has increased. There has also been a shift away from longer-term, high-risk investment which has weakened the Canadian capacity to find and develop new, environmentally responsive technologies. A major challenge for innovation in Canada is the limited degree to which there are strong linkages between publicly-funded R&D and industry. The climate change field will face insurmountable challenges to its knowledge base unless new public investment is forthcoming.

Demonstration and First Commercialization requires:

- risk reduction in the technical and commercial demonstration of new or improved technologies;
- commitment built on comprehensive private sector involvement; and
- improvement in the awareness of life-cycle performance of technologies.

The initial introduction of new technologies in the market place is a major challenge. Newly introduced greenhouse gas mitigation technologies will not have a track record of performance. Support for initial commercial use is

considered an essential element in the innovation system in order to initiate domestic diffusion and to form a basis for export sales, and has been a weak point in the system for some time.

Business Climate requires:

- reduction in the difficulty faced by smaller firms by making their financial capacity more robust through national certification programs, industry consortia, links with larger firms to obtain financial capacity to undertake large breakthroughs. Financial risk dominates lenders' considerations, while the full merits of opportunities are not recognized;
- importation and adaptation of off-shore technologies by subsidiaries of major international firms;
- clear and uniform rules for the administration of intellectual property rights;
- better interfirm linkages so technology development firms are less vulnerable to changing demand;
- access to more patient capital; and
- better linkage between user and supplier firms, sometimes the result of the short-term focus.

In the technology user/supplier relationship, there is a potential deficiency in the receptor capacity of technology users. Typically, technology users are large, financially strong firms with good international market linkages. Technology suppliers are generally small, do not have significant cash flow, and have weak international linkages. A linkage between technology suppliers and users would be advantageous. It would enable the linked organization to align technology strategy with business strategy, to integrate and combine inputs from within and outside the firm, to explore, fund and evaluate a range of technological solutions, and to implement and integrate new technology with existing technology.

In addition, there are relatively few policies and programs that create a domestic market for new technologies, compared to other countries. For example, Canada has few policies and programs on public procurement, regulations that stimulate technological advancement, and taxation measures that incorporate externalities.

***Human Resources requires*:**

- enhancement to the quality of human resources skills, particularly since the challenges cut across all fields of research and sectors of the economy.

Some commonly recognized challenges in Canada include maintaining a world class cadre of scientists and engineers, and a lack of focus on continuing education.

The above requirements to enhance the innovation system for greenhouse gas mitigation technologies, along with the technological requirements to enhance the promising illustrative technologies, define the challenges which the Table's options address.

Chapter 6

Options for Ministers' Consideration

The Table has highlighted requirements in the innovation system relating to greenhouse gas mitigation technology – particularly in the areas of knowledge infrastructure and demonstration. It has also identified a number of promising illustrative technologies that could be the focus for consideration of future targeting by program options. The challenge that remains is to identify investment required to fill the gaps and realize the potential of targeted technologies.

In this chapter, a series of investment options are presented for consideration by Ministers that will promote the development of the innovation system for greenhouse gas mitigation technologies. The options would focus on the technologies such as the promising illustrative technologies presented in Chapter 3. They are structured to incorporate appropriate risk-sharing between the players.

The options are presented according to the following components of innovation: knowledge infrastructure, demonstration and commercialization and business climate. Options which link the components in the Canadian innovation system are also presented as they maximize the effectiveness of individual components. The human resource infrastructure is not addressed directly. However, options proposed have indirect benefits which would help enhance the human resource base for greenhouse gas mitigation technologies.

We need to focus on targeted greenhouse gas mitigation technologies. The 25 groupings of promising technologies are illustrative of areas where Canada has the capability to respond to domestic and international needs, but they are at various stages of development and require further investment. Options under the knowledge infrastructure target those technologies that need medium and longer-term R&D.

Further work needs to be undertaken to develop an approach and action plan to advance the promising technologies to market-ready-status. Typically, there are a number of challenges that need to be addressed, each specific to a technology. Considerable effort is required to design programs and co-ordinate expertise and the Canadian knowledge base to assess needs. An example is provided in Figure 6. In order to ensure that the users' needs are met and that Canada's companies are ready to supply the technology, there must be involvement of the technology user, the companies that could supply the technology and the laboratory or university doing the research work. The formation of such partnerships at the outset is fundamental.

Figure 6 – Example of the Effort Required to Develop a Promising Technology

Significant effort is typically required to elaborate a plan for the development, pilot test and demonstrate a promising new GHG mitigation technology. An example is provided by the industry-provincial-federal work to develop a path forward for technologies related to the capture, transportation, use and storage of CO_2 .

The technological need has been defined by operators of large point sources of CO_2, such as fossil-fired electricity generation plants. They require efficient and cost effective technologies to capture CO_2 from stack gases, and transport the gas to a location where it can be used for other commercial purposes by industry, or to where it can be disposed of in underground reservoirs.

At present, the technologies for capture, transportation, use and storage of CO_2 are at various stages of development. Technologies for transportation are at hand now, whereas those for capture and concentration of CO_2 from stack gases need considerably more work. It was recognized that a coordinated effort was needed to develop technologies for each stage of the CO_2 management process, on a component by component basis, in order to create a compatible path forward.

The ingredients include:
- identify the nature of the needs for the technology
- identify the technologies required to meet these needs
- identify the Canadian capability to supply cost effective technologies which fit the bill
- identify the work that is required to develop candidate technologies – e.g., R&D to solve problems with specific components of the technology, demonstration of proven technologies on a small scale pilot, full-scale pilot test, etc..
- identify those technologies that require investment to develop an effective integrated system
- develop an integrated plan for investments and effort
- mobilize resources to advance the work plan.

Activities to date have consisted of :
- two workshops attended by industry-provincial-federal officials and international experts to size up the problem, establish a common understanding of the science and potential technological solutions (Calgary May 1999, Halifax July 1999)
- advance a draft path forward, hold a workshop to finalize the work plan, broaden involvement (October 1999)
- mobilizing resources to undertake projects.

The current innovation infrastructure already provides the underpinnings to enhance Canadian capabilities and opportunities. Much of the machinery is in place. The competency exists. However, neither are resources sufficiently, nor focused or aligned to the scope of the challenge of >*Kyoto and beyond*=. Efforts in all jurisdictions need to be reviewed, and mandates and essential infrastructure need to be enhanced.

The options presented[10] by the Technology Issues Table are:

- **The Knowledge Infrastructure**

    1. National Climate Change Discovery Competition
    2. Enhanced Support for Basic Knowledge Generation
    3. Climate Change Technology Development Fund

- **Demonstration and Commercialization**

    4. Climate Change Technology Demonstration Program

- **Business Climate for Innovation**

    5. International Marketing
    6. Reducing Risk and Facilitating Accreditation

- **Fostering Linkages**

    7. Technology Nodes and Roadmaps
    8. Communication Forum for Technology Initiatives

The Table believes that the commitment suggested for these options must be sustained, but the level of required investment is presented only over the first five year period. Once the power of the suggested option has been assessed, after three or four years, a comprehensive review should provide a basis for establishing program levels beyond this initial five year period.

The Technology Issues Table believes that the status quo is not an option, and that concerted, sustained commitment is essential.

The options are believed to provide the optimal means to raising the competitiveness of Canadian firms, to lowering energy and carbon equivalent intensities of Canadian products with the double benefit of reducing operating costs, while supporting achievement of greenhouse gas reductions in the long-term. However, it should be emphasized that the investment levels identified by the Table reflect the level of effort thought to be necessary to achieve success, but do not commit governments or industry to making these investments.

6.1 The Knowledge Infrastructure

In order to stimulate the discovery and development of new climate-friendly technologies in Canada, the nation needs to make substantial targeted investments in its related

[10] The options are not presented in any order of priority. Rather, they are grouped according to the components of innovation.

knowledge infrastructure. National capacity to discover and develop world-leading solutions to the climate change problem must be built up.

By bringing existing technologies to the point of commercial demonstration and developing a new generation of climate change mitigation technologies, Canada has the capacity to become a major supplier of these technologies to growing global markets.

The nation needs to enhance research attention on the challenges of climate change, and develop the opportunities for new, cross-cutting technological solutions. The Technology Issues Table feels that new funding must encourage a greater degree of collaboration across the research community. In particular, alliances among industry, universities and governments are considered to be especially effective. Linkages between technology developers, suppliers and users must be forged.

The Technology Issues Table has developed three options to address the knowledge infrastructure:

i) National Climate Change Discovery Competition;
ii) Enhanced Support for Basic Knowledge Generation; and
iii) Climate Change Technology Development Fund.

Option One: National Climate Change Discovery Competition

There is a need to seek new technological ideas and concepts. **The objective of the National Climate Change Discovery Competition is to develop new concepts and ideas that could lead to new, novel greenhouse gas mitigation technologies**. This would 'seed' innovation to create input into the development of new and improved technologies. A national competition would provide funding for supporting the development of such ideas and concepts, up to the proof of concept stage. The competition would be open to individuals and to teams which could include university researchers, government researchers and the private sector. The competitive nature of the fund will help raise awareness of the issue within the technology community and the public at large.

An announcement for the competition would be issued twice per year. Consideration by the selection committee would include originality, prior experience, potential impact, regional needs and relevance to Canada. Funds would be advanced against the work statement in the project proposal and would be non-repayable (i.e. contributions or grants). Twenty-five to fifty projects would be funded per year. The intellectual property would be performer owned, but the report would be in the public domain.

A national selection committee would be appointed with regional representation. The Federal Government would provide secretariat support.

The funding required for this national competition would be $25 million per year. It should originate entirely from federal sources.

Option Two: Enhanced Support for Basic Knowledge Generation

There is a need to undertake more long-term fundamental research on climate change mitigation technologies. This is particularly relevant for many of the enabling technologies. **The objective of added support for basic knowledge generation is to enhance the knowledge base for opportunities that could have a long-term impact on greenhouse gas mitigation technologies.** This would provide a better understanding of the linkages and synergies between various technologies. This would not duplicate the national competition, but would complement its activities and could even provide more ideas for entrepreneurs.

The support would be administered through Natural Sciences and Engineering Research Council (NSERC).

The funding required would be $5 million per year, through new federal allocations to NSERC.

Option Three: Climate Change Technology Development Fund

In examining the state of the promising illustrative technologies, it was evident that in each case there is a need for further development to the technological base. There is also a need to turn future knowledge ideas and concepts into products, processes, systems or services if they are to have an eventual impact on emissions. **The Climate Change Technology Development Fund would assist in developing technologies from concept to point of demonstration.** The fund would support development of targeted technologies that hold potential for domestic greenhouse gas abatement and international sales.

The implementation of the Development Fund would present opportunities for federal, provincial and industry partnerships, and would draw on the knowledge generated by government and university researchers as well as the private sector. The program would be administered with technical expertise and regional sensitivity and federal-provincial partnerships.

Selection criteria would include strength of individual partners and the nature of partnerships, the likelihood of technical success, leverage and market potential. Funds could be awarded for periods of several years, but subject to satisfactory progress being shown at designated intervals. Some delivery mechanisms could involve re-payments. The intellectual property would reside with the performer.

The investment in the fund should ramp up from $20 million per annum in year one to $200 million per annum in year five. The approximate portfolio investment should stem from up to 50% from federal sources, 25% from provincial sources and 25% from industry sources. Funding ratios could be different for different projects.

6.2 Demonstration and Commercialization

Option Four: Climate Change Technology Demonstration Program

A major challenge in innovation is the initial introduction of new technologies and services into the marketplace. An important consideration for potential developers/suppliers of new greenhouse gas (or any) technology is how receptive the market will or will not be to an innovation they are considering. Prudent technology users want credible evidence that a technology will perform as the supplier claims before agreeing to acquire it. Newly introduced GHG technologies will not have a track record of performance. **The Climate Change Technology Demonstration Program would offset some portion of the financial risks involved in early domestic commercialization of greenhouse gas mitigation technologies.**

The Technology Table's analysis of the promising illustrative technologies showed that support for the initial commercial use is considered essential to initiate domestic diffusion and to form a basis for export sales. The availability of such a program would also help to persuade firms to invest in developing new greenhouse gas mitigation technologies, knowing there would be assistance available to develop a receptive market for effective innovations.

The Climate Change Technology Demonstration Program would present opportunities for federal, provincial industry partnerships and would foster technology user/supplier alliances. The Demonstration Program would have strong regional sensitivity and would be designed with components to support/promote the market adoption of targeted technologies by:

S **supporting technical demonstrations** up to the first full-scale implementation.

S **reducing the risk of the >first buy=.** The first user of a new technology is always taking the risk that the technology may not perform as expected. Governments in partnership with the user or a consortium of potential users and supplier of new technologies, can reduce the risk to an acceptable level.

S **developing and sharing performance experience.** An established track record for the performance of a technology is something potential users want to see. The Climate Change Technology Demonstration Program would make verified performance data and experience from the funded first installation available to subsequent potential users. Verifiable performance data/experience on subsequent installations on a voluntary basis would build a database on the performance of the technology. For some new greenhouse gas mitigation technologies, there will be environmental, safety or other societal concerns.

Performance information related to such concerns would also be assembled and made available as part of this process.

- **providing awareness and visibility.** Traditional awareness mechanisms, including trade-targeted government advertising, trade show exhibits and technology awards, all promoting new greenhouse gas mitigation technologies, would help make the market aware of, and more receptive to, the technologies. This activity could be cost-shared among participants and with government.

The Climate Change Technology Demonstration Program would be administered by existing mechanisms, with the help of regional agencies. Proposals would be assessed for technical merit, with industry and market knowledge.

The investment in the fund should ramp up from $60 million per annum for year one to $300 million per annum for year five. The federal government should provide – on a portfolio basis – up to 30% of the investment, with the remainder originating from provincial and industry sources. The federal component would be re-payable.

6.3 Business Climate for Innovation

Option Five: International Marketing

The preliminary results of the international needs analysis revealed that growing opportunities exist for suppliers of greenhouse gas mitigation technologies. Innovation can be exported, but aggressive and flexible facilitation measures already offered by other economies such as the US, Japan and the European Union will provide stiff competition for Canadian suppliers. **There is a role for government to create the climate for enhanced international marketing of climate change technologies and thus support achievement of the second part of the Technology Table's mandate.**

OECD countries will provide the best market opportunities in the short-term given existing relations, greenhouse gas reduction commitments, infrastructure, etc. However, demand in developing countries should grow exponentially in the coming years. This demand is driven by local environmental and economic needs – more than by greenhouse gas mitigation pressures. Fortunately, the nature of mitigation technologies serve multiple objectives and could fulfill several requirements. For example, companies which offer equipment that simultaneously reduce greenhouse gases and other emissions and provide energy system infrastructure will have a high demand for their products.

To access the markets, particularly those in developing countries, Canadian companies must overcome several barriers. There are different business, tax and cultural conditions at play. New information is costly to import, many innovators keep their secrets in order to maintain their competitive position, and foreign governments sometimes block the transfer of technology. In addition, it is rare that a technology can be transferred without any modification to suit local conditions. Past experience has demonstrated that successful exporting requires an investment of time and other resources to understand foreign markets, business practices, cultivate contacts, and to learn the nuances of international transactions.

The Technology Issues Table recommends that, within the constraints of world trade regulations, a comprehensive international marketing strategy be developed as soon as possible. The strategy should link application of technologies in domestic markets with potential export markets. For example, if certain sets of technologies are serving the energy industry in Canada, how might they best serve the energy industry internationally? This might involve the creation of global networks between technology suppliers from Canada and demand organization or networks in other countries.

The strategy developed would have to be flexible to take account of the different applications and end-uses among the various greenhouse gas mitigation technologies. Components of an international marketing strategy that merit further study include:

- assisting for 'readiness for global trade consideration' for companies which wish to export greenhouse gas mitigation technologies. This could include items such as assistance with the global intellectual property provisions for technologies, international standards, languages, information and operations;
- establishing GHG mitigation trade commissioners in various Canadian embassies;
- identifying the current relationships that Canadian businesses now share with international companies and use these relationships to penetrate the market;
- working to harmonize environmental standards;
- reducing trade barriers and securing greater trade liberalization in goods, services and investments; and
- establishing and leveraging memoranda of understanding on technology co-operation with selected countries to pave the way for Canadian companies, and build receptor capacity in developing countries. This component would provide constructive engagement of developing countries and would help facilitate Canada taking advantage of flexibility mechanims, should they be fully accepted by the international negotiating community.

The international marketing strategy should be developed by federal departments and agencies, in collaboration with the private sector. This would require $400,000 from the federal government for one year. The cost of implementation would depend on the strategy itself, but could be in the order of $8 million annually for five years.

Option Six: Reducing Risk and Facilitating Accreditation

Investment in innovation can be costly and risky, and access to capital is critical, particularly for SMEs. **There is a need to undertake comparative analyses of the recognition of risk in the technology innovation process granted by other countries,**

and provide similar benefits to Canadian firms. The outcome, if warranted by the analysis, could involve some mechanism for preferential capital gains treatment for longer-term investments in qualifying greenhouse gas mitigation technologies, as is found in many countries. This type of tax related measure provides an incentive for the developer of greenhouse gas technologies. Given that it only costs the governments in instances where technologies are successfully commercialized and earn a profit, there is limited negative consequence from a fiscal standpoint.

The analysis should examine criteria for the tax measure, such as the qualifying investment timeframes, the kind of investment required to qualify and appropriate vehicles that can be used (e.g. labour sponsored pension funds). In addition, the types of capital gains tax that could be awarded for recognizing the risk should be examined. Such a tax system would help place Canadian companies on an equal footing with foreign competitors.

To complement the tax system, Canadian companies also need to access, and be accredited under, international standards such as the ISO 14000 series of environmental management systems. ISO 14000 accreditation is rapidly becoming a pre-condition for conducting business in Europe. Such accreditation will also provide an equal footing for Canadian firms. Outreach programs and more aggressive campaigns by the Standards Council of Canada should be examined.

These studies should be undertaken by federal, provincial and territorial governments. Costs are estimated at $200,000 for one year.

6.4 Fostering Linkages

Option Seven: Technology Nodes and Roadmaps

To capitalize on the power of innovation, the linkages between the components have to be efficient as they allow firms to interact successfully with the marketplace. Canadian firms must be well-linked to the knowledge infrastructure so that they can look to future markets and draw knowledge inputs. **The objective of this option on Technology Nodes and Roadmaps is to develop improved strategic understanding of technological opportunities for greenhouse gas mitigation technologies in and across industrial sectors, and between technology suppliers and technology users.**

i) Technology Nodes

Various networks already exist in selected technology areas, however, greenhouse gas mitigation technologies often cut across several disciplines and lines of research. An example is cross-cutting and enabling technologies. Advancements in these technologies can at times provide breakthroughs for the more direct mitigation technologies. To this end, funds are proposed as a means to create *technology nodes*, between the research community, industry, universities and governments.

Technology nodes are mini systems that focus and coordinate efforts, including funding in some instances, on a particular technology or family of technologies. A suite of nodes would have some of the following characteristics:

- they would be strategically located;
- regional aspects would be present;
- they would focus and co-ordinate innovation in a technology area;
- they would involve government, industry and academic players;
- they would prevent duplication of effort; and
- they could use federal/provincial agreements to establish a participatory framework.

Funds would provide support for co-operative mechanisms to build the capacity for working across the various players in the innovation system. They would support the cost of setting up and managing various centres, nodes and collaborative research networks whose purpose it is to organize and co-ordinate the national effort in a particular aspect of climate-friendly technologies.

Eligible costs would include initial set-up, ongoing management, developing a roadmap for the technology area, recruiting members, setting up and running web-sites and other communication mechanisms, and annual technology workshops

ii) Technology Roadmaps

Technology roadmaps are a forecasting and planning tool to determine future market needs for technological products and services. Technology roadmap exercises are action-oriented. They are specifically designed to lead to collaborative technology-related initiatives amongst the participants. Technology roadmaps are industry-led exercises with a concentrated industrial focus. They are, however, fairly new tools. Some of the lessons learned thus far are shown in Figure 7.

Figure 7 – Experiences with Roadmaps

A number of lessons have been learned from road-map exercises conducted to date in the US and Canada. It is recognized that road-mapping is a relatively new methodology designed to create sound and supportable technology development work plans.

Some of the issues and difficulties encountered to date include:

- finding ways to attract and engage industry in the process
- taking a strategic and forward-looking perspective that projects beyond the present to look to the future
- finding the appropriate balance between the role of government, as a convening and facilitating service, and the role of industry, as a lead agent and dominant participant in the overall process
- defining the appropriate dimensions and scope for the target area – needs to be more narrowly defined than an entire industrial sector, yet not focused too narrowly on specific technologies
- relating the exercise to future market conditions, particularly in cases in which the market structure regulatory paradigm is shifting rapidly.

Technology roadmaps benefit all participants. For companies, they are a strategic planning tool to identify gaps between their current technological capabilities and future requirements, and to make technology investment decisions to close this gap. They are specifically designed for them. However, government and research organizations can also benefit. For research organizations and educational institutions, they provide guidance for structuring future programs. For governments, they provide a strategic direction for industrial development activities, policy and program development and regulatory decisions. The key element is that the roadmap exercise catalyzes a multi-player partnership led by industry to develop a coordinated and carefully planned work plan to bring needed technological products and services to market-ready status.

Technology nodes and technology roadmaps for promising greenhouse gas mitigation technologies should be administered regionally, where it is logical to do so, and should build on existing networks. Federal-provincial partnerships could be used.

The funding required for nodes and roadmaps would be $5 million per annum; of which 60% would be from the federal sources and 40% from provincial sources.

Option Eight: Communication Forum for Technology Initiatives

Technology nodes will provide centers for dialogue on specific technology areas. However, there is a need for a broader forum to discuss general issues related to innovation for greenhouse gas mitigation technologies and to co-ordinate efforts by all stakeholders. **The objective of this option is to ensure that decision-makers responsible for the investment of the limited resources available for technology**

development have the benefit of adequate knowledge and information for informed and sound decisions. In essence, decision-makers require an open forum that provides for:

- exchange of information on ongoing activities related to technology development;
- airing of program ideas and plans;
- identification of areas of mutual interests;
- identification of areas of collaboration ; and
- avoidance of duplication and overlap.

Features of such a coordination mechanism should include:
- information dissemination that would help active groups, organizations and companies to augment their knowledge and linkages to advance their work in the development of GHG mitigation technologies;
- sensitivity to regional interests;
- participants from industry, governments and academia;
- linkages with the communities interested in technology development;
- participants are to primarily include decision-makers that have the opportunity to influence the strategic planning and direction of technology development investments;
- access to international information and perspectives on technology development strategic thinking, programs and investments.

Any structure created to provide such a forum should be seamless and flexible. It should be designed to provide for an ongoing flow of communication to achieve the stated goals, with a strong virtual presence. The creation of a new, centralized administrative structure that could serve to control or limit actions of the parties must be avoided.

These principles present significant, and often conflicting, challenges. It is understood that the purpose of this forum is to influence the decisions made within existing programs regarding the content of programs and allocations of funds.

As an example, existing structures such as the National Air Issues Coordinating Committee on Climate Change (NAICC-CC) could serve as the mechanism for this approach.

The NAICC-CC is the coordinating committee of senior federal and provincial officials for the National Implementation Strategy on Climate Change. The Committee has a decade-long history of federal-provincial work on environmental issues, including acid rain and now climate change. This established mechanism may be a suitable platform for coordination of technology initiatives.

One arrangement could involve a sub-committee of the NAICC-CC focused on technology strategies and coordination. Members would be representatives of the energy and environment departments of each level of government, supplemented by heads of programs and agencies, representatives of other departments which have an interest in technology and innovation or other experts as guided by the issues at hand. The fact that the NAICC-CC already has an interest and a degree of involvement in technology matters would facilitate the creation and supporting structure for such a committee.

Funding for the Communication Forum would be $300,000 per annum, from federal and provincial and possibly industry sources.

6.5 Summary of Options and Implementation Principles

A summary of the options and their funding profiles over a five year period is presented in Table 6.

It has not been possible to make *ex-ante* estimates of the full impacts arising from the sizeable investment recommended. This is due to a number of factors.

First, given the extended time required to advance a technology from the inception stage, to commercialization, it is difficult to track the impact of an investment at the early stage of a cycle, over the decade or more, to the time when a technology finally becomes available on the market. It is far easier to follow the scientific and technical advancements along the way.

Second, as is typical in R&D programs, breakthroughs achieved in one line of research often have application in a related area. Tracking this cross-feeding is almost impossible.

Third, the reality of R&D is that lines of investigation occasionally fail to produce the anticipated results and the investments may appear to be wasted. Proper accounting of total R&D investments will include these “dead-ends”, and as a result the impact assessment is weighted with these situations.

However, some general implementation principles are suggested.

- The implementation of the options will be focused on specific outcomes, which will have to be reported on a regular basis and thus provide a system of accountabilities to the federal and provincial governments.
- To the full extent possible the implementation of options should involve sectoral buy-ins, with leveraged funds.
- The implementation of options should be done on a collaborative basis between federal and provincial governments and industry.
- The implementation of each project needs to be assessed in terms of the range of potential greenhouse gas impacts from key technologies which may relate to the option.
- The range of potential contribution of each option to multiple benefits and quality of life factors such as health should be qualitatively defined.

In addition, a range of impacts under various conditions through such techniques as scenario modeling could be undertaken.

Table 6 – Summary of Options and Funding Profiles

		Funding					
Options	Objective	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Sources**
1. National Climate Change Discovery Competition	To develop new concepts and ideas that could lead to new greenhouse gas mitigation technologies	$25M	$25M	$25M	$25M	$25M	federal
2. Enhanced Support for Basic Knowledge Generation	To enhance the knowledge base for opportunities that could have a long-term impact on greenhouse gas mitigation technologies	$5M	$5M	$5M	$5M	$5M	federal
3. Climate Change Technology Development Fund	To assist in developing technologies from concept to point of demonstration	$20M	$40M	$80M	$150M	$200M	federal: up to 50% provincial: 25% industry: 25%
4. Climate Change Technology Demonstration Program	To alleviate some portion of the financial risks involved in early domestic commercialization of greenhouse gas mitigation technologies	$60M	$90M	$150M	$240M	$300M	provincial and industry: 70% federal: 30%
5. International Marketing	To create the climate for enhanced international marketing of climate change technologies and thus achieve the second part of the Technology Table's mandate	$400K	Dependent on strategy				federal (for year 1)
6. Reducing Risk and Facilitating Accreditation	To undertake comparative analyses of the recognition of risk in the technology innovation process granted by other countries	$200K					federal and provincial

		Funding					
Options	Objective	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Sources**
7. Technology Nodes and Roadmaps	To develop improved strategic understanding of technological opportunities for greenhouse gas mitigation technologies in and across industrial sectors, and between technology suppliers and technology users	$5M	$5M	$5M	$5M	$5M	federal: 60% provincial: 40%
8. Communication Forum	To ensure that decision-makers responsible for the investment of the limited resources available for technology development have the benefit of adequate knowledge and information for informed and sound decisions	$300K	$300K	$300K	$300K	$300K	federal and provincial
		$115.9M	$165.3M+	$265.3M+	$425.3M+	$535.3M+	

Chapter 7

Conclusions and Further Study

The social and economic context in which we live is shaped by the technologies that are produced and used. Through technology, humans have acquired capabilities to transform their natural environments locally, regionally, and, more recently, globally[11]. It is now generally recognized that technological evolution is not a linear process. Neither is it simple. The evolution of technology is uncertain, dynamic, systemic and cumulative. Just as uncertainty is a basic fact of life, so is the *shape* the technology will assume.

There is no one-to-one relationship between research and development into technologies and an anticipated outcome. In the present situation, there is no direct, predictable relationship between research and development into greenhouse gas mitigation technologies and their anticipated deployment and, ultimately, emissions reduction. However, by experimenting with a broad range of solutions, the odds of success increase.

The Technology Issues Table is of the firm view that it has developed Options for Ministers' consideration that will improve the odds of developing and commercializing greenhouse gas mitigation, which ultimately will be available for deployment within the relevant sectors of the economy. By focusing on innovation system as a whole, the Options – if implemented – will build Canadian capability in technologies to reduce greenhouse gas emissions, will enhance opportunities for Canadian companies in domestic and international markets, and will build Canadian capacity to provide solutions over the longer-term.

The investment required for the eight Options is sizeable – but so is the challenge of reducing greenhouse gas emissions in the Kyoto attainment period and beyond. To succeed, it will be important to act now, and to maintain a national approach - built upon federal-provincial partnerships and regional contributions.

It will also be important to undertake further study in several areas.

First, continual investigation of the *needs* for reducing greenhouse gas emissions is crucial. This applies to both the domestic and international markets. The latter could provide better market intelligence for Canadian companies wishing to capitalize on the expanding global markets for greenhouse gas mitigation technologies.

Second, there is a need to undertake an elaboration of a detailed approach and action plan to advance each promising technology to market-ready-status. Typically there are a number of challenges that need to be addressed, each specific to a particular technology.

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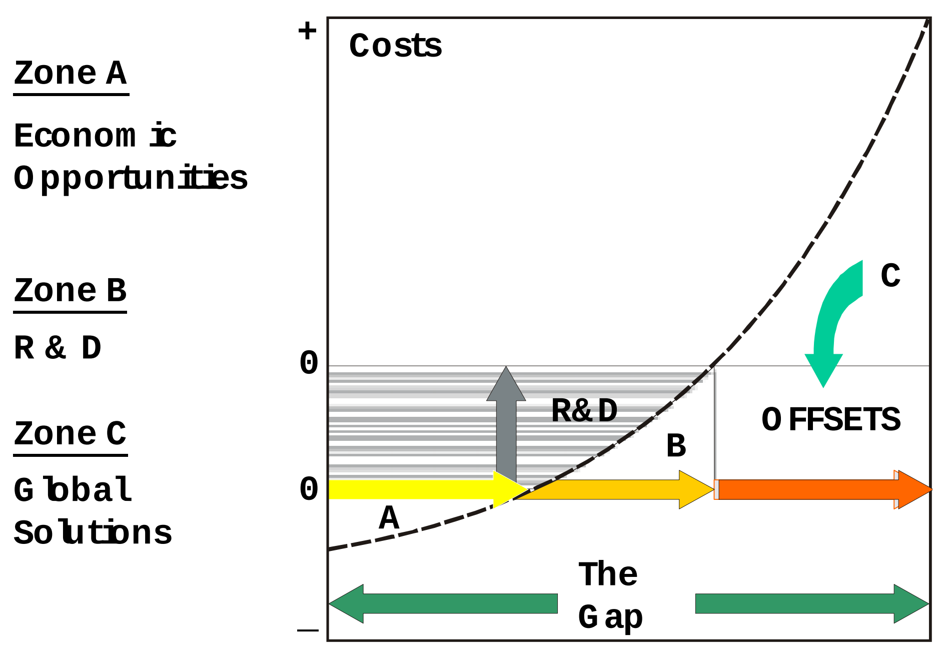
[11] *Technology and Global Change*, Arnulf Grübler, International Institute for Applied Systems Analysis, Laxenburg, Austria. Cambridge University Press, 1998.

To do so effectively, partnerships will have to be built around present strengths and expertise.

Finally, more work into assessing the impacts of investments in the development of particular technologies, at the project level, is needed. Although the results would only be indicative, they would provide a glimpse of the effects of technology development on typical cost curves as shown in Figure 8. One impact of R&D investments is to lower the cost of each technology along the curve. In the ideal case, the investment can shift the zero cost line upward, thereby making a large share of the solutions from positive cost to cost saving (diagramatically shown by the vertical arrow in Figure 6). A second possibility si effectiveness of each component of the curve, at the same cost (diagramatically shown by Arrow B in Figure 8). Analysis of the impacts of R&D investments on the cost curves produced by the Sector Tables would be an interesting means to assess the potential impacts of the targeted investments in particular technological solutions.

Figure 8 - Suncor Decision Model for GHG Actions[12]



[12] From a presentation by Barry Stewart, Group Executive Vice President, Suncor Ltd.

Appendix 1

Members of the Technology Issue Table*

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Appendix 2

Methodology for Assessments of Domestic Technology Needs

The methodology utilised in the domestic technology needs assessment involved a survey and a review of the literature. These methods were used to develop a 'Master List' of technology needs from which a "Detailed List of Domestic Technology Needs" were developed. Additionally, these technologies were categorised by sector and sub-sector. Each of these elements and their current status are described in detail below.

2.1 Assembly of the GHG Technology 'Master List'

The first task performed by the Project Team was to assemble a long 'Master List' of domestic GHG emission reduction technology needs. This list, which contains 265 different technologies pertaining to a wide variety of industrial sectors, was generated by focusing research efforts on the following:

- a literature review of documentation pertaining to GHG technologies, their needs and their applicability; and,
- surveys of representatives from a cross-section of Canadian industrial sectors to augment the literature review.

The Master List provided the Technology Table with a list of all of the technology needs identified to date. The Master List contains:

- the title of each technology,
- a technology number, and
- the sources of information (whether literature or survey response) used in obtaining data to the describe technologies in the Domestic Needs Summary Table, and the Detailed List.

A number of technologies on the Master List were discussed in more than one source and both references are provided. The Master List was used to select technologies for more detailed description in the Detailed List. It also provided the Technology Table with an index of a large number of technology needs from a wide variety of sources.

Literature Review

The literature review component of the research effort focused initially on the various sectoral 'Foundation Papers' prepared for the National Climate Change Secretariat. Foundation Papers considered in the literature review included the following:

Transportation Table	Foundation Paper on Climate Change: Transportation Sector
Electricity Table	Electricity Industry Issues Table Foundation Paper
Sinks Table	National Sinks Table Foundation Paper

Agriculture and Agri-Food Table	Agriculture and Agri-Food Foundation Paper
Forest Sector Table	Foundation Paper: A Survey of the Forest Sector and Forest Sector Options
Municipalities Table	Municipalities Foundation Paper

Buildings Table

- Institutional & Commercial: Foundation Paper
- Residential Sector Climate Change Foundation Paper

Industry Table

- Industry Table Foundation Paper: Other Manufacturing Activities
- Oil and Natural Gas Industry Foundation Paper
- Foundation Paper for the Transportation Equipment Manufacturing Sector
- Minerals and Metals Climate Change Foundation Paper

As a component of these papers the authors of the study were instructed to discuss possible technological options (short- term and long- term) to address the reduction of GHG emissions in their respective sectors. It should be noted, however, that the discussion of technologies in these papers was very uneven. Some Foundation Papers contained comprehensive discussions of technologies (i.e., Transportation, Mineral and Metals, Residential Buildings, and Oil and Gas) while in other papers (i.e., Forestry, Other Manufacturing) the amount of information provided on technological needs was fairly minimal. Despite the lack of information in some cases, all of the technology needs identified from each of the foundation papers are represented in the Master List. It is assumed that the representatives of the Sectoral Tables identified the technology needs that are most relevant to the challenge of reducing GHG emissions. Ongoing research on the part of the Sectoral Tables will help to determine the economic feasibility of meeting many of these needs.

The literature review also included a search of resources on the Internet, a review of internal documents, and a series of phone calls to selected government departments such as the National Research Council, Natural Resources Canada, Ministry of Environment, and Industry Canada to identify further material. Additional documents utilized in the literature search and included in the Master List include:

- *Climate Change Technologies and Canadian Supply Capabilities: A Scoping Study.* This study, which was prepared for Industry Canada outlines, in detail, over 60 different GHG emission reduction technologies and the ability of Canadian firms to supply these technologies.
- *Out of the Box and into the Future: Futures Technology Workshop.* This NRCan document contains the proceedings of an Energy Technology Futures Project workshop held in August, 1998.
- *The Role of Transportation Technologies in Reducing Greenhouse Gas Emissions*. Ontario Ministry of Transportation. 1995.
- *A Utility Perspective on Technology Related to Greenhouse Gas Abatement (Draft).* By D.K. Blamire for Nova Scotia Power Inc. February, 1999.
- *CO_2 Capture, Reuse and Storage Technologies for Mitigating Global Climate*

Change. Energy Laboratory, Massachusetts Institute of Technology. January, 1997.

Survey

In order to supplement the literature review and to obtain additional input from industry representatives on technology needs, a survey was developed, with the assistance of the Technology Table Needs Working Group.

A cross-section of industry representatives was selected, with input from the Technology Table Needs Working Group, for the survey. This survey asked respondents for a brief description of:

- three priority GHG mitigation technology needs (existing and future technologies);
- the scope and timing of each need; and,
- the commercial availability of the technology (with specific reference to whether the technology is available from Canadian- owned firms).

In order to obtain a large sample, the consulting team distributed over 80 surveys by fax and e-mail during the months of February and March, 1999. Furthermore, several follow-up inquiries to potential respondents were made by telephone and/or by email the week after survey distribution. Responses to the survey were good, given the short time frame provided for completion. Some of the surveys were completed over the phone, while most were received by fax. In total, 34 surveys were completed by respondents from a broad cross-section of industry sectors.

Almost all of the surveys received contained value-added information on technology needs that supplements the literature review. Most respondents provided detailed descriptions of needs while several provided more general input. All of the technologies identified in the survey responses have been included in the 'Master List' and many have been written up in the Detailed List.

2.2 Development of the Detailed List of Domestic Technology Needs

As part of its Final Report, the Project Team agreed to describe, in more detail, over 80 of the technologies identified in the Master List. The profile of these technologies is meant to facilitate aggregate level analysis of domestic GHG mitigation technology needs and provide more detailed information to be used in the integration phase of the Technology Table's research. Eighty-three technologies were selected from the Master List using these four criteria, applied in the following priority.

1. There is a sufficient amount of quality, detailed information describing the technology (note: many of the technology needs in the Master List have very limited amounts of information for this purpose);

2. A technology need is referenced in more than one source, (note: this may be taken as an additional indicator of the degree or extent of the need);

3. All technology categories (see subsection below) are well represented; and,

4. A technology has medium-high potential for reducing GHG emissions (Note: at this stage in the research process, this criterion was very difficult to accurately judge given the lack of meaningful data available. This is likely due to the complex nature of estimating emissions reductions. It is also difficult to quantitatively compare the emissions reductions potential of different technologies because this is a function of their relationship to existing technologies and it involves generating estimates of market diffusion rates, data for which are not readily available with more intensive research).

A template was developed with input from the Technology Needs Working Group to allow for concise descriptions of these technologies and to facilitate an aggregate analysis and integration with the International technology needs research. This template also corresponded to the questions used in the survey. The template consisted of the following elements:

- Technology Number and Name (For cross referencing with Master List and Exhibit 2.2)
- A Brief Description of the technology need.
- Technology Category – one of the six GHG mitigation opportunities
- Type of Technology – Incremental improvement or a new technological direction.
- Scale of the Need (Domestic, international etc.)
- Timing of Need
- Availability of Need (Currently available, pre-2008, 2008-2012, post 2012)
- Impact of the Technology (Any data related to GHG emission reductions)

While the majority of the required information to complete the 83 technology descriptions was available from the literature and survey data, in some cases the required information was unknown or unavailable. With some technologies, particularly those under development or at the ‘concept’ level, there is a lack of quantifiable data (i.e. the potential per cent GHG emission reduction). An analysis of the technologies contained in the Detailed List is presented below.

Appendix 3

List Of 1300+ Existing, Emerging and Future Global Technologies Available For Reducing GHG Emissions

1. TECHNOLOGIES TO REDUCE ENERGY RELATED GHG EMISSIONS

1.1 FOSSIL FUEL SUPPLY

1.1.1 Production

1.1.1.1 Coal Mining: Pre-Mining Degasification (1)
- 1.1.1.1.1 Vertical Wells (10)
- 1.1.1.1.2 Enhanced Gob Well Recovery (1)
- 1.1.1.1.3 Horizontal Bore Holes (11)
- 1.1.1.1.4 Cross-measure Bore Holes (11)

1.1.1.2 Coal Mining: Methane Utilization (11)
- 1.1.1.2.1 Catalytic Flow Reversal Reactor
- 1.1.1.2.2 Sell as Pipeline Quality Natural Gas (11)
- 1.1.1.2.3 Electricity Generation (11)

1.1.1.3 Coal Mining: Ventilation Air Utilization (10)
- 1.1.1.3.1 Use in a Combustion Device
- 1.1.1.3.2 Utilization of Fans to Transport Vented Air (10)

1.1.1.4 Oil and Natural Gas Exploration and Drilling (35)
- 1.1.1.4.1 More Efficient Motors in Drilling Equipment (35)
- 1.1.1.4.2 Horizontal Drilling Methods (35)
- 1.1.1.4.3 Drilling of Multiple Wells from a Single Pad (35)
- 1.1.1.4.4 Acid Gas and CO2 Reinjection to Deal with Sulphur
- 1.1.1.4.5 Well Testing Information Gathering Systems (43)
- 1.1.1.4.6 Flaring Instead of Venting during Drilling and Well Tests (43)

1.1.1.5 Oil & Natural Gas Production: Low Emission Technologies and Practices (1)
- 1.1.1.5.1 Low or No Bleed Pneumatic Devices (11)
- 1.1.1.5.2 Installing Flash Tank Separators on Dehydrators (11)
- 1.1.1.5.3 Metallic Coated Seals (11)
- 1.1.1.5.4 Sealant and Cleaner Injections for Valves (11)
- 1.1.1.5.5 Dehydrator Pump Replacement to Run on Electricity (23)
- 1.1.1.5.6 Level Gauges on Separators (23)
- 1.1.1.5.7 Electrification of Well-Sites (35)
- 1.1.1.5.8 Down-Hole Oil-Water Separation Equipment (35)
- 1.1.1.5.9 Converting Wellsite Gas Pressure to Mechanical Energy (35)
- 1.1.1.5.10 Laser Technology to Identify Sources of Methane and Carbon Dioxide (35)
- 1.1.1.5.11 Optimize Purge Gas Consumption (e.g. use vapour seals on flares) (43)
- 1.1.1.5.12 Clustering/Consolidation of Facilities (43)
- 1.1.1.5.13 Use Fewer Compressors at Multi-unit Facilities (43)
- 1.1.1.5.14 Change-out Oversized Compressors (43)
- 1.1.1.5.15 More Frequent Tune-ups of Compressor Engines (43)
- 1.1.1.5.16 Use Air Instead of Fuel Gas as the Supply Medium for Gas-operated Devices (43)
- 1.1.1.5.17 Pump Scrubber Liquids to Compressor Discharge Rather than to Atmospheric Storage (43)
- 1.1.1.5.18 Use Hot Taps to Tie-in Wells (43)
- 1.1.1.5.19 Switch from Gas-Operated to Electric Drive Pumps (43)
- 1.1.1.5.20 Vent Controls for Gas-Operated Pumps and Instrumentation (43)
- 1.1.1.5.21 Storage Tank Vapour Controls (43)
- 1.1.1.5.22 Compressor Seal Vent Controls

1.1.1.6 Oil & Natural Gas Production: Reduced Venting and Flaring of Gas During Production (1)
1.1.1.6.1 Recover Associated Gas (10)
1.1.1.6.2 Reinject Natural Gas (10)
1.1.1.6.3 Efficient Flaring of the Natural Gas (10)
1.1.1.6.4 Well Work-overs (10)
1.1.1.6.5 Flare Rather Than Vent (43)
1.1.1.6.6 Optimize Glycol Circulation Rate on Dehydrators (43)
1.1.1.6.7 Provide Vent Controls on Glycol Dehydrators (43)
1.1.1.6.8 Control Surface Casing Vent Blows (43)
1.1.1.7 Oil & Natural Gas Production: Other (23)
1.1.1.7.1 Solvent Based In-Situ Bitumen Production (23)
1.1.1.7.2 Cogeneration of Process Steam and Electricity
1.1.1.7.3 Utilization of Casing Gas (43)
1.1.1.8 Oil Sand Extraction
1.1.1.8.1 Low Temperature Oilsands Extraction (23)
1.1.1.8.2 Truck and Shovel Selective Mining in Place of Electricity Intensive Drag Lines and Bucket Wheels (35)
1.1.1.8.3 Hydraulic Transport of the Ore to Conveyors (35)
1.1.1.8.4 Improved Energy Integration Between Extraction and Upgrading and On-site Electricity Generation (35)
1.1.1.8.5 Added Co-generation Using Natural Gas (35)
1.1.1.8.6 Recovery of Light Olefins from Fuel Gas (35)
1.1.1.8.7 Minimize Exposed Oil Sands Areas (43)
1.1.1.8.8 Reduce Hydrocarbon Carry-over to the Tailings Ponds (43)
1.1.1.8.9 Deasphalt at the Mine Site in Oil Sands Operation (43)
1.1.1.8.10 Oil sand upgraders and refineries with cokers landfill coke (43)
1.1.1.9 Hydrogen
1.1.1.9.1 Recover Hydrogen from Gases now Burned (43)
1.1.1.9.2 Obtain Byproduct Hydrogen from Other Sources (43)
1.1.1.9.3 Use More Selective Hydrogenation and Hydrocracking Catalysts to Reduce H_2 Loss to Light Ends (43)
1.1.1.9.4 In Refinery, Use Continuous Catalytic Reforming of Naphtha (43)
1.1.1.9.5 Optimize Split of Processing at Upgrader and Refinery to Minimize Overall Need for DeliberaHydrogen Production (43)
1.1.1.9.6 Expand Use of Byproduct Hydrogen and Nitrogen Available from Air Separation Plants (Ammonia Production) (43)
1.1.1.10 Other
1.1.1.10.1 Reinjection of acid gases (H_2S and CO_2) (43)
1.1.1.10.2 Bottoming Cycle on Steam Condensed above Atmospheric Pressure (43)
1.1.1.10.3 Methanol Injection in Lieu of Gas Dehydration (43)

1.1.2 Distribution and Transmission

1.1.2.1 Oil & Natural Gas: Compressor Operations (1)
1.1.2.1.1 Low or No Bleed Pneumatic Devices (11)
1.1.2.1.2 Catalytic Converters to Reduce Methane Emissions from Reciprocating Engines (11)
1.1.2.1.3 Pipeline Blowdown Gas Recovery Systems (23)
1.1.2.1.4 “Cool Stop” of Compressors (23)
1.1.2.1.5 Compressor Station Leaks Repair Program (23)
1.1.2.1.6 Use of Seal Oil Trap Vent and Dry Gas Seals of Compressors (23)
1.1.2.1.7 Replace Existing Compressor Facilities with Larger Diameter Pipe (35)
1.1.2.1.8 Replacement of Gas Engines with Electric Units (35)
1.1.2.1.9 Heat Recovery from Compressor Exhaust (43)

1.1.2.2 Improved Leak Detection and Repair (10)
- 1.1.2.2.1 Detection (10)
- 1.1.2.2.2 Using “Smart” Regulators in Distribution Systems (11)
- 1.1.2.2.3 Pipeline Pig Valves to Reduce Flaring/Venting During Inspection (35)
- 1.1.2.2.4 Composite Wraps for Pipeline Repair (11)
- 1.1.2.2.5 Portable Transfer Compressors (23)
- 1.1.2.2.6 Operation of Pipeline at High Line Pack (23)
- 1.1.2.2.7 Internal Pipeline Coating (23)
- 1.1.2.2.8 “Sweep” instead of “Pig” Pipelines (23)
- 1.1.2.2.9 Discharge Gas Coolers (23)
- 1.1.2.2.10 Pre-Planning and Pre-Installation of Stubs, Lock-o-Ring Flanges, Stopple Tees, Etc. (23)
- 1.1.2.2.11 Pipeline Cross-Overs (23)
- 1.1.2.2.12 Hot Tapping (23)
- 1.1.2.2.13 Reduction of Blowdown Volume by Use as Fuel Gas (23)
- 1.1.2.2.14 Installation of Additional Block Valves on Pipelines (23)
- 1.1.2.2.15 Installation of Linebreak Block Valves (23)
- 1.1.2.2.16 Use of Stop-off Fittings to Reduce Pipeline Blowdown for Pipe Repairs (23)
- 1.1.2.2.17 Advanced Welding Methods and Pipe Material (35)

1.1.2.3 Liquid Hydrocarbon Pipelines (35)
- 1.1.2.3.1 Installation of Larger Diameter Pipe (35)
- 1.1.2.3.2 Reallocation of Products to Various Pipelines to Increase Operating Efficiency (35)
- 1.1.2.3.3 Use of Drag Reducing Agents (35)
- 1.1.2.3.4 Variable Frequency Drives (35)
- 1.1.2.3.5 Use of Heated Pipelines for Heavy Oil

1.1.2.4 Mains and Services (23)
- 1.1.2.4.1 Pre-Installation of Sewer and Water Line Stubs to Reduce Third Party Damages to Gas Mains(23)
- 1.1.2.4.2 Sectionalization of Downtown Distribution System by the Installation of Block Valves (23)
- 1.1.2.4.3 Use of Mobile Compressor to Minimize Purging (23)
- 1.1.2.4.4 Nitrogen Plug for Purging of Distribution Mains (23)
- 1.1.2.4.5 Service Riser Valve Change Procedure (23)
- 1.1.2.4.6 Meter Protection Posts (23)

1.1.2.5 Distribution Stations (23)
- 1.1.2.5.1 Fully Welded Regulating Stations (23)
- 1.1.2.5.2 New Regulating Station Design to Minimize Gas Released by Routine Maintenance (23)
- 1.1.2.5.3 Replacement of Continuous Bleed Gas Control Equipment with Low-Bleed and No-Bleed Equipment (23)
- 1.1.2.5.4 Gas Sampler Orifice Reduction (23)
- 1.1.2.5.5 Flaring of Odorant Tank Instead of Venting (23)

1.1.2.6 Distribution, Others (23)
- 1.1.2.6.1 New Ground Thawing Techniques (23)
- 1.1.2.6.2 Generation From Pressure Letdown at Major Users and at Delivery Points to Local Gas Transmission Systems (43)

1.1.2.7 Transmission Lines (23)
- 1.1.2.7.1 Replacement of Snap Acting Relief Valves with Modulating Relief Valves (23
- 1.1.2.7.2 Adjustment of Bleed Rates on Pneumatic Devices (23)
- 1.1.2.7.3 Lower Frequency of Orifice Plates Inspection (23)

1.1.2.8 Petroleum Refining and Marketing (35)
- 1.1.2.8.1 Heat Exchanger Improvements/Additions (35)
- 1.1.2.8.2 Recovery of Flare Gas (35)
- 1.1.2.8.3 More Efficient Process Control Instrumentation (35)

1.2 ENERGY PRODUCTION

1.2.1 Electricity Generation and Cogeneration

1.2.1.1 Pulverized Coal Combustion for Electricity Generation
1.2.1.1.1 Conventional Designs
1.2.1.1.2 Ultra-supercritical Plants
1.2.1.1.3 Coal Beneficiation (1)
1.2.1.2 Natural Gas Combined Cycle (NGCC) Power
1.2.1.3 Integrated Gasification Combined Cycle (IGCC)
1.2.1.3.1 Air Blown Fixed Bed
1.2.1.3.2 Oxygen Blown Fixed Bed
1.2.1.3.3 Fluid Bed
1.2.1.3.4 Entrained Bed Coal Gasification
1.2.1.3.5 Orimulsion-Fired Plant/Heavy Oil Gasification (16)
1.2.1.3.6 Incorporation of a Shift Reaction Stage (16)
1.2.1.4 Atmospheric Fluidized Bed Combustion (AFBC)
1.2.1.4.1 Bubbling Fluidized Bed Combustor
1.2.1.4.2 Circulating Fluidized Bed Combustor
1.2.1.5 Pressurized Fluidized Bed Combustion (PFBC)
1.2.1.5.1 Bubbling Systems
1.2.1.5.2 Circulating Bed Systems
1.2.1.5.3 Second Generation PFBC/Partial Gasification
1.2.1.6 Inter-cooled Steam Injected Gas Turbine (1)
1.2.1.7 Gas/Oil Fired Steam Units (1)
1.2.1.8 Diesel Cogeneration (1)
1.2.1.9 Combustion Turbines (1)
1.2.1.10 Combustion of Fossil Fuels in an Atmosphere of Recycled CO2 (15)
1.2.1.11 Partial Gasification

1.2.2 Renewable Energy

1.2.2.1 Biomass Resource Activity
1.2.2.1.1 Improved Recovery Of Forestry And Agricultural Residues As Well As Of Landfill, Municipal and Industrial Biomass Waste Streams.
1.2.2.1.2 Perennial Herbaceous Energy Crops (22)
1.2.2.1.3 Annuals (e.g. whole-plant cereal crops) (22)
1.2.2.2 Biomass Combustion
1.2.2.2.1 Combined Cycle Plants
1.2.2.2.2 Cofiring by Direct Firing of Solid Biomass
1.2.2.2.3 Pelletized Biomass Combustion (1)
1.2.2.2.4 Biomass: Biomass Conversion for Electricity and Heat Generation (2)
1.2.2.2.5 Biomass: Biomass Gasification and Liquid Fuel Production (2)
1.2.2.2.6 Biomass: Hydrogen from Biomass (2)
1.2.2.2.7 Biomass: Fuel/Electricity for Developing World
1.2.2.3 Biochemical Conversion - Fuel Ethanol from Cellulosic Biomass
1.2.2.3.1 Ethyl Tertiary Butyl Ether (ETBE)
1.2.2.3.2 Lignocellulosic Conversion (22)
1.2.2.3.3 Acid Hydrolis of Cellulose Biomass
1.2.2.3.4 Enzymatic Hydrolis of Cellulosic Biomass
1.2.2.4 Biomass Thermochemical Conversion
1.2.2.4.1 Slow Pyrolysis For Waste Disposal
1.2.2.4.2 Integrated Gasification/Fuel Cell Concepts.
1.2.2.4.3 Black Liquor Gasification
1.2.2.4.4 Biodiesel Production From Vegetable Oils Through Esterification.

- 1.2.2.5 Wind Energy Systems
  - 1.2.2.5.1 Windfarms
  - 1.2.2.5.2 Integrated Wind/Diesel Systems for Remote Communities
  - 1.2.2.5.3 Water Pumping
  - 1.2.2.5.4 Battery Charging for Navigation and Communication Installations
- 1.2.2.6 Photovoltaics (33)
- 1.2.2.7 Solar Thermal Electric Technologies
  - 1.2.2.7.1 Power Tower
  - 1.2.2.7.2 Parabolic Trough
  - 1.2.2.7.3 Parabolic Dish with Heat Engine (usually stirling engine)
  - 1.2.2.7.4 Solar Ponds (1)
- 1.2.2.8 Solar Low Temperature Heating And Cooling Technologies
  - 1.2.2.8.1 Glazed Flat-plate Solar Collectors
  - 1.2.2.8.2 Vacuum Tube Solar Collectors
  - 1.2.2.8.3 Compound Parabolic Collector
  - 1.2.2.8.4 Batch Heating Solar Collectors
  - 1.2.2.8.5 Unglazed Flat-plate Solar Collectors
  - 1.2.2.8.6 Unglazed, Perforated Solar Collector
  - 1.2.2.8.7 Glazed Flat-plate Solar Collectors
  - 1.2.2.8.8 Unglazed, Perforated Solar Collector with Heat Recovery
  - 1.2.2.8.9 Space Heating and/or DHW Heating from Solar Energy Plants with Thermal Storage
  - 1.2.2.8.10 Solar Space Heating (33)
  - 1.2.2.8.11 Solar Ventilation Air Heating (33)
  - 1.2.2.8.12 Solar Space Cooling
  - 1.2.2.8.13 Solar Domestic Hot Water Heaters (33)
    - 1.2.2.8.13.1 Batch Collectors (33)
    - 1.2.2.8.13.2 Glazed Collectors (33)
    - 1.2.2.8.13.3 Thermo-siphon Systems (33)
    - 1.2.2.8.13.4 Evacuated Tube Collectors (33)
  - 1.2.2.8.14 Solar Pool Heaters (33)
  - 1.2.2.8.15 Integrated With HVAC systems
  - 1.2.2.8.16 Combined Solar Water Heating and Space Heating/Cooling
  - 1.2.2.8.17 Combined Solar Water Heating with Cogeneration
- 1.2.2.9 Solar Advanced Photoconversion Technologies
  - 1.2.2.9.1 Photo-electrode, dye-sensitized, Titanium Dioxide solar cells
  - 1.2.2.9.2 Photochemical Cells
  - 1.2.2.9.3 Photochargeable Batteries
  - 1.2.2.9.4 Hot-carrier Photoconversion
  - 1.2.2.9.5 Photoelectro-chemical and Photobiological
  - 1.2.2.9.6 Thermo-chemical
  - 1.2.2.9.7 Direct absorption/ conversion
  - 1.2.2.9.8 Photochemical
  - 1.2.2.9.9 Solar Steam Reforming
  - 1.2.2.9.10 Photo-biological processes
  - 1.2.2.9.11 Photocatalytic processes
  - 1.2.2.9.12 Photocatalytic oxidation processes
  - 1.2.2.9.13 Photocatalytic reduction of CO2
- 1.2.2.10 Small-Scale Hydro
- 1.2.2.11 Geothermal Energy
- 1.2.2.12 Tidal Energy
- 1.2.2.13 Ocean Wave Energy
- 1.2.2.14 Biodiesel (22)

1.2.3 Nuclear
- 1.2.3.1 Light Water Reactors (1)
  - 1.2.3.1.1 Pressurized Water Reactors (12)
  - 1.2.3.1.2 Boiling Water Reactors (12)
- 1.2.3.2 Heavy Water Reactors (1)
- 1.2.3.3 Liquid Metal Fast Reactors (1)
- 1.2.3.4 Gas Cooled Reactors (1)
- 1.2.3.5 Nuclear Fusion

1.2.4 Hydrogen
- 1.2.4.1 Derived From Renewable Resources (15)
- 1.2.4.2 Hydrogen Storage (23)

1.2.5 Energy Transfer
- 1.2.5.1 Efficient Electrical Transformers (1)
- 1.2.5.2 Electric Transmission and Distribution Systems (1)
- 1.2.5.3 Thermal Energy Storage Systems (1)
- 1.2.5.4 High-Voltage Direct-Current Transmission (1)
- 1.2.5.5 Power Transmission/Utilization
  - 1.2.5.5.1 Superconductivity

1.3 ENERGY END-USE

1.3.1 Industrial

1.3.2 Industrial: Petroleum Refining
- 1.3.2.1 Hybrid Membrane Separation for Propylene Recovery
- 1.3.2.2 Fouling Mechanisms
- 1.3.2.3 Advanced Fluid Catalytic Cracker

1.3.3 Industrial: Glass and Ceramics Industry
- 1.3.3.1 Integrated Batch and Cullet Preheat System
- 1.3.3.2 Recovering and Reusing Waste Heat from Oxy-Fired Furnaces
  - 1.3.3.2.1 Regenerative Oxygen Heat Recovery
  - 1.3.3.2.2 Synthetic Air Concept
- 1.3.3.3 New Plasma Melting Techniques and Ultrasonic Refining
- 1.3.3.4 Use of Microwaves in Firing Ceramics
- 1.3.3.5 Glass Furnace Side Port Oxygen Enrichment
- 1.3.3.6 High Luminosity Low NOx Oxy-Gas Burner
- 1.3.3.7 Synthesis and Design of Intermetallic Materials
- 1.3.3.8 Contact Temperature Sensor
- 1.3.3.9 Advanced Combustion Space Models

1.3.4 Industrial: Food Industries
- 1.3.4.1 Biotechnical Means of Reducing High Moisture Content in Raw Materials
- 1.3.4.2 Improved Separation Processes
  - 1.3.4.2.1 Membranes
  - 1.3.4.2.2 Absorbing surfaces
  - 1.3.4.2.3 Freeze Crystallization
- 1.3.4.3 Improved Sterilisation
  - 1.3.4.3.1 Ultraviolet
  - 1.3.4.3.2 Ionisation

1.3.5 Industrial: Cement Industry
- 1.3.5.1 Improvements to the Energy Efficiency of the Process (20)
  - 1.3.5.1.1 Raw Meal Homogenizing Systems (20)
  - 1.3.5.1.2 Conversion From Dry to Multi-stage Preheater Kiln (20)
  - 1.3.5.1.3 Conversion From Dry to Precalciner Kiln (20)
  - 1.3.5.1.4 Conversion from Cooler to Grate Cooler (20)
  - 1.3.5.1.5 Improved Preheating (20)
  - 1.3.5.1.6 Efficient Grinding Technologies (20)
  - 1.3.5.1.7 High Efficiency Classifiers (20)

1.3.5.1.8 Fluidised Bed Kiln (20)

1.3.5.2 Shifting to a More Energy Efficient Process (20)
1.3.5.2.1 Conversion From Wet to Dry Process (20)
1.3.5.2.2 Conversion From Wet to Semi-Dry Process (20)
1.3.5.2.3 Conversion From Wet to Semi-Wet Process (20)
1.3.5.3 Replacing High Carbon Fuels with Low Carbon Fuels (20)
1.3.5.3.1 Application of Waste Derived Alternative Fuels (20)
1.3.5.4 Application of Alternative Cements (Mineral Polymers) (20)
1.3.5.5 Shifting to Mineral Polymers (20)

1.3.6 Industrial: Aluminum Industry (Primary)

1.3.6.1 Raw Materials-Enhanced Alumina Technology
1.3.6.1.1 1 mega-amp Hall-Heroult Cell
1.3.6.1.2 Improved Anode/Cathode Materials and Controls
1.3.6.1.3 Continuous On-line Sensors
1.3.6.1.4 Alternative Smelting Techniques
1.3.6.1.5 Strip/Spray Casting Optimization
1.3.6.1.6 Aluminum Powder Optimization
1.3.6.1.7 Alloy Optimization
1.3.6.1.8 Advanced Process Controls
1.3.6.1.9 Cost Effective Retrofit of Soderberg Reduction Cell
1.3.6.1.10 Skim/Dross Processing
1.3.6.1.11 Saltcake Recovery/treatment.
1.3.6.2 Manufacturing
1.3.6.2.1 Near-net Shape Casting
1.3.6.2.2 Enhanced Joining Technology
1.3.6.2.3 New Forming Technology
1.3.6.2.4 New/optimized Coating Techniques
1.3.6.3 Carbo-thermic Reduction Using an Electric Arc Furnace to Directly Reduce Aluminum
1.3.6.4 Spray Forming of Aluminum Sheet to Replace the Conventional Process of Ingot Casting and Reheating for Rolling

1.3.7 Industrial: Aluminum Industry (Secondary)

1.3.7.1 Improve Furnace Efficiency of Melting and Holding Furnaces for Secondary Recovery
1.3.7.1.1 Recuperators
1.3.7.1.2 Regenerators
1.3.7.1.3 Oxygen Assisted Combustion
1.3.7.2 Recovery of Saltcake from Process Brines
1.3.7.3 Innovative Vertical Flotation Melter for Processing Aluminum Scrap

1.3.8 Industrial: Iron and Steel (24)

1.3.8.1 Increase in Electric Arc Furnace Capacity (24)
1.3.8.2 Increased Natural Gas, Oil, Pulverized Coal Injected into Blast Furnaces (24)
1.3.8.3 New Walking Beam Reheating Furnaces (24)
1.3.8.4 More use of Ladle Metallurgy Furnaces and Electromagnetic Stirring (24)
1.3.8.5 Oxygen Lance, Oxy-Burner Systems and Foamy Slag Practices in EAFs (24)
1.3.8.6 BOF Process Gas Recovery (24)
1.3.8.7 New Smelting-Reduction Plant (24)
1.3.8.8 New Direct Reduced Iron Plant (24)
1.3.8.9 Thin Slab Casting (24)
1.3.8.10 Co-Generation (Combined Cycle Power Generation) (24)

1.3.8.11 Other
1.3.8.11.1 Incorporates both Iron and Steel Making into One System with Thin Strip Casting as a Final Product
1.3.8.11.2 Incorporate a Coal-based Reductant Process Coupled with Steel Making
1.3.8.11.3 Use Computer Technology to Provide Feedback
1.3.8.11.4 Development of Sensors for all Aspects of Process Control
1.3.8.11.5 Scrap Pre-heating by EAF Off-Gases to Reduce Energy and Improve Production
1.3.8.11.6 Hot Connections to Move Forms from the Continuous Casting Operation to the Rolling Operation with Minimal Cooling
1.3.8.11.7 Near Net Shape Casting
1.3.8.11.8 Steel Plant Dust and Waste Oxide Sludge Recycling
1.3.8.11.9 Electrochemical Removal of Zinc from Steel Scrap
1.3.8.11.10 Microstructure Engineering for Hot Strip Mills
1.3.8.11.11 Online Mechanical Properties Measurements
1.3.8.11.12 Phase Measurement and Temperature Measurement of Galvanneal

1.3.9 Industrial: Semi-Fabricating Metals Processing
1.3.9.1 Energy Efficient Natural Gas Furnaces (24)
1.3.9.2 Delivery of Molten Aluminum (24)
1.3.9.3 Design, Geometry and Insulation of the Heating/Holding Furnaces (24)
1.3.9.4 One Phase Medium and High Frequency Coreless Melting Furnaces (24)
1.3.9.5 Wider Copper Profiles in Coreless Melting Furnaces (24)
1.3.9.6 Utilization of Recycled Water (24)
1.3.9.7 Moisture Curable Cross-linking (24)
1.3.9.8 Optimized Coreless Induction Melting
1.3.9.9 Sensor Installations
1.3.9.10 Electromagnetic (EM) Casting
1.3.9.10.1 EM Stirring
1.3.9.10.2 EM Confinement
1.3.9.11 Advanced Lost Foam Technology
1.3.9.12 Intelligent Control of the Cupola Furnace
1.3.9.13 Dimensional Control and Fatigue Life Prediction.

1.3.10 Industrial: Minerals Processing (24)
1.3.10.1 Automated Kiln Process Controls (24)
1.3.10.2 More Efficient Refractories (24)
1.3.10.3 Continuous Feed Mechanisms on Shaft Kilns (24)
1.3.10.4 Improve Process Water Handling (24)
1.3.10.5 Install Improved Fuel Burner Designs (24)
1.3.10.6 Install Equipment to Improve Fuel/Air Mixing (24)
1.3.10.7 Install Preheaters (24)
1.3.10.8 Install New, Higher Efficiency Kilns (24)
1.3.10.9 Install Co-generator Systems (24)

1.3.11 Industrial: Mining
1.3.11.1 Iron Ore Mining
1.3.11.1.1 Converting from Dry to Wet Autogenous Grinding Process (24)
1.3.11.1.2 Automating Induration Machines (24)
1.3.11.1.3 Improved Furnace Travelling Grates Systems (24)
1.3.11.1.4 Improved Insulation (24)
1.3.11.2 Potash Mining (24)
1.3.11.2.1 Computerized Process Optimization Systems (Fuzzy Logic) (24)
1.3.11.2.2 New Higher Efficiency Rotary Dryer (24)
1.3.11.2.3 Increase Crystallization Stages (24)
1.3.11.2.4 Fluid Bed Dryer (24)
1.3.11.2.5 New Boilers (24)
1.3.11.2.6 Improved Insulation (dryers, buildings, crystallizes, etc.) (24)
1.3.11.2.7 Using Cooling Pond Technology (24)

1.3.12 Industrial: Transportation Equipment Manufacturing
1.3.12.1 Process Modifications (31)
1.3.12.1.1 Closed Loop Drying Systems Based on Dehumidification Instead of Evaporation (31)
1.3.12.1.2 Replacing Conventional Stamping with Hydroforming (31)
1.3.12.2 Improving Energy Efficiency of Steam Production (31)
1.3.12.2.1 Improve Efficiency of Existing Boilers (31)
1.3.12.2.1.1 Reducing Flue Gas Heat Loss (31)
1.3.12.2.1.2 Repairing Steam Leaks (31)
1.3.12.2.1.3 Cleaning Heat Exchanger Surfaces (31)
1.3.12.2.1.4 Flue Gas Economizers (31)
1.3.12.3 Compressed Air Systems (31)
1.3.12.3.1 Ultrasonic Leak Detectors (31)
1.3.12.3.2 Automatic Shut-off Valves (31)
1.3.12.3.3 Flowmeters on Large Air Consuming Machines (31)
1.3.12.3.4 Air Compressor System Control Systems (31)
1.3.12.4 Reducing Energy Consumption for Space Heating and Ventilation (31)
1.3.12.4.1 Set Back Temperatures (31)
1.3.12.4.2 Reducing Air Make-Up/Exhaust Rate in Paint Spray Booths When not in Use (31)
1.3.12.4.3 Solar Walls to Preheat Building Make-up Air (31)
1.3.12.4.4 Computer Controlled Lighting and Heating Systems (31)
1.3.12.4.5 Ceiling Fans to Destratify Air (31)
1.3.12.5 Reducing Energy Consumption by Cooling Tower Operation (31)
1.3.12.5.1 Increasing Temperature Differential between Incoming and Outgoing Cooling Water
1.3.12.5.2 Regular Maintenance to Reduce Scaling (31)

1.3.13 Industrial: Forest Sector
1.3.13.1 Adopt More Energy Efficient Processes and Equipment (39)
1.3.13.1.1 Installation of More Efficient Equipment (39)
1.3.13.1.2 Increased Use of Cogeneration (39)
1.3.13.1.3 Black Liquor/Biomass Gasification (39)
1.3.13.1.4 Changes in Logging Practices (39)
1.3.13.2 Encourage Fuel-Switching (39)
1.3.13.2.1 Increased Use of Natural Gas (39)
1.3.13.2.2 Increased Use of Biomass (39)
1.3.13.2.2.1 Improvements in Hog Fuel Quality (Dewatering) (39)
1.3.13.2.2.2 Retrofitting/Upgrading Fossil Fuel Boilers to Allow Co-firing with Hog Fuel (39)
1.3.13.2.2.3 Retrofitting/Upgrading Hog Fuel Boilers to Allow Increased Hog Firing (39)
1.3.13.2.2.4 New Hog-Fuel and Recovery Boilers (39)
1.3.13.2.2.5 Water Reduction Prior to Hog/Slurry Combustion
1.3.13.2.3 Increased Use of Others Forms of Renewable Energy (e.g. Hydro) (39)
1.3.13.3 Changes in Production/Industrial Structure (39)
1.3.13.3.1 Systems Approach to energy Use in the Entire Raw Material Processing Chain (39)
1.3.13.4 Enhance Use of Forest Biomass for Biopower and Liquid Biofuels (39)
1.3.13.4.1 Biomass for Electricity and Space Heating (39)
1.3.13.4.2 Biomass for Liquid Fuel (39)
1.3.13.5 Other
1.3.13.5.1 Ultrasonic Sensor Technology
1.3.13.5.2 Polyoxometalate Bleaching of Softwood Pulps
1.3.13.5.3 Sulphur Free Pulping
1.3.13.5.4 Process Control Optimization and Greater Speed on the Production Line
1.3.13.5.5 Impulse Drying of Paperboard.
1.3.13.5.6 Membrane technology to Recover Chemicals from Black Liquor

1.3.14 Industrial: Chemical and Synthetic Resins Sector
1.3.14.1 Co-generation Systems (42)
1.3.14.2 Energy Services and Feedstock Synergies for Close Proximity Existing Chemical Plants (42)
1.3.14.3 Advanced Bioprocessing Capabilities
1.3.14.4 Flexible Chemical Processing of Post-consumer Polymeric Materials into Chemicals
1.3.14.5 Biological/Chemical Caprolactam Process
1.3.14.6 Innovation in Catalysis
1.3.14.6.1 Theoretical and Experimental Tools to Improve Understanding
1.3.14.6.2 Methods to Improve the Speed of Catalyst Discovery
1.3.14.6.3 Novel Reactors and Reaction Engineering Including Reactive Separation Concepts
1.3.14.7 Phenolics from Wood Waste to Replace Petroleum Feedstock Requirements
1.3.14.8 Recovery of Chlorosilane Intermediates from Silicon By-Products
1.3.14.9 Inorganic Polymer Membrane
1.3.14.10 Automotive Materials Recycling Techniques
1.3.14.11 Advanced Electrodialysis for Separations and Pollution Prevention
1.3.14.12 Bioprocessing Technologies to Develop Biocatalysts
1.3.15 Energy End-Use: Buildings
1.3.16 Buildings: Advanced Building Envelope Systems
1.3.16.1 Advanced Windows
1.3.16.1.1 Gas Filled, Low-Emissivity Glazing Systems
1.3.16.1.2 Switchable (Chromogenic) Glazing
1.3.16.1.3 Thermally Broken and Insulated Frames
1.3.16.1.4 Insulated Spacers
1.3.16.1.5 Electrically Heated Glazings
1.3.16.1.6 Superwindows
1.3.16.1.7 Prismatic Devices, Holographic Films, Orientated Coatings
1.3.16.2 Advanced Insulation Systems
1.3.16.2.1 Gas Filled Panels (1)
1.3.16.2.2 Transparent Insulation
1.3.16.2.3 Solid-filled Insulation Panels
1.3.16.2.3.1 Vacuum powder-filled
1.3.16.2.3.2 Vacuum fiber-filled materials
1.3.16.2.4 Structurally Re-inforced Beaded Vacuum Panels
1.3.16.2.5 Switchable Evacuated Panels
1.3.16.2.6 Compact Vacuum Insulated Panels (metal clad evacuated panels)
1.3.16.2.7 High Thermal Resistance Foam Insulations.
1.3.16.3 Building Design
1.3.16.3.1 High-Albedo Materials (1)
1.3.16.3.2 Prefabricated Building Panels
1.3.16.3.3 Thermal Mass Storage (26)
1.3.17 Buildings: Advanced Residential HVAC Systems
1.3.17.1 Fossil Fired Heating Systems
1.3.17.1.1 Condensing Gas Fired Space and Water Heaters
1.3.17.1.2 Condensing Oil Furnaces (33)
1.3.17.1.3 Power Vented Gas or Oil Vented Space and Water Heaters
1.3.17.1.4 Kerosene Stoves (2)
1.3.17.1.5 Biomass Stoves (2)
1.3.17.2 Heat Pumps
1.3.17.2.1 Residential Gas-Fired Absorption Heat Pumps
1.3.17.2.2 Utilizing a Heat Pump in an Integrated System
1.3.17.3 Ventilation systems
1.3.17.3.1 Mechanical Ventilation
1.3.17.3.2 Heat Recovery from Waste or Exhaust Air
1.3.17.3.3 Ground Pre-conditioning of Supply Air
1.3.17.3.4 Desiccant Pre-conditioners for Treating Ventilation Air

1.3.17.4 Domestic Hot Water systems
1.3.17.4.1 Low Tech Solar to Preheat Hot Water Prior to Gas or Electric Tank
1.3.17.4.2 Combined Refrigerator and DHW Heater with Auxiliary Water Heating Using Indoor Air
1.3.17.4.3 Low-flow Showerheads and Faucets (33)
1.3.17.4.4 Insulated Jackets for Existing Water Heaters (33)
1.3.17.4.5 Integrating Hot Water Supply with Space Heating Systems (33)
1.3.17.4.6 Grey Water Heat Recovery (33)
1.3.17.4.7 Properly Insulated Hot Water Pipes (33)
1.3.17.4.8 High Efficiency or Stand Alone Water Heaters in Apartments (33)
1.3.17.5 Cogeneration
1.3.17.5.1 Micro co-generation (33)
1.3.17.5.2 Free Piston Stirling Engine Alternators (33)

1.3.18 Buildings: Advanced Commercial Building HVAC Systems

1.3.18.1 Fossil Fired Heating Systems
1.3.18.1.1 Condensing Gas Fired Space and Water Heaters
1.3.18.1.2 Gas Fireplaces: Forced Air Heat Recovery, Direct Vent Combustion Air Supply and Doors (33)
1.3.18.1.3 Power Vented Gas or Oil Vented Space and Water Heaters
1.3.18.1.4 Pulse Combustion Boilers
1.3.18.1.5 Improved Burners
1.3.18.1.6 Set Back Controls (33)
1.3.18.2 Passive, Hybrid and Low Energy Cooling
1.3.18.2.1 Free Cooling
1.3.18.2.2 Cool Storage Roofs
1.3.18.2.3 Indirect/direct Evaporative Cooling
1.3.18.2.4 Ground Cooling with Air or Water
1.3.18.2.5 Slab Cooling with Air or Water
1.3.18.2.6 Chilled Ceiling Combined with Displacement Ventilation
1.3.18.2.7 Desiccant Cooling
1.3.18.2.8 High Efficiency Packaged Air Conditioning Units
1.3.18.2.9 High Temperature Collectors
1.3.18.2.10 Desiccant Dehumidification Combined with Vapour Compression Sensible Cooling (26)
1.3.18.2.11 Widespread Use of Economizers Integrated with Ventilation Systems for Free Cooling (26)
1.3.18.2.12 Radiant Ceiling Panels (33)
1.3.18.2.13 Smart Controllers for Use of Outside Cool Air (33)
1.3.18.3 Heat Pumps (for space heating and cooling)
1.3.18.3.1 Gas, Electric or Chemically Driven Heat Pumps
1.3.18.3.2 Gas Fired Absorption Heat Pumps
1.3.18.3.3 Air Source (ambient and exhaust air) Heat Pumps
1.3.18.3.4 Ground Source Heat Pumps
1.3.18.3.5 Advanced Heat Exchangers and New Chlorine Free Refrigerants and Advanced Vapour Compression Cycles
1.3.18.3.6 Zeotropic Refrigerants
1.3.18.4 Ventilation Systems
1.3.18.4.1 Mechanical Ventilation
1.3.18.4.2 Heat Recovery from Waste or Exhaust Air (including exhaust air heat pumps)
1.3.18.4.3 Ground Pre-conditioning of Supply Air
1.3.18.4.4 Desiccant Pre-conditioners for Treating Ventilation Air
1.3.18.4.5 • Solar Pre-heat to Ventilation Air (perforated or transpired collectors for ventilation preheat
1.3.18.4.6 Carbon Dioxide Sensors to Maintain Preset Level of CO_2 (26)
1.3.18.4.7 Low Temperature Cooling Water and Air Distribution Systems to Reduce Fan and Pump Energy (26)
1.3.18.4.8 Radiant Cooling Panels Combined with Displacement Ventilation to Reduce Fan Energy (26)
1.3.18.4.9 Fan Speed Reduction to Reduce System Airflow (26)
1.3.18.4.10 Energy Efficient Step-Down Transformers to Reduce Losses (26)
1.3.18.4.11 Advanced Diagnostic Controllers (33)

1.3.18.5 Domestic Hot Water Systems
   1.3.18.5.1 Air-Source Heat Pump Water Heaters (2)
   1.3.18.5.2 Exhaust Air Heat Pump Water Heater (2)
   1.3.18.5.3 Pilotless Instantaneous Gas Water Heaters
   1.3.18.5.4 Low Standby Losses
   1.3.18.5.5 Water Efficient Fixtures
   1.3.18.5.6 Heat Pump Water Heaters
   1.3.18.5.7 Combined Refrigerator/Water Heater
   1.3.18.5.8 High Temperature Heating Water Distribution Systems (26)
   1.3.18.5.9 Pump Impeller Modifications to Match Reduced Water System Head and Flow (26)
1.3.18.6 HVAC Distribution Systems
   1.3.18.6.1 Duct Component Products with Reduced Air Leakage
   1.3.18.6.2 Advanced Heat Exchangers (electrohydrodynamic heat transfer enhancement)
   1.3.18.6.3 Energy Management Systems (1) (2)
   1.3.18.6.4 Integrated or Multi-Function Appliances (26)
1.3.18.7 Intelligent Building Systems
   1.3.18.7.1 Computer-based Building Commissioning and Operation Tools

1.3.19 Buildings: Advanced Residential Electrical Systems

1.3.19.1 Advanced Refrigerants Cycles And Systems
1.3.19.2 Efficient Cook Stove Elements (Solid Disk, Radiant, Halogen)
1.3.19.3 Sealed Combustion Natural Gas Ranges (33)
1.3.19.4 Gas Elements With Electronic Ignition
1.3.19.5 Convection Ovens (Gas And Electric)
1.3.19.6 Horizontal Axis Clothes Washers
1.3.19.7 Microwave Ovens
1.3.19.8 Microwave And Heat Pump Clothes Dryer
1.3.19.9 Natural Gas Fired Dryers (33)
1.3.19.10 Heat Recovery on Dryer Exhaust (33)
1.3.19.11 Front-Loading Washing Machines (33)
1.3.19.12 Efficient Refrigerators (1) (2)
1.3.19.13 Increased Clothes Washer Spin Speed (2)
1.3.19.14 Efficient Computers (2)
1.3.19.15 Efficient Dishwashers (33)
1.3.19.16 Low Power Mode for Equipment (2)
1.3.19.17 Improved Appliance Insulation
1.3.19.18 Improved Appliance Controls
1.3.19.19 Green Plug Motor Controller For Appliances
1.3.19.20 Advanced Cleaning Technologies (21)
   1.3.19.20.1 Electrolytic (21)
   1.3.19.20.2 Ultrasonic (21)
   1.3.19.20.3 Ozonated (21)
1.3.19.21 Alternative Refrigeration Equipment with Low Greenhouse Warming Potential (21)
   1.3.19.21.1 Stirling Cycle (21)
   1.3.19.21.2 Brayton Cycle (21)
   1.3.19.21.3 Acoustic (21)
   1.3.19.21.4 Magnetic (21)
   1.3.19.21.5 Thermal Electric (21)

1.3.20 Buildings: Advanced Commercial Systems

1.3.20.1 Daylighting

1.3.20.1.1 Skylights and Rooflights

1.3.20.1.2 Clerestories

1.3.20.1.3 Automatic Controls for Blinds

1.3.20.1.4 High Reflectance Paints

1.3.20.1.5 Spectrally Selective Glazing or Films and Optical Switching (electrochromic) Glazing Systems.

1.3.20.1.6 Light Shelves, Light Pipes

1.3.20.1.7 Atria

1.3.20.2 Artificial Light

1.3.20.2.1 Compact Fluorescent Lights

1.3.20.2.2 Efficient Fluorescent Lamps (2)

1.3.20.2.3 Controls and Dimmable Ballasts

1.3.20.2.4 Time-based and Occupancy or Daylight-linked Controls

1.3.20.2.5 Efficient Electronic Ballasts

1.3.20.2.6 Optimum Spectrum, Scotopic Lamps which Improve Vision and are Energy Efficient

1.3.20.2.7 Halogen Lamps with IR Reflective Coatings

1.3.20.2.8 Electrodeless and Solid State Lighting

1.3.20.2.9 Specular Reflective Surfaces (2)

1.3.20.2.10 Low Power Sulphur Lamps (21)

1.3.20.2.11 Small LED Lamps (for Exit Signs and other low intensity purposes) (26)

1.3.20.2.12 High Intensity Discharge Lamps (26)

1.3.20.2.13 New Electrode Solutions for Large and Small Capacities (26)

1.3.20.2.14 Mini-HID Sources and Solid State LED or Laser-Diode Sources (26)

1.3.20.2.15 Centralized Lighting: Hollow Light Guides or Light Pipes (26)

1.3.20.2.16 Improved Fixture Design: Highly Reflective Surfaces (26)

1.3.20.2.17 Improved Fixture Design: Refractive and Diffracting Materials (26)

1.3.20.2.18 Improved Fixture Design: Non-Imaging Optical Designs (26)

1.3.20.3 Office Equipment

1.3.20.3.1 Low Energy Desktop Computers

1.3.20.3.2 Improved Inkjet Printers and Faxes

1.3.20.3.3 • Improved Cold-fusing and Low Energy Fusing Copiers, Printers and Faxes

1.3.21 Energy End Use: Transportation

1.3.22 Transportation: Air Transportation

1.3.22.1 Advanced Engine Technologies

1.3.22.1.1 Thermal Efficiencies (36)

1.3.22.1.2 Propulsive Technologies (36)

1.3.22.2 Propfans

1.3.22.3 Lightweight Materials

1.3.22.4 Hybrid Laminar Flow Control

1.3.22.5 Aerodynamic Efficiencies (36)

1.3.22.6 Larger Capacity Aircraft (36)

1.3.22.7 Advanced Aviation Systems (36)

1.3.22.7.1 User Request Evaluation Tool (36)

1.3.22.7.2 Terminal Air Traffic Control Automation (36)

1.3.22.7.3 Cockpit Display of Traffic Information (36)

1.3.22.7.4 Data Link (36)

1.3.22.7.5 Oceanic Enhancements (36)

1.3.22.7.6 Self-Managed Arrival Resequencing Tool (36)

1.3.23 Transportation: Advanced Conventional Vehicles

- 1.3.23.1 Direct Injection Diesel and Gasoline Engines
- 1.3.23.2 Turbo Compressors and Intercooling with Diesels
- 1.3.23.3 Engines with Lean or Stratified Fuel Mixtures
- 1.3.23.4 Two Stroke Engines,
- 1.3.23.5 Continually Variable Transmission (CVT)
- 1.3.23.6 Efficient Tires (1)
- 1.3.23.7 Reduced Rolling Resistance (4)
- 1.3.23.8 Improved Aerodynamics (4)
- 1.3.23.9 Improvements to Efficiency of 4 Stroke Gasoline Engines (4)
- 1.3.23.10 Changes in Engine Combustion Chamber Design (2)
- 1.3.23.11 Computer Technology to Improve Vehicle and Engine Management (2)
- 1.3.23.12 Reduced Refrigerant Leakage in Air Conditioning and Other Cooling Circuits (2)
- 1.3.23.13 More Efficient Electrical Systems (4)
- 1.3.23.14 Energy Recovery Systems (e.g. efficient recovering and utilizing exhaust energy and braking energy) (4)
- 1.3.23.15 Energy Efficient Conversion Systems (4)
- 1.3.23.16 Weight Reduction
  - 1.3.23.16.1 Lightweight Materials
  - 1.3.23.16.2 Redesign for Equal Structural Integrity with Less Material
- 1.3.23.17 Drive Train System Efficiency Improvements
  - 1.3.23.17.1 Reduced Friction and Pumping Losses
  - 1.3.23.17.2 Higher Thermodynamic Efficiency
- 1.3.23.18 Advanced Electronic Controls (36)
- 1.3.23.19 Gasoline Direct Injection (36)
- 1.3.23.20 Advanced Diesel Engines (36)
- 1.3.23.21 Advanced Automatic Transmission s(36)
- 1.3.23.22 Stirling Engines (36)
- 1.3.23.23 Waste Heat Recovery Technology (36)

1.3.24 Transportation: Heavy Trucks/Rail and Marine

- 1.3.24.1 Advanced Diesel Engine Technologies
  - 1.3.24.1.1 Direct-Injection
  - 1.3.24.1.2 High cylinder Pressures
  - 1.3.24.1.3 Thermal Barrier Coatings
  - 1.3.24.1.4 High Pressure Injection Systems
  - 1.3.24.1.5 Friction and Wear Reduction
  - 1.3.24.1.6 High Strength Materials
  - 1.3.24.1.7 Improved Turbocharger Efficiency.
- 1.3.24.2 Oxygen-Enrichment
- 1.3.24.3 Software Technology
- 1.3.24.4 Advanced Tires
- 1.3.24.5 Friction Reduction
- 1.3.24.6 Advanced Materials
- 1.3.24.7 Regenerative Braking
- 1.3.24.8 Aerodynamic Improvements (36)
- 1.3.24.9 Insulated Engines (36)
- 1.3.24.10 Marine: Gas Turbines (36)
- 1.3.24.11 Marine: Diesel Electric Systems (36)

1.3.25 Transportation: Hybrid and Electric Vehicles

1.3.25.1 Battery Electric Vehicles (preferably from renewables) (4)
1.3.25.1.1 Lead Acid Batteries (4)
1.3.25.1.2 Sodium Sulphur Batteries (4)
1.3.25.1.3 Nickel Cadmium Batteries (4)
1.3.25.1.4 Metal Air Batteries (4)
1.3.25.1.5 Lithium-Iron Disulphide Batteries (4)
1.3.25.1.6 Nickel-Metal Hydride Batteries (4)
1.3.25.1.7 Lithium Polymer Batteries (4)
1.3.25.2 Electric Hybrids (4)
1.3.25.2.1 Flywheel Technology (4)
1.3.25.2.2 Turbo Generator (4)

1.3.26 Transportation: Transportation and Traffic Management

1.3.26.1 Intelligent Transportation Systems
1.3.26.1.1 Advanced Traffic Management Systems (4)
1.3.26.1.1.1 Traffic Network Monitoring and Control (4)
1.3.26.1.1.2 Electronic Toll Collection (4)
1.3.26.1.1.3 Priority for High Occupancy Vehicles (4)
1.3.26.1.2 Advanced Traffic Information Systems (4)
1.3.26.1.2.1 On-Board/Voice Navigation and Route Guidance Systems (4)
1.3.26.1.2.2 On-Board Displays of Maps and Roadway Signs (4)
1.3.26.1.2.3 Systems to Interpret Digital Traffic Information Broadcasts (4)
1.3.26.1.2.4 On-Board/Voice Traffic Hazard Warning Systems (4)
1.3.26.1.2.5 Highway Advisory Radio (4)
1.3.26.1.3 Advanced Vehicle Control Systems (4)
1.3.26.1.3.1 Cruise Control (4)
1.3.26.1.3.2 Anti-Locking Braking Systems (4)
1.3.26.1.3.3 Traction Control (4)
1.3.26.1.3.4 Enhanced Vision Systems (4)
1.3.26.1.3.5 Collision Avoidance Systems (4)
1.3.26.1.4 Commercial Vehicle Operations/Advanced Fleet Management Systems (4)
1.3.26.1.4.1 Satellite-Based Fleet Tracking (4)
1.3.26.1.4.2 Centralized Computer-Aided Dispatching (4)
1.3.26.1.4.3 Two-way Communications Between Fleet Operators and Vehicles (4)
1.3.26.1.4.4 Automated Vehicle Identification (4)
1.3.26.1.4.5 Automatic Vehicle Classification (4)
1.3.26.1.4.6 Electronic Placarding/Bill of Lading (4)
1.3.26.1.4.7 Automatic Clearance Sensing (4)
1.3.26.1.4.8 Automated Roadside Safety Inspections (4)
1.3.26.1.4.9 Hazardous Materials Systems (4)
1.3.26.1.5 Advanced Public Transit Systems (4)
1.3.26.1.5.1 Fleet Monitoring and Dispatch Management (4)
1.3.26.1.5.2 On-Board Display for Operations and Passengers (4)
1.3.26.1.5.3 Real-Time Displays at Bus Stops (4)
1.3.26.1.5.4 Intelligent Fare Collection (4)
1.3.26.1.5.5 Ride Share and High Occupancy Vehicle Information Systems (4)
1.3.26.1.5.6 Automatic Vehicle Identification (4)
1.3.26.1.6 Advanced Rural Transportation Systems (4)
1.3.26.1.6.1 Route Guidance and Traveler Information (4)
1.3.26.1.6.2 Two-Way Communication (4)
1.3.26.1.6.3 Automatic Vehicle Location (4)
1.3.26.1.6.4 Incident Detection (4)
1.3.26.1.6.5 Automated Mayday Systems with Co-ordinated Dispatching (4)
1.3.26.1.6.6 Roadway Edge Detection (4)
1.3.26.1.6.7 Systems to Allow the Passing of Slow-Moving Vehicles in Areas with Limited Sight Distance (4)

1.3.27 Transportation: Reduce Use of Private Vehicles
1.3.27.1.1 Increase Vehicle Occupancy Rates
1.3.27.1.2 Integration of Modes
1.3.27.1.3 Increase Use of Public Transportation
1.3.27.1.4 Optimization of Urban Space
1.3.28 Transportation: Alternative Fuels
1.3.28.1 Natural Gas
1.3.28.2 Propane
1.3.28.3 Methanol (36)
1.3.28.4 Ethanol (36)
1.3.28.5 Biodiesel (36)
1.3.29 Transportation: Other
1.3.29.1 Improved Pavement Technology (36)
1.3.29.1.1 Recycling of Wastes (36)
1.3.29.1.2 Premium Quality Asphalt (36)
1.3.29.1.3 Upgrading of Materials (36)
1.3.29.2 Intermodal Road-Rail Freight (36)
1.3.29.2.1 Iron Highway - Specially Designed Locomotives (36)
1.3.29.2.2 Ecorail - More Efficient Motive Power to Haul Containers over Short Distances (36)
1.3.29.2.3 Railrunner - Independent Detachable Bogie (36)
1.3.29.2.4 Roadrailer (36)
1.3.29.2.5 Double Stacking (36)
1.3.30 Energy End Use: Agriculture
1.3.30.1 Integrated Pest Management (22)
1.3.30.2 Reduce Fertilizer Use (2)
1.3.30.3 More Effective Application (25)
1.3.30.4 Grow Legumes to Reduce Fertilizer Consumption (25)
1.3.30.5 Efficient Application of Manures (25)
1.3.30.6 Irrigation Scheduling (2)
1.3.31 Energy End-Use: Municipalities
1.3.32 Municipalities: Small-Scale Combined Heat and Power
1.3.32.1 Spark-Ignition Gas Engine
1.3.32.2 Gas-Turbine-based Plants
1.3.32.3 CHP Plants for District Heating Networks Or Industrial Clients
1.3.33 Municipalities: Large-Scale Combined Heat and Power
1.3.33.1 Powered by Fossil Fuels
1.3.33.2 Powered by Biomass
1.3.33.3 Powered by Municipal Solid Waste
1.3.33.4 Powered by Nuclear Energy
1.3.33.5 Powered by Solar Energy
1.3.34 Municipalities: Thermal Energy Storage
1.3.34.1 Long- Term (Seasonal) Storage Of Thermal Energy Using Water Or Rocks (E.G. Aquifers Or RoCaverns) As The Storage Medium
1.3.34.2 Short-Term (Diurnal) Storage Of Coolness In Air-Conditioned Buildings
1.3.34.3 Systems Using Phase-Change Materials (PCMs)
1.3.35 Municipalities: Electrical Energy Storage
1.3.35.1 Hydro Pumped Storage for Utilities
1.3.35.2 Off Peak Storage
1.3.35.3 Energy Storage in Electric and Hybrid Drive Trains
1.3.35.4 Home Co-generation:
1.3.35.5 Battery Energy Storage
1.3.35.6 Superconducting Magnetic Energy Storage
1.3.35.7 Flywheel Energy Storage
1.3.35.8 Compressed Air Technology

1.3.36 Municipalities: Multi-functional Equipment

1.3.36.1 Integrated Water Heating/Space Conditioning System

1.3.36.2 Energy-Efficient Air Filtration, Humidity and Temperature Control

1.3.36.3 Office Appliances that Serve as a Networked Printer, Copier, Scanner and Paper-less Fax MachineError! Bookmark not defined.

1.3.37 Municipalities: Transportation Opportunities

1.3.38 Municipalities: District Energy Systems

1.3.38.1 District Energy Sites

1.3.39 Municipalities: Community Refrigeration/Heat Pumps

1.3.39.1 Night Ventilation, Night Sky Radiative Cooling And Evaporative Cooling

1.3.39.2 Ground Cooling With Air Or Water That Make Use Of Low Ground Temperatures

1.3.39.3 Water/Zeolite Adsorption Systems (Desiccant Cooling)

1.3.39.4 Active Solar Cooling With Absorption, Desiccant, Or Rankine Cooling Equipment And Passive Solar Cooling

1.3.39.5 Absorption Chillers Using LiBr/H_2O As The Working Fluid.

1.3.40 Municipalities: Industrial Combined Heat and Power

1.3.40.1 • High-efficiency Turbines Fueled by Gas, Biomass and Landfill Gas

1.3.40.2 High Temperature CHP

1.3.40.2.1 Used to Heat Process Feed

1.3.40.2.2 Uses Exhaust Heat in a Waste Heat Oil Heater

1.3.40.3 Topping Cycle Co-generation

1.3.40.4 Bottoming Cycle Co-generation

1.3.40.5 Super Heat Pumps with COPs Greater than Seven

1.3.40.6 Absorption Refrigeration

1.3.40.7 More Efficient Condensers and Evaporators, Expansion Valves, Motor Drives and Fan Controls.

1.3.41 Streetlighting, Water and Sewage Treatment (32)

1.3.41.1 High Pressure Sodium Vapor Streetlights (32)

1.3.41.2 Metal Halide Lamps (32)

1.3.41.3 Pipeline Twinning for Water Supply (32)

1.3.42 Municipalities: Heat Pumps/Heat Transformers

1.3.42.1 Vapour Compression

1.3.42.2 Mechanical Vapor Recompressors

1.3.42.3 Thermal Vapor Recompressors

1.3.42.4 Advanced Chemical Heat Pumps

2. TECHNOLOGIES TO REDUCE NON-ENERGY RELATED GHG EMISSIONS

2.1 INDUSTRIAL

2.1.1 Adipic Acid Production

2.1.1.1 Catalytic Reduction of Nitrous Oxide (5)

2.1.1.2 Conversion of Nitrous Oxide Back to Nitric Acid (Oxidation) (5)

2.1.2 Nitric Acid Production

2.1.2.1 Catalytic Reduction (5)

2.1.2.2 Thermal Reduction (5)

2.1.2.3 Change in Catalyst Precious Metal Content (5)

2.1.2.4 Post Reaction Heat Exchange System Changes (5)

2.1.3 Lime Production - Pulp and Paper Mills
- 2.1.3.1 Higher Efficiency Pulp Washing to Recover a Greater Amount of Pulping Chemicals (5)
- 2.1.3.2 Oxygen Injection in the Lime Kiln to Increase Efficiency (5)
- 2.1.3.3 Improved Process Control (5)
- 2.1.3.4 Ethanol Based Pulping (5)
- 2.1.3.5 Modified Continuous Cooking- MCC (5)
- 2.1.3.6 Oxygen Delignification (5)
- 2.1.3.7 Ozone Delignification (5)
- 2.1.3.8 Enzymes (5)
- 2.1.3.9 Closed -Cycle Bleached Kraft Mills (5)
- 2.1.3.10 Upgrading Mechanical Pulps (5)
- 2.1.3.11 Carbon Dioxide Use at Kraft Mills
  - 2.1.3.11.1 Manufacture of Calcium Carbonate (PCC) On-site (5)
  - 2.1.3.11.2 Brownstock Washing (5)
  - 2.1.3.11.3 Waste Water Neutralization (5)
  - 2.1.3.11.4 Neutralization of Alkaline Streams (5)
- 2.1.3.12 Paper Recycling and Deinking (5)

2.1.4 Lime Production - Portland Cement Manufacturing Plants
- 2.1.4.1 Blended Cements (20)
  - 2.1.4.1.1 Use of Coal Fly Ash in Cement (5)
  - 2.1.4.1.2 Use of Blast Furnace Slag (20)
  - 2.1.4.1.3 Other Pozzolanic Material (e.g. volcanic material) (20)
- 2.1.4.2 Sequestering CO_2 in Concrete (5)

2.1.5 Lime Production - Merchant Lime Producers
- 2.1.5.1 Sequestering and Disposition of Carbon Dioxide
  - 2.1.5.1.1 Sequestering CO2 in Carbonates (5)
  - 2.1.5.1.2 Sequestering CO2 in Cement (5)

2.1.6 Petrochemicals
- 2.1.6.1 NGLs and Crude Oil Feedstock Based Petrochemicals
  - 2.1.6.1.1 Anticoking Additives (5)
  - 2.1.6.1.2 Alternative Feedstocks (5)
  - 2.1.6.1.3 Loss Prevention and Other (5)

2.1.7 Aluminum Production
- 2.1.7.1 Inert Anodes (5)
- 2.1.7.2 Replacement with Prebake Anode Technology (5)
- 2.1.7.3 Improved Alumina Feed Process Control (5)
- 2.1.7.4 Point Feeder Systems (24)

2.1.8 Magnesium Production
- 2.1.8.1 Reducing Utilization Rate Through Improved Process Control (5)
  - 2.1.8.1.1 Gas Mixing Units (24)
  - 2.1.8.1.2 Desiccant Systems (24)
- 2.1.8.2 Replacement with Alternate Blanket Gas Component (5)
  - 2.1.8.2.1 SO2 (24)
- 2.1.8.3 Salt-based Fluxes (24)
- 2.1.8.4 Thixo-Molding for Die Casters (24)

2.1.9 SF6, PFCs and HFCs for Other Uses
2.1.9.1 SF6
2.1.9.1.1 Improved Recycling from Electrical Switchgear (5)
2.1.9.1.2 Air or Vacuum Insulated Circuit Breakers in Switchgear (5)
2.1.9.2 PFCs
2.1.9.2.1 Substitution - Hydrofluoroethers (HFEs) (5)
2.1.9.2.2 Capture and Recycling (5)
2.1.9.3 HFCs
2.1.9.3.1 Other HFCs (5)
2.1.9.3.2 Hydrocarbons (5)
2.1.9.3.3 Ammonia (5)
2.1.9.3.4 Carbon Dioxide (5)
2.1.9.3.5 Water/Zeolite Adsorption Systems (5)
2.1.9.3.6 Stirling Cycle (5)
2.1.9.3.7 Air Cycle Systems (5)
2.1.10 Hydrogen Reduction of Metal Oxide Ores (2)
2.1.11 N2O Reduction from Nylon Production (2)
2.2 AGRICULTURE
2.2.1 Livestock - Enteric Fermentation
2.2.1.1 Improved Cow-Calf Productivity (5)
2.2.1.1.1 Feed Supplements (11)
2.2.1.1.2 Estrus Synchronization (11)
2.2.1.2 Improve Animal Genetics and Fertility (2)
2.2.1.2.1 Transgenic Manipulation (10)
2.2.1.2.2 Twinning (10)
2.2.1.2.3 Defaunation (10)
2.2.1.2.4 Embryo Transplant (10)
2.2.1.2.5 Artificial Insemination/Estrus Synchronization (10)
2.2.1.2.6 Bioengineering of Rumen Microbes (10)
2.2.1.2.7 Inducement of Acetogenic Bacteria Population in the Rumen (25)
2.2.1.3 Increased Nutrition/Strategic Supplementation (1)
2.2.1.3.1 Probiotic Feed Additives (11)
2.2.1.3.2 Amino Acid Feed Additives (11)
2.2.1.3.3 Molasses/Urea Multinutrient Blocks (10)
2.2.1.3.4 Molasses/Urea Blocks with Bypass Protein (10)
2.2.1.3.5 Targeted Mineral/Protein Supplements (10)
2.2.1.3.6 Use of Escape Protein (25)
2.2.1.3.7 Lipid Addition (25)
2.2.1.3.8 High Grain Diets (25)
2.2.1.3.9 Fibrolytic Enzymes (25)
2.2.1.4 Production-Enhancing Agents (1)
2.2.1.4.1 Bovine Somatotropin (10)
2.2.1.4.2 Anabolic Steroid Implants (10)
2.2.1.4.3 Ionophores (11)
2.2.1.4.4 Better Ration Balancing (11)
2.2.1.4.5 Antibiotics (22)
2.2.1.4.6 Bovine Somatotrophin (25)
2.2.2 Livestock Manure
2.2.2.1 Covered Lagoons (5)
2.2.2.2 Large Scale Digesters (5)
2.2.2.2.1 Plug Flow Digesters (5)
2.2.2.2.2 Complete Mix Digesters (5)

2.2.2.3 Small Scale Digesters (5)
2.2.2.3.1 Floating Gas Holders (5)
2.2.2.3.2 Flexible Bag Holders (5)
2.2.2.3.3 Fixed Dome (5)
2.2.2.4 Centralized Digesters (11)
2.2.2.5 Slurry Digesters (5)
2.2.2.6 Mesophilic Anaerobic Digesters (5)
2.2.2.7 Thermophillic Anaerobic Digesters (22)
2.2.2.8 Constructed Wetlands (5)
2.2.2.9 Solid Manure Management Systems (11)
2.2.2.9.1 Aerobic Composting (5)
2.2.2.9.2 Daily Spread (11)
2.2.2.9.3 Incineration (11)
2.2.2.9.4 Batch Aerobic Composter
2.2.2.9.5 Enhanced Moisture Aerobic Compost System
2.2.2.9.6 Continuous Vertical Aerobic Composting
2.2.2.10 Bioreactors (5)

2.2.3 Fertilizers

2.2.3.1 Biotechnology
2.2.3.2 Fertilizer Management Practices (5)
2.2.3.2.1 Test Soil (22)
2.2.3.2.2 Time Fertilizer Applications (22)
2.2.3.2.2.1 Air Seeders
2.2.3.2.3 Use Advanced Fertilization Techniques (22)
2.2.3.2.3.1 Controlled Release Fertilizers (22)
2.2.3.3 Nitrification Inhibitors (5)
2.2.3.3.1 Nitrapyrin (22)
2.2.3.3.2 Acetylene (22)
2.2.3.4 Irrigation Water Management (5)
2.2.3.5 Organic Farming (5)
2.2.3.6 Substitution Among Fertilizers (5)
2.2.3.6.1 Switch From Using Anhydrous Ammonia (25)
2.2.3.7 Reduction in Use of Nitrogen Fertilizer(1)
2.2.3.8 Modified Rhizobium (22)

2.2.4 Biomass Burning (10)

2.2.4.1 Improving the Efficiency of Biomass as a Fuel (10)
2.2.4.1.1 Efficient Biomass Cook Stoves (10)
2.2.4.1.2 High Efficiency Gasifiers for Crop Residues (10)

2.3 WASTE MANAGEMENT

2.3.1 Landfills

2.3.1.1 Methane Gas Recovery
2.3.1.1.1 Vertical Recovery Wells (10)
2.3.1.1.2 Horizontal Trenches (11)
2.3.1.1.3 Collection Header Systems (11)
2.3.1.1.4 Motor/Blower Vacuum Unit (11)
2.3.1.2 Flaring
2.3.1.2.1 Open Flare Combustors (11)
2.3.1.2.1.1 Candle Flares (11)
2.3.1.2.1.2 Pipe Flares (11)
2.3.1.2.2 Enclosed Combustors (11)

2.3.1.3 Methane Utilization
2.3.1.3.1 Electric Power Generation
2.3.1.3.1.1 Internal Combustion, Reciprocating Engines (11)
2.3.1.3.1.2 Turbines (11)
2.3.1.3.1.3 Rankine Cycle (Steam) Engines (11)
2.3.1.3.1.4 Combined Cycle Combustion Turbines
2.3.1.3.2 Gas Delivery Systems (11)
2.3.1.3.2.1 Sale as a Medium BTU Fuel (11)
2.3.1.3.2.2 Sale as a High BTU Fuel (11)
2.3.1.3.3 Production of Liquid Fuels and Industrial Chemicals (11)
2.3.1.4 Aerobic Landfill Management
2.3.1.4.1 Semi-Aerobic Landfills (10)
2.3.1.4.2 Recirculatory Semi-Aerobic Landfills (10)
2.3.1.4.3 Aerobic Landfills (10)
2.3.2 Wastewater Management (10)
2.3.2.1 Aerobic Primary Treatment (10)
2.3.2.1.1 Oxidation Ponds (10)
2.3.2.1.2 Primary Ponds (10)
2.3.2.1.3 Mechanical Aeration (10)
2.3.2.2 Aerobic Secondary Treatment (10)
2.3.2.2.1 Mechanical Aeration (10)
2.3.2.2.2 Fixed Bed or Rotating Cylinder (10)

3. MANAGEMENT OF CARBON DIOXIDE EMISSIONS

3.1 CARBON DIOXIDE CAPTURE
3.1.1 Carbon Absorption (3)
3.1.1.1 Chemical (3)
3.1.1.1.1 Monoethanolamine (MEA) (3)
3.1.1.1.2 Diethanolamine (DEA) (3)
3.1.1.1.3 Hot Potassium Carbonate (3)
3.1.1.2 Physical (3)
3.1.1.2.1 Selexol (dimethylether of polyethylene glycol) (3)
3.1.1.2.2 Rectisol (cold methanol) (3)
3.1.1.3 Hybrid (3)
3.1.1.3.1 Purisol (3)
3.1.1.3.2 Sulfinol (3)
3.1.1.3.3 UCARSOL (3)
3.1.2 Carbon Adsorption Technologies (3)
3.1.2.1 Pressure Swing Adsorption (3)
3.1.2.2 Temperature Swing Adsorption (3)
3.1.2.3 Stream or Fluid Adsorption (3)
3.1.2.4 Chromatographic Adsorption (3)
3.1.3 Cryogenics Technologies (3)
3.1.4 Membrane Technologies (3)
3.1.4.1 Gas Separation Membranes (3)
3.1.4.2 Gas Absorption Membranes (3)
3.1.5 Coal Gasification and Reforming of Synthesis Gas (2)
3.2 CARBON SEQUESTRATION
3.2.1 Advanced Chemical and Biological Conversion/Sequestration
3.2.1.1 Chemical Sequestration as Mineral Carbonate
3.2.1.2 Micro Algae Sequestration
3.2.1.3 Direct Solar Conversion of CO2 to Methanol
3.2.1.4 Advanced Conversion of Coal to Hydrogen

3.2.2 Terrestrial Storage of CO2
3.2.2.1 Drilling, Stimulation and Completion of Injection Wells
3.2.2.2 Processing, Compression and Pipeline Transport of the CO2
3.2.2.3 Subsurface Reservoir Engineering and Characterization
3.2.2.4 Storage in Saline Aquifers.
3.2.3 Elemental Carbon Sequestration
3.2.3.1 High Temperature Reactors
3.2.3.2 Molten Metal Reactors
3.2.3.3 Particulate Removal From Gas Streams
3.2.4 Carbon Sequestration in Biomass
3.2.4.1 Management Practices
3.2.4.1.1 Reforestation/Afforestation and Prevention of Deforestation (1)
3.2.4.1.2 Increasing Efficiency/Intensity of Forest Management (1)
3.2.4.1.3 CO2 Sequestration in Long-Term Forest Plantations (7)
3.2.4.1.4 Increasing Agroforestry Endeavours (1)
3.2.4.1.5 Reduce Slash and Burn Agriculture/Ranching (2)
3.2.4.1.6 Management of Logging Residues and By-Products (5)
3.2.4.1.7 Reduced Impact Logging (5)
3.2.4.2 Fossil Fuel Displacement
3.2.4.2.1 Urban Forestry (5)
3.2.4.2.2 Substitution of Fossil Fuels with Sustainably-Grown Fuelwood (1)
3.2.4.2.3 Bioelectricity Production from Wasteland and Degraded Lands (2)
3.2.4.2.4 Short Rotation Cropping to Produce a Woodchip Fuel for Power Generation (7)
3.2.4.2.5 Substitute Sustainably Grown Wood for Non-Sustainably Harvested Wood and for Non-Wood Products (e.g. cement, steel) (2)
3.2.4.2.6 Increase Field and Satellite Monitoring (2)
3.2.4.2.7 Improve Boundary Measures (2)
3.2.4.3 Demand Side Management
3.2.4.3.1 Demand Side Management: Improved Stoves (2)
3.2.4.3.2 Demand Side Management: Charcoal Kilns (2)
3.2.5 Soil Sequestration (16)
3.3 CARBON DIOXIDE STORAGE/DISPOSAL
3.3.1 Deep Ocean Storage and Fertilization to Promote CO_2 Sequestration
3.3.1.1 Production of Solid CO2 (Dry Ice) (6)
3.3.1.2 Nitrogen Enrichment
3.3.1.3 Deep Ocean engineering
3.3.1.4 Land Based Pipe (15)
3.3.1.5 Moving Ship (15)
3.3.1.6 Vertical Pipe from Stationary Structure (15)
3.3.2 Disposal in Exhausted Oil Reservoirs (6)
3.3.3 Disposal in Exhausted Gas Reservoirs (6)
3.3.4 Disposal in Deep Aquifers (6)
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3.4 CARBON DIOXIDE USES

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PROFILES OF THE PROMISING ILLUSTRATIVE TECHNOLOGIES

ENABLING/CROSS-CUTTING TECHNOLOGIES

NATURAL GAS PIPELINES

Issue

Methane is emitted as a result of a number of activities during the transportation of natural gas to market. One of the largest contributions comes from fugitive and engineered emissions from compressors and related facilities. Other emissions occur from purging of lines, during construction and maintenance activities.

Technological Overview and Status

Hot tapping is a specialized technique that reduces methane emissions which occur when new pipe is connected to an in-service pipeline at or near full line pressure.

Research has been underway in the last few years to develop new and improved methane emission detection technologies for detecting fugitive emissions associated with transmission and distribution systems. Innovative sensors include optical fibre, digital sonar, and laser devices.

Work is underway to design and engineer pipelines that will increase flow efficiency, thereby reducing compression requirements and potential leaks, and inhibit corrosion, preventing catastrophic failure. Advances in welding methods and pipe material also have the potential to minimize methane emissions. The development and application of high-strength steels (X100 and more) in natural gas pipelines will increase considerably the efficiency of transportation.

The development of no-bleed and low-bleed pneumatic instruments means that it is possible to reduce the fugitive emissions associated with pneumatic devices that are used in gate stations to regulate the flow and pressure of natural gas throughout the distribution network.

Inspection of pipelines is an area of additional research. As pipelines age it becomes important to detect defects during pipeline operation. This area of defect detection and sizing, and with current environmental sensitivities and concern for public safety, continues to be an area of emphasis.

Timeframe to Commercialization: short and medium term (now to 2012).

Canadian Innovation Capacity

The oil and gas industry is international and so too are the suppliers of technology to the industry. In general, a majority of the technological requirements of Canadian gas operations are met by American or British suppliers. Some Canadian companies are involved in developing technologies, e.g. Argus Machine Company Ltd. (specialized pig valves) and TransCanada PipeLines (system to manage fugitive emissions, hot tapping procedures, aligned roughness instrument).

Co-operative research in Canada is currently carried out by NRCan (Mineral and Metals Sector), the University of Victoria, the Canadian Gas Association, and funding from PERD.

Market Potential

There should be a large market for technologies to reduce emissions from natural gas pipelines. Currently, worldwide methane emissions from natural gas transmission and storage systems add up to 18.2 Mt/yr (38% of total methane emissions in the oil and gas industry), but these could technically be reduced to 2.9 Mt/yr. Also, consumption of natural gas is expected to increase due to its relatively low GHG emissions.

Barriers to Commercial Opportunities

- Economic barriers, and to a lesser extent, technical barriers limit the pace and magnitude of the penetration of emission reducing technologies in natural gas distribution.
- Deregulation of the natural gas industry has resulted in an unbundling of the transportation and marketing roles of local distribution companies which could diminish the incentive of local distributors to invest in the development of new technologies to reduce GHG emissions.
- Implementing system-wide leak detection and repair programs will be hampered by the vast number of potential sources and the geographic area that needs to be considered. Only cost-effective measurement and quantification methodologies that have limited reliance on field resources will be considered attractive.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>
- More coordination of and support for RD&D into high strength steels, leak detection, flow efficiency increases, hot tapping and higher efficiency measures.

<u>Commercialization, Demonstration</u>
- Funding and manpower made available for demonstrations and to minimize operations disturbance.

Business Climate
- Reduce cost/risk associated with new technologies.

System Linkages
- Create partnerships between pipeline companies, research collaboratives and suppliers such as steel and coating specialists. Encourage suppliers and users to identify solutions (like GRI Canada, BGTechnology Petroleum Technology Alliance Canada (PTAC)).

Market Linkages
- Encourage maintenance suppliers to use new technologies.

Human Resources
- Training programs for personnel applying new technologies.

Funds Required: $10 million per year.

PROCESS TECHNOLOGIES RELATED TO ENERGY AND CARBON PROCESSING EFFICIENCY

Issue

Canadian crude oil production occurs in the Western Canadian Sedimentary Basin (WCSB) as well as in the frontiers (east coast offshore) and in south western Ontario. The source of the oil varies from light sweet or sour crude, heavy oil, crude bitumen and oil sands. Each of the oil products has its own unique production and energy use issues. Several technologies have been identified that can reduce energy use or improve well productivity and are given below.

Technological Overview and Status

Downhole separation technology for oil/water is used today to reduce the large volumes of water typically brought to the surface of aging oil wells and to lower the costs associated with corrosion, water disposal and energy consumption. This technology is at the demonstration stage

Rodless screw pump technology accelerates production volumes and eliminates failures and hazards associated with traditional surface pumps. It also helps to substantially lower operating costs and increase recoveries, particularly for heavy oil. This technology is being commercialized.

Thermal gravity processes and steam assisted gravity drainage can be applied to the in-situ recovery of heavy oil and oil sands. These technologies are varied between demonstration and commercialization, but much more work needs to be done to lower the energy and carbon intensity of production.

Solvent processes could become a primary recovery process, or be used as a follow-up process in pressure-depleted reservoirs. For instance, CO_2 can be used as a solvent to overcome forces that trap oil in tiny rock pores and it helps sweep the immobile oil that has been left behind after the effectiveness of water injection falls off. This work is very much at the R&D stage and requires inexpensive sources of high purity CO_2.

Several other techniques and production strategies have been proposed to improve oil recovery from bottomwater reservoirs. Horizontal wells have been drilled to produce heavy to-medium gravity oil from bottomwater reservoirs. While drilling of horizontal wells have been optimized, production optimazation RD&D still has a lot of potential. Anti-Water-Coning Technology (AWACT) involves the injection of a gas (methane in most cases) to reduce the effective permeability of water during the production phase. The injection of a polymer slug can improve waterflood efficiency.

Membrane separation technology has potential for energy savings in general separation using membranes compared with distillation. Synergy between upgrading technology and gas to liquids technology would offer an opportunity for reduction of CO_2 emissions and the production of cleaner fuels.

The oilsands have already announced significant energy reduction process changes (shovel and truck mining, cold water extraction) and are continuing to work on new opportunities.

Timeframe to Commercialization: short and medium term (now to 2012).

Canadian Innovation Capacity

Technology development for conventional and heavy oil is focussed through individual companies as well as through Petroleum Technology Alliance Canada (PTAC). Research, development and demonstration on use of CO_2 for enhanced oil recovery has dropped to minimal effort and may require some initiative from government and associations to stimulate renewal of this work.

Several research and governmental organizations are involved in the development of in-situ process technologies, e.g. the Alberta Research Council's (ARC) Heavy Oil and Oils Sands group, the Alberta Department of Energy, the NCUT (National Centre for Upgrading Technology), the Canadian Heavy Oil Association, the University of Alberta and the University of Saskatoon, CONRAD, Petroleum Technology Alliance Canada, and CANMET (Western Research Centre, Advanced Technologies for Process Optimization and Control).

Canadian companies involved in the area of the development of in-situ process technologies for oil recovery include (but are not limited to):

- Suncor Energy Inc., e.g. bitumen extraction and cleaning;
- Colt Engineering, e.g. design and construction of technology for treating primary and thermally produced oil.

Market Potential

The potential exists to use new and developing oil recovery technologies, partly due to the large number of oil fields that have been abandoned world-wide (due to high operating costs and low oil prices). Once the "marginal" fields are abandoned, they are expensive to reopen -- rendering any remaining oil inaccessible because costs of recovery are equal to or greater than expected profits. There is reported to be an increasing number of abandoned fields than have substantial amounts of potentially recoverable oil.

Barriers to Commercial Opportunities

The economics of production does not favour using some enhanced oil recovery methods when the price of oil is below US$20/barrel.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure

- More R&D required, particularly for liquid/liquid, gas/gas, gas/liquid separation, process simulation and modeling.
- Improve operational knowledge of geological formations.

Commercialization, Demonstration

- Support for pilot and demonstration projects.

Business Climate

- Reduce cost of technologies, improve access to finance, and lower corporate risk.

System Linkages

- Require improved and more industry consortia.

Market Linkages

- Need to be closer to market and take into account refiner/upgrader concerns.

Human Resources

- Training programs for personnel employing new technologies.

Funds Required: $10 million per year.

REDUCE OR USE FUGITIVE GAS EMISSIONS FROM FOSSIL FUEL PRODUCTION

Issue

Technologies are being developed to reduce or use greenhouse gas emissions (methane in particular) escaping to the atmosphere during the production and transmission of fossil fuels. Addressing fugitives in a cost effective manner in the upstream oil and gas sector is complicated by sources being a myriad of small volume, low pressure leaks usually at unmanned facilities.

Technological Overview and Status

Upstream Oil and Gas

Most of the emissions from the upstream oil and gas industry are due to the venting or leaking of associated gas. To reduce emissions where there is no natural gas infrastructure, the gas must be re-injected or flared rather than vented. Mechanical energy (e.g. through a piston) can be extracted from inherent well-site gas pressure instead of venting the gas to the atmosphere if volume and quality of gas are . Where gas is flared, efficient flaring reduces methane emissions by a significant amount compared with venting. However, flaring may have a poor combustion efficiency (as low as 70%) resulting in emissions of incompletely combusted hydrocarbons including methane. Methane can also be used as a fuel for mini-turbines or internal combustion engines for power generation. [Re-injection of gas into the oil field produces lower emissions and may even enhance oil production].

Emissions from natural gas production facilities can be reduced using alternative operating and maintenance procedures, for example:

- High pressure separating systems used in the production stage allow well operators to re-enter existing wells, re-complete, stimulate and clean them up, while still producing gas for the processing facility without gas flaring or venting.
- Improvements in the accuracy and durability of downhole pressure and temperature gauge technology decrease the need for rig maintenance and venting gas.
- Use of coiled tubing results in less venting to atmosphere to “dewater” shallow gaswells.

There may be opportunities to implement cost-effective leak detection and repair programs in the upstream oil and gas industry. A study is to be conducted in the summer of 1999 by CAPP and the Gas Research Institute.

Underground Coal Mining

The easiest option for tackling emissions from underground coal mining operations is to either remove as much methane as possible prior to mining or capture the methane as it is released, during and after coal production. Methane removed directly from coal beds is generally of high purity, particularly where it is recovered from seams which have never previously been mined. In many cases it could be supplied directly to a natural gas distribution system if convenient. In other cases, it could be used for power generation, heating or sold to third parties. Methane drained from the coal during or after production, on the other hand, is of very variable quality and current technologies only capture about 25% of emissions. Moreover, much of the captured methane is vented or flared, with only about 10% of total emissions being utilized. Because of the large proportion of the emissions which is exhausted in the ventilation air, methane recovery or destruction technologies are being considered. Technology improvements in this area are expected which will allow oxidation of low concentrations of methane; with heat recovery for power generation, net costs should be small.

Timeframe to Commercialization: short and medium term (now to 2012).

Canadian Innovation Capacity

The fossil fuel industry is international and so too are the suppliers of technology to the industry. In general, a majority of the technological requirements of Canadian fossil fuel operations are met by American suppliers. Some Canadian companies are playing a role in developing and/or manufacturing fugitive emission reduction technologies in the upstream oil and gas sector (e.g. Sunada Technology Corporation, Central Production Testing, MJBlair Corporation, and the Mercury Electric Corporation).

Canadian co-operative research programs in this field are carried out by CANMET's Combustion Research Laboratory, CONRAD, and PTAC. The federal government's CANMET Energy Technology Centre is involved in related research involving ceramic membranes that will be used to produce liquid fuels. CANMET's Energy Diversification Research Laboratory is developing a flow reversal catalytic reactor for the conversion of methane gas from coal mines.

Market Potential

The market potential of technologies to reduce or use fugitive emissions from fossil fuel extraction will depend on the value of reducing greenhouse gas (GHG) emissions and the extent it can help in reducing operation and maintenance costs.

Barriers to Commercial Opportunities

- Economic barriers, and to a lesser extent, technical barriers limit the pace and magnitude of the penetration of emission reducing technologies in the fossil fuel industries.
- The introduction of mini-turbines to generate electricity from flare gas may be hampered by regulatory restrictions to sell the power off-site.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure
- Technology development to lower costs.
- R&D program to develop efficient flaring, and capture and utilization of energy in flare.

Commercialization, Demonstration
- Pilot and demonstration plant support required.

Business Climate
- Further deregulation of electricity sector may help on-site micro-turbine electricity generation using flare gas as the fuel source.

System Linkages
- Communicate successes and failures.

Market Linkages

Human Resources
- Specialized training required for operators of new technologies and processes.

Funds Required: $5 million per year.

TECHNOLOGIES FOR INCREASED NATURAL GAS SUPPLY

Issue

Currently Canada produces 6 TCF of conventional natural gas annually. The development of 3-D seismic, advanced drilling, completion, and stimulation technologies will help to increase the overall profitability of exploration and production of both conventional and non-conventional natural gas resources. Research, development and demonstration of technologies are suggested to provide better recovery, lower operating costs and improved energy intensity in conventional gas production. Significant resources (>200TCF in Canada) are locked away in geologically complex formations that necessitate deeper drilling and/or production under severe conditions.

Technological Overview and Status

Conventional natural gas production

Existing conventional natural gas reservoirs have the potential to provide additional gas supply into the future if a number of considerations are studied. Use of horizontal drilling and new completion techniques to enhance recovery from reservoirs, technologies to repressure reservoirs using water or other fluids (similar to enhanced oil recovery) and improved geophysical techniques are examples. Work being done in the San Juan basin in the U.S. is probably the state of the art. Improved pipeline design and construction technologies (similar to the Alliance project now under way) could contribute to lower transportation costs and allow economic access to conventional natural gas reserves in areas of Canada that production is currently not economic.

Non-conventional natural gas production

Large continuous gas accumulations are present in tight reservoirs rocks, such as low-permeability sandstones, gas shales, coal and chalk. The gas deposits require stimulation to be produced economically. For instance, in shale formations, natural gas producers often inject nitrogen and aqueous foam under intense pressure to fracture the rock, creating pathways for gas to flow. However, water in the foam causes clay in the shales to swell, and the formation can eventually plug, throttling the flow of hydrocarbons. A relatively new technology, CO_2-sand fracturing, offers an alternative to conventional aqueous foam. It provides enough force to create long, propped fractures, and the absence of water or oil-based fluids offers a near damage-free way to enhance oil and gas production. For near-wellbore damage, propellant stimulation uses instantaneously created high pressures of CO_2 (30,000 psi in a 1 sec event) to clean out the damage and create minifracs.

In coalbed methane (CBM), production enhancement is also be tested by injection of CO_2 and N_2. CO_2 adsorbs to the coal replacing the methane while N_2 lowers the partial pressure of methane in the cleats by driving it to the production well. Enhancement factors greater than 3 have been observed in field tests but the technology is not yet economic.

New approaches are being developed for locating and evaluating fractured areas in tight gas reservoirs. Some efforts have focused on: geologic field characterization, well analysis and *in situ* stress analysis; optimized geophysical detection of fractures; and low-permeability reservoir modelling. Successful technologies include high resolution aeromagnetic and 3-D seismic surveys.

Production technologies for the exploitation of natural gas hydrates are not tested but aim to alter the thermodynamic conditions in the hydrate stability zone such that the gas hydrate decomposes. There are three approaches which are being tested at the lab scale: depressuration, thermal stimulation and chemical destabilation by lowering the activity of water (e.g. introduction of a brine).

Timeframe to Commercialization: tight sands and coalbed methane – short, gas shales – medium, natural gas hydrates – long.

Canadian Innovation Capabilities

Natural gas hydrate research is being carried out by the Geological survey of Canada. University of Calgary has expertise in 3-D Seismic work. Canadian Fracmaster has a patent on CO_2 Fracing. (research into 'tight gas' unknown). Computalog developed propellant stimulation. A number of Canadian companies are expert in underbalanced drilling, coiled tubing drilling and horizontal drilling. The 4 largest natural gas producers in Canada are Amoco, Petro-Canada, PanCanadian, and Alberta Energy.

Market Potential

The ability of the conventional natural gas resource base to meet the world's growing supply needs is limited by the fact that a substantial portion of it is not located close to major and developing gas markets and would therefore require enormous investments in pipelines and other facilities to move the gas to market. The huge volumes of non-conventional natural gas resources is therefore an attractive alternative source of supply. In the long term, gas hydrates are either known or expected to exist in a relatively concentrated form at numerous locations and large deposits are located near expected demand growth areas (e.g. Nova Scotia). In the short term, large reservoirs of coalbed methane exist in the Plains area of the Alberta basin.

Barriers to Commercial Opportunities

Historically, tight reservoirs have been uneconomical sources of gas because of low natural flow rates. However, gas is now being recovered from the better quality tight reservoirs, especially the relatively continuous blanket-type sandstones that have been stimulated by massive hydraulic fracturing. Both shale gas and coalbed methane are being produced commercially in the US. Adequate conventional gas supply and low pipeline capacity are reasons for lack of interest in unconventional gas production in Alberta.

Significant safety and environmental concerns are also associated with the exploitation of natural gas hydrates, ranging from their possible impact on the safety of conventional drilling operations to greenhouse gas impacts.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>

- Considerable research is needed to characterize more completely and accurately the location, composition, and geology of the natural gas deposits and to provide new technologies for production.

<u>Business Climate</u>

- Access to natural gas market (planned pipelines).
- Tax credit to stimulate non-conventional gas production (US experience can be used as a guideline)

<u>Market Linkages</u>

- Requirement for natural gas in fueling new power plants

Funds Required: $10 million/year (50% Govt – 50% Industry) for 25 years. Currently very low level of research – $1 million/year ??

ELECTRICITY FROM CO_2-FREE/RENEWABLE SOURCES

Issue

Small scale hydro, wind power and photovoltaics (PV) use renewable energy to generate electricity without CO_2 emissions. These are highly sustainable options, and their expanded implementation results in a decreased need for fossil fuel generated, GHG related electricity. These technologies also lend themselves to more distributed generation, which can reduce the losses/emissions associated with long distance transmission. To varying degrees, all three technologies have a common drawback. They are not consistently available

Technological Overview and Status

Small scale hydro is a mature renewable electrical power generation technology based on the water height differentials in rivers. The most abundant type of installed small scale hydro is ‘run-of-river’ hydro plants, which only use the natural flow of the river. Other hydroelectric plants have dams and water reservoirs to provide storage and power on demand. There is no firm size cut-off for small hydro, but the following is based on installations from a few kW (micro hydro) up to 15 MW.

Wind turbines capture the energy of moving air to generate electricity. Various configurations have been tried. The most successful are of the horizontal-axis variety, with a 3 blade rotor, gearbox and electrical generator. All of this equipment is mounted on top of a tower. Wind turbine installations can range from a single unit of less than one hundred watts supplying a single small load to a ‘wind farm’ of several large units, each up to 750 kW, whose electricity is fed into the utility grid and distributed.

Photovoltaics (PV) uses solid-state semiconductor devices to convert sunlight into direct-current (DC) electricity. This electricity can be used directly, stored in batteries for later use, converted to AC for use or delivery to the utility grid, or various combination of these. By linking together the appropriate number of PV modules, systems of varying peak generating capacity can be assembled. The dominant form of PV technology in today’s marketplace is based on crystalline silicon. It is the material of choice for high-performance and reliability, and while it is not cost effective now, it could be in the 2020 – 2030 timeframe.

Timeframe to Commercialization: short term (before 2008).

Canadian Innovation Capabilities

There are 5 manufacturers of microhydro generating equipment in Canada while there are more than 10 Canadian manufacturers of mini-hydro and small-hydro generating equipment. In addition, it has been estimated that there are approximately 20 Canadian developers and 50 engineering firms involved in small hydro projects. With respect to R & D, CETC’s Small Hydro Program is assisting Canadian manufacturers in the development of ultra low-head hydro turbines and digital automatic control systems. These products have been sold to international markets, including China and Poland. There is an operating small hydro turbine testing laboratory at Laval University.

In Canada, the supply of wind power technology is provided by a few small companies that design and develop wind systems. Wenvor-Vergnet Canada (Guelph, Ontario) is manufacturing in Canada 25 kW wind turbines for grid-connected and stand-alone applications and it is planning to expend its production line in the future, to include 10 kW and 60 kW turbines. Polymarin Huron Composites (Huron Park, Ontario) is a medium size company manufacturing blades for all sizes of wind turbines. There is only one large-scale wind turbine manufacturer in Canada, NEG-Micon in Boucherville, which has begun production of 750KW turbines and has delivered its first order of 23 units to the U.S. market. With respect to R&D, the Canadian Wind Energy Research and Development (WERD) Program is coordinated by Natural Resources Canada's CANMET Energy Technology Centre in Ottawa. There are a number of operating wind test and pilot project sites in Canada. The Atlantic Wind Test Sites (AWTS) are located in North Cape, PEI. An INRS-énergie group is working on combining wind with hydraulic storage in reservoirs. The Québec Natural Resources ministry has initiated a detailed inventory of windfarm sites in the Gaspé peninsula and the lower north shore of the Saint Lawrence.

Photovoltaic production in Canada has recently undergone some consolidation and at least one globally competitive Canadian company, ATS has invested in Photovoltaics. During the last four years, Canrom Photovoltaics (Hamilton, Ontario) purchased all production equipment of Silonex, Darentek, Astropower Canada, and GPS (U.S.) and presently is the only Canadian company manufacturing PV solar modules in Canada. However, ATS (Automated Tooling Systems) of Cambridge Ontario has purchased Photowatt, a French solar cell and module manufacturer in 1997. Since then, they have increased the production of the French plant by a factor of five, making it the fourth largest PV company. They are now manufacturing in Canada equipment to automate their plant and are planning to commercialize their manufacturing equipment globally. They are also conducting a competitive analysis to locate a module assembly plant, most likely in Canada, to service the North American market. The CANMET Energy Diversification Research Laboratory (CEDRL) has a Photovoltaic Program focused on the development and implementation of photovoltaic technologies in domestic and international markets. The laboratory is equipped with state-of-the-art test facilities to assist clients conducting R&D or technology evaluations. The National Solar Test Facility (NSTF) at ORTECH has world class testing and solar simulation capability.

Market Potential

In Canada, there is currently about 1,200 MW of installed small hydro capacity, with annual additions currently in the range 75-100 MW worth $150-$200 million. Globally, the current installed capacity is believed to be in the 25,000-35,000 MW range. Global small hydro capacity is expected to increase by 1,000 to 2,000 MW annually for the next 25 years, requiring an investment of $2-4 billion per year. A large portion of this potential lies in developing countries and will serve as a major renewable energy source for rural electrification. There is significant opportunity for upgrading and refurbishment of existing small hydro plants worldwide. Wind is the world's fastest growing energy source. In 1997, there was about 23 MW of installed wind energy capacity in Canada. In 1992, EMR the technical potential for wind in Canada to be

28,000 MW. Wind power development in Canada had been less aggressive than elsewhere, but has picked up recently. In the largest initiative, Hydro-Québec began operating a 2.25 MW pilot project at Saint-Ulric-de-Matane in 1998, and is implementing the100 MW Le Nordais wind farm in Gaspésie which will provide up to 5% of the Gaspé and lower St. Lawrence electricity needs. Alberta is now also seeing significant new wind development. Global installed capacity has tripled in three years and, with the addition of 2,100 MW worth $3 billion in 1998, reached 9,600 MW. The bulk of this growth has been in Europe and made possible through government incentives or directives. The US has also had significant growth, with 235 MW added in 1998, bringing total capacity to over 1800 MW. A large market may exist in many developing countries in the coming years. The Canadian wind industry has been successful in exporting about $30 million worth of components over the past 5 years.

Millions of PV systems have been installed world-wide in niche applications. Worldwide module sales in 1998 are estimated to be about 160 MW, or about US$ 600M worth for modules and over a billion dollars (US) for PV systems. This market is growing at a rate between 15% and 20% every year. This strong growth rate is expected to continue, in part benefiting from favourable government policies in many countries. PV has the greatest immediate potential in developing countries, where sizeable populations are beyond reach of the electricity grid and cheap alternative energy supplies. Unlike hydro or wind power, large-scale centralized PV power generation is not expected to reach competitiveness for perhaps another 20 years but PV integrated in the built environment will gradually penetrate high value markets such as Japan and sun belt countries. In Canada, there have been some larger demo installations at grid connected sites, but commercial installations are generally smaller niche applications (emergency phones, data gathering, small residential, etc.) at off-grid locations.

Barriers to Commercial Opportunities

The main non-technical barriers to further development of renewables like small hydro, wind, and PV are financial and institutional. Renewables have higher financing costs and/or small project sizes, making it difficult to use traditional financing techniques. Bankers may also be reluctant to invest in new technologies, technologies whose power source is uncertain or intermittent, or technologies supported by certain government incentive programs. In some jurisdictions, renewable energy technologies may not be permitted to sell power to the electricity grid.

Current research is aimed to bring down further the cost of renewable energy technologies. For example, new ultra low-head hydro turbines provide economic application in irrigation and navigation canal systems, and automatic control systems provide remote operation of micro/mino hydro and diesel plants. There is scope to improve the economics of wind energy technologies, such as increasing the size of the turbines through new blade materials, improving control and gearing systems, and more mass production of smaller systems. As well, direct drive, variable speed generators and higher towers, will contribute to improved reliability and better performance. For solar, the cost of producing silicon-based modules continues to be a major limiting factor in market penetration. Recent research efforts have focused on automation of manufacturing, on alternative materials as well as on less expensive means of producing solar-grade silicon.

For wind and PV, energy intermittence is a major challenge when there is no grid connection. There is little scope to reduce the cost of batteries/storage, which forms a major expense. However, there is an opportunity for integrating small hydro with wind and PV to match the load demand.

Some environmental challenges exist for renewables. Some technologies are being developed to reduce these problems, e.g. fish-friendly design of advanced hydro turbines and by-pass or acoustic systems to deter fish in hydro schemes, noise reduction for wind turbines, and disposal methods for materials used in PV modules.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure

- Greater knowledge required of environmental impacts of renewable energy. Developing appropriate technologies for the Canadian climate. Developing manufacturing techniques.

Commercialization, Demonstration

- Required for ultra low-head, fish-friendly design of small hydro, renewable/conventional hybrid technologies, and as other technology developments occur.

Business Climate

- Various government incentives could help promote renewable energy technologies, targeting capital costs or production. These could be in the form of tax incentives or subsidies. Alternatively, renewable energy technologies could be promoted by penalizing less clean forms of electricity production. Deregulation may help the development of some renewable energy projects and access to electricity grids.
- Need global restructuring of electricity sector to facilitate utility grid access

System Linkages

- Need to engage utilities to make them more receptive. Integration of different renewable energy systems with total energy systems for communities should be promoted.

Market Linkages

- Need to support networking opportunities between suppliers and users
- More information and awareness
- Expanded international marketing efforts.

Human Resources

- Engineering course for electricity from renewables, including environmental engineering and numerical simulation
- Training on automatic control and on-site turbine performance testing

Funds Required: $20 million per year for 5 years, split between government and industry.

BIOMASS COMBUSTION TO ELECTRICITY

Issue

Sustainable sources of biomass from agriculture or forests offer attractive fuels with high CO_2 reduction potential since the carbon dioxide emitted during combustion is sequestered in energy crops or harvested forests.

Technological Overview and Status

Direct combustion of biomass is a primary conversion technology for the production of electricity. Direct combustion involves the oxidation of biomass with excess air, giving hot flue gases that are used to produce steam in boilers.

Combustion power plants differ mainly in the areas of boiler designs and fuel composition. Steam turbines and generators which are used in the different plants do not show many differences in basic design, except for differences between condensing and back-pressure turbines used for cogeneration purposes (combined heat and power). From an economic and applicability point of view, the combustion of biomass often takes place in multi-fuel boilers, which additionally use natural gas, oil or coal. Combustion boiler technologies in use today include pile burners, stoker fired boilers, suspension-fired boilers, fluidized bed boilers, and biomass gasification/combustion. Stoker-fired grate boilers are the most mature combustion technologies, but improvements can still be made, particularly using learner-based control co-firing.

Most co-fired generation stations (suspension) can take up to 10% biomass with improved overall performance and reduced emissions. Most large-scale units burn at 50% moisture. As a result, there is an opportunity for 20% to 25% efficiency gain for latent heat recovery (condensing).

Timeframe to Commercialization: short term (now to 2008).

Canadian Innovation Capacity

There are several Canadian engineering companies that can provide design and construction expertise, based on extensive experience serving the pulp & paper and wood products industries. Several small technology companies provide variations and improvements to heat transfer designs. There are major, Canadian-based, boiler manufacturers that can provide boilers designs for biomass fuel. Utilities, independent power producers and industry bring together the design services, financing, components to produce installed systems where economically feasible.

The Renewable Energy Technologies Program (RETP) and the CANMET Advanced Combustion Technology Labs, both of the CANMET Energy Technology Centre are also developing direct combustion technologies for biomass.

Market Potential

There is a potential to use biomass-fired power generation in some selected northern and rural strategic locations. Canada has a good potential to increase its biomass-fired power generation since it has a high number of pulp and paper mills and wood product plants producing wood waste. Commercial agricultural biomass-fired power generation has not been developed. The critical issue is to ensure a large and steady supply of biomass fuel from a nearby source to maintain reliable of boiler operation. It is also important to have a local demand for waste steam heat to increase the overall thermal energy efficiency. The highest potential for this technology in Canada occurs when biomass fuel is used in conjunction with other fuels such as natural gas in a location close to a pulp and paper or wood product plants. Many wood product facilities already use biomass and will be increasing their demands in-line with rapidly growing production. Wood waste can also be used to supplement coal-fired plants, but the wood supply source must be within a short distance.

Barriers to Commercial Opportunities

Despite rapid growth in the 1980s, the numbers of active biomass power projects decreased in the 1990s. There are several reasons for the lack of current project activity. The capital cost of wood fired boiler is four to five times more expensive than an equivalent sized natural gas units and competition for a limited feedstock source can drive up the price of the fuel substantially and limit the number of projects within a geographic region. The use of feedstock with characteristics that differ substantially from the fuel for which a given boiler was designed affects both unit performance and reliability. Competition from natural gas-fired generators has also dampened the market for biomass projects.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>
- Further R&D

<u>Commercialization, Demonstration</u>
- Pilot testing and demonstration

<u>Business Climate</u>
- Encourage wood industry to consider use of biomass power.
  Electrical utilities develop acceptable purchasing practices.

<u>System Linkages</u>
- Develop infrastructure for fuel production, collection, and transport.

Funds Required: $5 million per year.

BIOMASS CONVERSION TO FUELS

Issue

Biomass conversion refers to processes that transform biomass into energy fuels. Technologies include gasification, pyrolysis and biochemical conversion.

Technological Overview and Status

Gasification is a two-step, endothermic process in which a solid fuel such as biomass is thermochemically converted into a low or medium-energy gas. Gasification is regarded as being in the demonstration phase and holds promise for electrical power generation.

Pyrolysis is defined as the transformation of a compound into one or more other substances by heat alone, i.e., without oxidation. Pyrolytic change may also involve isomerization and formation of higher molecular weight compounds. Application of pyrolysis to biomass for conversion to energy is currently focused as a route for the production of biocrude oils from which liquid chemicals can also be separated. An advantage with this approach is that the production of the energy commodity can be de-coupled from its utilization.

Biochemical conversion of biomass to energy is focused on the production of ethanol, which holds promise for GHG reduction through its use in gasoline blending or as a neat fuel. Fermentation of starch derived sugars is the dominant technology in the ethanol industry today, but its applicability has been limited to processing starch sources (corn grain or wheat grain) to produce ethanol. A new enzymatic hydrolysis process, which is under development, would utilize cellulose and hemicellulose from biomass crops, softwood residues and agriculture wastes to produce ethanol.

Timeframe to Commercialization: short to medium term (now to 2012).

Canadian Innovation Capacity

There is a handful of Canadian organizations that have strong research and development in the field of biomass conversion. There is Biothermica International (Montreal), for example, which is involved in the development, design engineering and construction of turn-key projects related to the thermal treatment of gases and waste. Biothermica has developed a *Biogat* process, which consists of gasifying the biomass and producing electricity using a combined cycle, and plans to build a demonstration plant by the year 2000. Canada is the world leader in the area of biomass fast pyrolysis, with Ensyn Technologies, Dynamotive Corp. and Pyrovac Intl. developing commercial systems. Iogen Corporation (Ottawa) is developing enzyme technology applicable to biomass conversion to ethanol, employing a process known as enzymatic hydrolysis. Iogen has successfully piloted the technology on two separate occasions and is planning the construction of a fully integrated, continuous-operating demonstration plant scheduled for completion in early 2000.

The Renewable Energy Technologies Programme (RETP), managed by the CANMET Energy Technology Centre, is developing technologies in cooperation with Canadian industry including the thermochemical and biochemical conversion of biomass to energy. Other relevant government support comes from PERD, Enviroment Canada, Agriculture & Agri-Food Canada, and Industry Canada. ENFOR also provides support.

Market Potential

In Europe and the US, major developmental efforts are underway to demonstrate and commercialize biomass-fueled Integrated Gasification and Combined Cycle (IGCC) systems. Other gasification systems are also being evaluated but at this time there is no clear preference. IGCC systems involve three distinct types of gasifiers and represent scales from 8 MWe to 75 MWe and include industrial and aeroderivative gas turbines.

The development of biomass-fueled power generation systems from gasification and pyrolysis, will grow by means of two different markets: self generation, mainly for use by agricultural or forestry industries that use biomass; and merchant generation, which serves the commodity market for electricity. Examples of attractive niches are: regions with special incentives; regions with high fossil fuel costs; regions with rural development concerns; areas with waste or residue disposal concerns; and areas where very low biomass costs are available. The number of these niches may be quite large internationally.

Barriers to Commercial Opportunities

High capital costs involved in the construction of a biomass gasification-to-energy plant facility is one barrier to the utilization of this technology. Compared to biomass combustion systems with equivalent generating capacity, gasification systems may be less costly to build. However, since power production from gasification of biomass or waste products has not yet been proven to be commercially viable or past the demonstration stage, there is a reluctance to provide financing for these plants.

The cost and availability of biomass sources will also present problems in the commercialization of energy schemes that will be in direct competition with fossil fuel sources.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure
- R&D required in biomass handling, conventional lignocellulosics, gas cleanup and the production of value added chemicals derived from biomass conversion.

Commercialization, Demonstration
- Further support for pilot and demonstration plants.

Business Climate
- Requires further incentives as a ‘green’ supply of energy.

System Linkages

- Will require stronger links into the agricultural and forestry resource bases.

Market Linkages

- The development of co-products will be required to allow these technologies to compete with conventional fossil fuels in the energy arena.

Funds Required: $5 million per year.

NUCLEAR FISSION

Issue

Nuclear power plants emit negligible amounts of greenhouse gases on a full CO2 life-cycle basis. Life extension and optimal use of existing plants can play a major role in controlling forecast growth in emissions from electricity production. The deployment of additional plants to offset fossil fuel electricity production could substantially reduce emissions from electricity production. Wider end use application of electricity, as well as direct application of nuclear energy to opportunities which exist in transportation, building and process heating applications, and in materials processing using electrotechnologies could extend the greenhouse gas benefits of nuclear technology. Each 700 MWe CANDU 6 power plant avoids on the order of about 5 million tonnes/year of CO2 relative to low efficiency coal plants which would typically be replaced. Canada's 22 reactors avoided about 100 million tonnes in 1995. The potential for GHG avoidance in a world anticipating hundreds of gigawatts of additional electricity is several billion tonnes.

Technological Overview and Status

All nuclear plants in Canada use CANDU reactors of various sizes(500-900Mwe) and vintages. These reactors employ natural uranium fuel and heavy water (D_2O) as both moderator and coolant. No new CANDU reactors are under construction in Canada, although development is continuing which currently focuses on the export market. Development effort is focused on improvement of the existing CANDU system to improve reliability and reduce cost through design refinement and enhanced construction techniques. Next generation system possibilities include more sophisticated fuel cycles (i.e. recycling of spent fuel from light water reactors) and cooling systems operating at much higher temperature and pressure (i.e. - supercritical steam conditions), with the goal of reducing overall system cost. Although technically acceptable interim spent fuel storage and long term disposal techniques have been developed it is important that an integrated infrastructure for waste management be established, and in due course, applied for present and future systems. Alternative reactor designs have been considered, in concept, internationally. Time will tell if breakthroughs leading to significant cost reduction are realized.

TimeFrame to Commercialization: short (before 2008) for waste management infrastructure; medium (2008-2012) for fuel cycles refinement; long term (after 2012) for more advanced fuel cycles or alternative reactors and development of significant CANDU cooling system changes.

Canadian Innovation Capacity

Over the past three decades nuclear technology has made a major contribution to the economic growth of Canada. In summary, the benefits include: 30,000 direct, high technology jobs - in over 150 companies across Canada, a $6 billion annual contribution to Canada's gross domestic product, $700 million annually in federal income and sales taxes, a net export industry - exceeded $800 million in 1994, world leading uranium exports, world leading production and supply of medical, industrial and food processing isotopes, and "Spin-off" industries - robotics, telecommunications, software, engineering and consulting services

At present Atomic Energy of Canada Limited (AECL) has the overall responsibility to design, build and market the CANDU power reactor, as well as research-scale reactors, and provides reactor support services. Ontario Hydro has operated all but two of the 22 (24 if one includes NPD and Douglas Point which operated on an advanced demonstration basis) CANDU reactors built in Canada since the 1960's. Several CANDU 6 reactors ($700MW_e$ class) are operational in the Republic of Korea, Argentina and Romania. CANDU 6 reactors are under construction in Korea and China. Many other Canadian companies are involved in uranium mining and processing, fuel manufacture, and reactor and balance of plant component supply. R&D capabilities exist at the Chalk River and Whiteshell laboratories of AECL and a number of other centers including Stern Labs and several universities. R&D activities have been reduced recently because of AECL budget constraints and reductions in cooperatively funded nuclear industry R &D programs.

Market Potential

The Canadian market is constrained through limited anticipated additional demand for electricity in the next few decades. Additional market for electricity could be encouraged in transportation and industry. This could pave the way for additional greenhouse gas avoidance by providing nuclear electricity as an alternative to traditional use of fossil fuel. The potential for new markets abroad for advanced CANDU technology is potentially large, and depends significantly on the local cost of producing electricity from alternative fuel sources and nuclear technology and security of supply considerations of potential customers. CANDU sales have been successful in markets where the technology is competitive. AECL's current business goal, established in 1996, is to sell one CANDU reactor per year for a ten year period. Implementation of the flexibility mechanisms could significantly shift the economic fulcrum toward nuclear energy. Canada's nuclear technology must remain competitive with other nuclear suppliers to win in the market place.

Barriers to Commercial Opportunities

The most significant barrier to deployment of additional reactors in Canada results from a lack of demand for electricity beyond the capabilities of Canada's existing electricity system. Current market forces also favor natural gas fueled new plants as a result of increased natural gas delivery capability and improvements in gas turbine technology which allow for the installation of highly efficient combined cycle and/or cogeneration power plants. The high capital costs of nuclear plants can be a barrier to installation, even though operating cost is very low, since financing capital intensive projects introduces additional costs. Although greenhouse gas emissions could be substantially reduced by the replacement of the existing capital stock of fossil fuel plants economic conditions do not support such action. In addition to such economic barriers, social factors have played a role in creating a perception that there is not a technical means of managing the spent fuel which is accumulating at reactor sites in Canada. It has been acknowledged, through public review, that interim storage measures are safe and effective and that a technical solution for long term disposal of fuel waste is available. Nevertheless, the Panel that reviewed AECL's concept for the disposal of Canada's nuclear fuel waste concluded that broad public support is lacking but necessary. The Panel made several recommendations aimed at developing and demonstrating the necessary public support for a waste management system which remain to be implemented in due course. Foremost among the recommendations were the creation of a nuclear fuel waste management organization and an evaluation of alternatives to the long term waste disposal system presented. Safe and effective interim storage techniques allow for the measured evaluation of alternative waste management systems.

Measures to Enhance Innovation

A number of challenges to the realization of the full potential of nuclear energy innovation potential have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. The process will include user and supplier nuclear industries in Canada and abroad as well as the established research community with relevant competence. The unique Canadian nuclear industry also faces competitive challenges from competing nuclear technologies. It is thus important that the innovation process be sustained to incorporate lessons learned from existing plants and that refinements be sought and incorporated to improve efficiency and reduce the unit cost of energy production. Finally, in order to gain the maximum GHG potential of nuclear energy, it is particularly important that it be linked with enabling and crosscutting technology such as the use of hydrogen as an alternate fuel and the expanded use of electricity as an alternative to fossil fuel.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>

- cost reductions through R&D and feedback from operating systems
- R&D on advanced materials and insulated fuel channel development to allow implementation of cooling systems utilizing high pressure and temperature steam.
- heating reactor demonstration project (i.e. building heating or industrial process such as oil sands extraction or hydrogen production)
- development of key high pressure fuel channel components in a research reactor
- support for fuel cycle development based on recycling light water reactor fuel
- evaluation of alternative waste disposal methods per review panel recommendation
- monitor developments in non-Canadian advanced pressurized light water reactors

<u>Commercialization, Demonstration</u>

- demonstrate effectiveness of interim waste storage while ultimate waste management system is established and resolved through implementation of the recommendations of the review panel.
- deployment of advanced construction techniques and IT to reduce construction schedules and hence project costs and interest during construction

<u>Business Climate</u>

- early retirement program for coal-fired power plants
- tax incentives for greenhouse gas free energy supply
- financing mechanisms to extend life of existing plants and install additional plants
- comparative environmental assessment to demonstrate low impact

- establishment by governments and utilities of a waste management organization -responsible for waste management including disposal

System Linkages
- improved linkages between partners and stakeholders - particularly with respect to waste management including disposal
- establish linkages between reactor technology and corporations needing process heat and greenhouse gas free hydrogen production
- establish financial link between flexibility mechanisms and funding for R&D support
- ensure the regulatory climate for nuclear technology with respect to safety and - environmental impact is consistent with competing technology

Market Linkages
- encourage use of electricity and/or hydrogen, which are prime currencies for nuclear energy, as replacements for fossil fuel in new electrotechnology applications
- ensure no artificial restrictions are established with respect to the flexibility mechanisms and nuclear energy systems and establish the national and international infrastructure needed to implement flexibility mechanisms

Human Resources
- encourage curriculum development in engineering based comparative environmental assessment - including CO2 accounting
- extend education programs to support international human resource development in nuclear engineering and environmental assessment

Funds Required

The federal government currently funds AECL at a level of around $100 million/year. A substantial fraction of this (~ 80 million) is slated to R & D to improve the knowledge infrastructure for the CANDU system. In addition to this funding Canadian nuclear utilities, through the CANDU Owners Group, provide about $15 million/year. Half of this is slated for safety and half for product refinement related knowledge infrastructure development.

We suggest that public funding be increased by up to $30 million per year. Basic research to increase the competitiveness of the CANDU technology should be increased immediately by $10 million/year. Another $5 million/year is needed immediately for a short time period to assist in developing additional knowledge of alternative waste management concepts. Later on, an additional $15 million/year would be phased in to support demonstration of nuclear heating applications in industry should GHG restrictions become a factor in constraining economic growth. This phase would require matching funds from private industry above and beyond those required for fossil fuel energy sources.

STATIONARY TURBINES

Issue

Advanced gas turbines systems (ATSs) are promising technologies that can result in the emission of less CO2 per kWh than conventional fossil based power generation technologies. CO_2 minimization can occur from: 1) increased turbine efficiency; 2) combined cycle technologies increasing energy efficiency; 3) cogeneration (which achieves the highest possible level of efficiency and thus the greatest level of CO_2 reduction); 4) combustion of a fuel with low (e.g., natural gas) carbon content: and 5) combustion/gasification of biomass or otherwise-wasted fuels. Turbines sized from 25 kW to 334 MW are commercially available. A promising technology is the solid-fueled gas turbine power plant which can achieve high efficiency and, when burning biomass fuel, is considered "CO_2 neutral". The approach is to use an indirectly-fired gas turbine engine (IFGT) which comprises an external heat source, a heat exchanger and a gas turbine generator. An alternative approach is the gasification of the solid fuel where the gas is burned directly in the gas turbine combustor (adapted for low or medium BTU gas). Integrated gasification combined cycle (IGCC) power plants are becoming increasing popular because of their inherently low emissions and high efficiency.

Technological Overview and Status

Combined cycle turbine technologies incorporate a gas turbine cycle with a steam turbine cycle to increase overall energy conversion efficiency. When this concept is extended to include cogeneration (the production and recovery of heat as well as electricity), the total system efficiency can increase to the highest possible levels. Carbon dioxide emissions are lowered due to the lowered fuel requirements to generate an equivalent amount of energy from conventional plants.

The first stage of the combined cycle turbine process involves the combustion of gas (primarily natural gas) with compressed air to generate high temperature combustion gases, which drive the turbine and subsequently the electricity generator. The versatility of a gas turbine system is its ability to run on a variety of fuels, including gasified coal or biomass and also landfill gas fuels. The second stage of combined cycle technology is the use of hot exhaust gases from the gas turbine to generate steam in a heat recovery steam generator, which can be used to drive a second electricity generator. The result is a major low-carbon emitting technology, with efficiencies of as high as 58% in some cases. When this technology is coupled with a heat load, the system is described as cogeneration (or combined heat and power, CHP); total cycle efficiencies of over 90% recovery of input have been reported when the full use of waste heat from the combined cycle turbine process is utilized. Total cycle efficiencies of 70% are certainly attained. Design for higher levels involves cost benefit trade-offs.

IFGT power plants can burn solid, liquid or gaseous fuels or mixtures of these. IFGT are expected to provide an excellent opportunity to generate power from sources such as coal, biomass, municipal waste, etc.

Timeframe to Commercialization: short term for cogeneration and indirectly-fired gas turbines (present to 2008); short-to-medium term for further advanced gas turbine developments including integrated gasification (present to 2012).

Canadian Innovation Capacity

Combined cycle plants have been installed in Canada by independent power producers and some local utilities to increase their electrical power generation capacity. These plants are in some cases comprised of domestically-manufactured gas & steam turbines and electricity generators. Some of the fully-integrated energy companies have divisions which supply the component systems, while others subcontract to international as well as domestic firms. Canadian manufacturers of gas turbine engines and components include: Siemens/Westinghouse (Hamilton), Pratt & Whitney (Longueuil), Rolls Royce/Allison (Lachine), Hawker Siddeley/Orenda Aerospace (Mississauga), and Standard Aero (Winnipeg).

The US DOE is investing around US$180M in the development of a high performance power system integrating IFGT technology for coal combustion. In Canada, CANMET/CETC is developing this technology with particular emphasis on biomass and municipal waste fuels. This will lead to GHG reduction from reduced methane emissions (e.g., rotting biomass) and reduced CO_2 emissions from the displacement of fossil-based energy generation.

Market Potential

CT/Combined cycle/Cogen plants can serve a wide range of electrical power requirements (e.g.- industrial complexes, factories, university campuses, commercial buildings, etc.). On average, the EPDC time for a combined cycle plant of 150 to 270MW is about 2 years, although depending on demand this could increase. For much smaller facilities time frames less than 1 year may be appropriate. The flexibility of gas turbine operation is a great attribute of this technology, as power can be suited for peak or intermittent or base load demand, and quickly turned on or off should power need vary. Their compact size, clean operation and possible low noise performance increases their likelihood of use in urban city centres, thus reducing the amount of transmission & distribution of electricity & hence lower losses needed to reach areas of greatest usage. Visual pollution due to urban vapour plumes can be a concern.

The recent global success of natural gas combined cycle plants in industrialized countries have resulted in predictions that they will, over the next decade, draw away from the current focus upon centralized generating stations. Over the next 10-15 years, as existing power plants near the end of their useful life, there should be an increase in demand for smaller, modular systems distributed throughout the load centre. However large centralized plants may lend themselves better to CO_2 capture & sequestration where practical. The U.S. Department of Energy estimates that within the next decade, the international market for advanced gas turbine systems will exceed $1 trillion.

Barriers to Commercial Opportunities

A significant barrier to the widespread adoption of combined cycle turbine technology is the availability & future cost of natural gas, a non-renewable resource. The Geological Survey of Canada data indicates that natural gas demand may outstrip supply sometime over the next decade. Nonetheless fuel changing to gasified coal [or other opportunity fuels such as heavy oil] is a long term option, particularly at large central generating plants utilizing combined cycle technology, again resulting in low emission power.

A significant barrier to the implementation of IFGT is the limited availability of high-temperature heat exchangers needed to achieve high efficiency. Current all-metal heat exchangers lead to efficiencies in the range of 15% to 20%. Ceramic heat exchangers are available that will give much higher efficiencies but their durability has not yet been demonstrated.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>
- Development of further advanced gas turbines (intercooled aero derivatives, etc)

<u>Commercialization, Demonstration</u>
- Demonstration of advanced gas turbine and microturbine based generation / cogeneration
- Demonstration of a small-scale IFGT.

<u>Business Climate</u>
- The generation of electricity from otherwise-wasted solid fuels can provide the needed incentive for the implementation of IFGT and gasification technologies.
-

<u>System Linkages</u>
- Networks of suppliers and users

<u>Human Resources</u>
- Develop engineering programs to meet current/future needs in this field

Funds Required: $10 million per year.

LARGE SCALE HYDRO

Issue

Worldwide, hydropower represents approximately a quarter of the total electricity generated and is growing in importance; in many countries, it is the dominant source of electric power. The generation of hydroelectricity does not add to the concentrations of carbon dioxide in the atmosphere. It also is a renewable energy resource and is an important element of sustainable development.

Canada gets about 62 percent of its electricity from hydroelectric sources. Five Canadian power utilities, Hydro-Québec, BC Hydro, Manitoba Hydro, Newfoundland and Labrador Hydro, and Ontario Power Generation have a combined hydroelectric generating power of more than 62 000 MW avoiding emissions on the order of 400 million tons of CO_2 compared to coal. Similar, or greater, capacity remains to be utilized in Canada representing a major opportunity for energy supply with minimal greenhouse gas emissions. For example, the capability of new hydro sites that can be developed in Manitoba and Québec alone amounts to more than 25 000 MW .

While some large 'run-of-the-river' hydroelectric developments, like Niagara, are possible, large hydroelectric plants are more often based on a large water-storage reservoir upstream of a dam. This concentrates the fall in water level to one location so it can be better utilised and, provides an important storage component in an integrated electricity supply system but introduces environmental issues. For example, emissions of methane (CH_4) and carbon dioxide (CO_2), may result from flooding peat soils and/or vegetation and some toxic materials may be released. There are also social and wildlife impacts to consider.

Increasing the efficiency of high voltage transmission infrastructure to reduce overall cost is desirable as new sites are relatively far from population centres.

Technological Overview and Status

Hydraulic energy was the first source of electricity in Canada. Early development of systems was based on exploitation of suitable sites near population centres. Once such sites had been developed, electricity generation from fossil fuel and nuclear thermal sources became competitive and were developed. A reduction of cost relative to these sources can facilitate the generation of electricity from potential new hydraulic sources

The new knowledge and new technologies that will allow the potential to be exploited depends on understanding environmental conditions and improving turbines, transmission lines, and interconnections to enhance overall system efficiency with consequent cost reduction. The following require improved knowledge infrastructure:

- Understanding and mitigation of the problem of CO_2, CH_4, and other emissions from the reservoirs
- Improvements in the forecasting and management of water reserves (*hydraulics*)
- Turbines reliability and degradation (*cavitation*)
- Very high voltage transmission lines efficiency and reliability

- Power grid management simulation systems (long transmission lines)
- Managing processes and techniques to increase utilisation factor
- Storage on electricity as a mean of improving large grids stability (superconductivity)
- Energy storage by coupling of wind plants and large reservoir

Timeframe to Commercialization: short to long term (now to 2020 and beyond). Canadian capacity for additional hydro electricity substantially exceeds expected Canadian demand and thus represents an export capability

Canadian Innovation Capacity

Canadian power utilities have developed an important innovation system and their expertise in large scale hydroelectric projects is internationally recognised.

Engineering and construction know-how is well developed and many projects underway at the international level include a substantial Canadian component:

- Peru: construction of a 220-kV transmission line (660 km) enabling the interconnection of the Mantaro and Socabaya systems.
- Nigeria: construction of 66-kV and 33-kV transmission and distribution lines over 200 km to provide electricity to 32 villages.
- Cameroon, Guinea Management of the Société Nationale d'Électricité du Cameroun (SONEL) and the Société Guinéenne d'Électricité (SOGEL), including administrative, financial and technical services.
- Algeria, Indonesia, Libya, Malaysia, Portugal, Saudi Arabia, Tunisia Training in live-line procedures for the maintenance of very high and high voltage lines.
- China: technical review of a 1 500 MW power station (Baishan) with a view to adding a 300-MW pumped-storage power station.

Market Potential

Hydroelectricity is already a major contributor to the economy. Together the five major provincial hydroelectric utilities, Hydro-Québec, BC Hydro, Manitoba Hydro, Newfoundland and Labrador Hydro, and Ontario Power Generation employ more than 30 000 people and electricity and the technology used in its production, are valuable export commodities.

On the national market, interconnections provide security of supply to the electrical industry and create economic opportunities for hydraulically generated electricity to substitute for fossil fuel generated electricity. The construction of additional east-west interconnections would serve to increase these opportunities for Canadian energy users. Additional north south connections could allow for the development of a very significant export market.

The hydro developments which is being planned on the Churchill River system in Labrador and the related developments in Québec offer the single largest block of achievable greenhouse gas emission reductions in Canada, which could account for up to 15 per cent of Canada's Kyoto commitment.

The greenhouse gas emissions reductions associated with the Churchill River developments in Labrador alone will range between 13 million tons annually compared to gas, to 22 million tons annually, compared to coal.

As indicated in the introduction, long term potential is much greater than these examples.

Barriers to Commercial Opportunities

The barriers to the construction of new large hydroelectric plants are mostly related to a better understanding of their environmental impact and the improvement of their overall efficiency.

The studies and R&D subjects mentioned earlier are key issues of a better knowledge of their potential with regard to GHG and cost reduction which will increase the contribution of already existing plants in meeting the excepted GHG reductions.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure
- Understanding and mitigation of the problem of $CO_{2,}$ $CH_{4,}$ and other emissions from reservoirs
- Cost reduction through more efficient forecasting and management of water reserves
- Power grid management simulation systems (long transmission lines)
- Energy storage optimization by coupling of other sources such as wind and nuclear plants and large reservoirs

Commercialization, Demonstration
- Turbines reliability and degradation
- Utilisation of “bubble” turbines on low watershed rivers
- Very high voltage transmission lines efficiency and reliability
- Managing processes and techniques to increase utilisation factor
- Interconnection technologies
- Storage of electricity as a mean of improving large grids stability (superconductivity)

Business Climate
- Comparative environmental assessment to demonstrate low impact and renewable nature of large scale hydroelectricity
- Economic studies of hydroelectric plants costs and efficiency
- Assistance to Canadian power utilities in the preparation and exploration of international projects
- Financing mechanisms to extend life of existing plants and install additional plants

System Linkages
- Improved linkages between partners and stakeholders - particularly with respect to environmental aspects
- Establish linkages between non hydraulic energy and large reservoir management

- Establish linkage with hydrogen production and large scale hydroelectricity (utilisation factor)
- Establish financial link between flexibility mechanisms and funding for R&D support

Market Linkages
- Encourage use of electricity as a replacement for fossil fuel in new electrotechnology applications
- Establish infrastructure needed to produce and distribute hydrogen fuel
- Ensure no artificial restrictions are established with respect to the flexibility mechanisms and hydroelectric systems
- Contribute to the establishment of the infrastructure needed to implement flexibility mechanisms

Human Resources
- Encourage curriculum development in engineering based comparative environmental assessment - including CO2 accounting
- Contribute to the formation of researchers and technicians in hydroelectricity related equipment and systems
- Contribute to the extension education programs to support international human resource development in hydroelectricity and environmental assessment

Funds Required :

Hydro-Québec is currently involved in research and development to maintain efficient generation, transmission, distribution, and energy utilisation. In 1997, some $144 million was allotted to R&D, in addition to resources totalling 778 person-years. BC Hydro and Manitoba Hydro are also conducting R&D activities with the same objectives. An additional $ 30 million/year of federal funding is suggested to accelerate this effort and ensure Canadian hydroelectricity technology and expertise is ready to contribute to greenhouse gas reduction in Canada and abroad.

FUEL CELLS

Issue

Fuel cells are electrochemical devices that convert chemical energy directly into electricity. They offer improved energy efficiencies versus non-electrochemical energy systems, e.g., the internal combustion engine and the gas turbine, whose energy efficiencies are limited by the Carnot cycle.

Technological Overview and Status

Fuel cells are electrochemical devices that enable the chemical energy of fuels to be converted directly into electricity. Fuel cells are similar to batteries in that both produce a DC current using an electrochemical process. Two electrodes, an anode and a cathode, are separated by an electrolyte in a fuel cell. Fuel cells consist of three major components: a fuel cell stack which consists of pairs of electrode/electrolyte assemblies arranged in series to produce a useful output voltage; a fuel processor which is generally employed to remove fuel impurities and sometimes increases the concentration of hydrogen in the fuel (a fuel processor is not required if electrolytic hydrogen is the fuel); and a power conditioner which transforms the direct current produced by the fuel cell into the alternating current used in most electrical applications and/or to match the voltage of the fuel cell stack to that of the user device.

There are a wide variety of fuels that can be processed to produce appropriate fuel for fuel cells, for instance: hydrogen, methanol, ethanol, natural gas**,** coal-derived gas, landfill gas, biogas and liquefied petroleum gas.

Fuel cells generally operate on hydrogen. Fuels such as methane, methanol, ethanol or gasoline can be converted to a hydrogen-rich stream in fuel processors, prior to use in fuel cells. The direct methanol fuel cell, described in the next paragraph, can use methanol directly. High temperature fuel cells can also use "town gas" directly, which is a mixture of hydrogen, carbon monoxide, and carbon dioxide, as well as hydrogen. Complete or partial reforming of natural gas inside the fuel cell stack is also possible with the high temperature fuel cells.

Fuel cells are generally divided into categories based on the electrolyte used. The operating temperature range of a fuel cell is largely dictated by the electrolyte used. There are two high temperature fuel cells, namely the molten carbonate electrolyte fuel cell and the solid oxide electrolyte fuel cell. Both are being developed as central power sources for utilities, buildings, factories and other industries. The solid oxide fuel cell in the planar configuration, compared to tubular for the larger generators, is also being developed for small stationary and mobile applications in the kW range. There is one medium temperature fuel cell, which is commercially the most advanced now, and that is the phosphoric acid electrolyte fuel cell, operating at about 200ºC. It has been developed for the distributed power market with units available at 200 kW, usually based on natural gas or landfill gas. The proton exchange membrane(PEM) and the alkaline electrolyte fuel cells are the two low temperature fuel cells, operating at about 80 °C. The alkaline fuel cell requires a carbon dioxide scrubber for the air to prevent the build up of solid carbonate particles in the fuel cell stack. The other low temperature fuel cell under development is the direct methanol fuel cell, which is a cousin of the proton exchange membrane fuel cell. It is less developed than the other two. All three low temperature fuel cells are being considered for transportation applications. All three types also have potential in small portable as well as specialty niche applications in sizes ranging from a few watts to several kilowatts. The alkaline fuel cell is still being used in the Space Shuttle. For terrestrial applications, the alkaline fuel cell has not been able to reach the same high power densities as the PEM system.

Timeframe to Commercialization: medium term (2008 to 2012).

Canadian Innovation Capacity

Canadian companies have concentrated on the development and manufacture of low temperature fuel cells. Canada has developed strong capabilities in the emerging field of ambient temperature fuel cells, through joint development with government. Ballard Power of Vancouver is the world leader in the development of proton exchange membrane fuel cells for generating electricity for transportation and stationary applications. H-Power Enterprises of Canada Inc. of St.Laurent,Quebec are developing PEM fuel cell systems for residential and other small power applications. Other companies include: Hydrogenics Inc. (Toronto). Energy Ventures Inc.(Toronto) is a relatively new comer but has bought the Astris Inc. alkaline fuel cell technology and is building on that base. There are two companies which have experience in the solid oxide fuel cell technologies: Ontario Power Technologies (Toronto) who are working closely with the tubular configuration with Siemens-Westinghouse; and Global Thermoelectric Inc., (Calgary) who are developing the planar configuration. There are no Canadian companies developing the molten carbonate or the phosphoric acid fuel cell at this time.

Federal and provincial R&D is carried out through PERD, CANMET Transportation Energy Technologies Program (TRANSET), National Research Council, Ontario Power Technologies, Department of National Defense, Industry Canada and Hydro-Québec.

Market Potential

While the range of potential uses for fuel cells is diverse, short-term applications are limited. The largest market potential is in the transportation sector as all the major car manufacturers have fuel cell car development programs underway. Several are committed to introducing limited editions of their fuel cell cars in the California market by the year 2004. Most of these use the Ballard fuel cell. Pre-commercial transit buses with compressed hydrogen as fuel for the fuel cell engines are already in fare service in Chicago and Vancouver. The central-station application (tens to hundreds of megawatts) for fuel cells is the least viable market given the current state of the technology.

Barriers to Commercial Opportunities

- High initial costs of the wider scale utilization of fuel cells.
- The technology and cost of reforming of new fuels.
- Distribution infrastructure for new fuels.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>
- Further R&D.

<u>Commercialization, Demonstration</u>
- Support to pilot plants and early commercialization efforts in several regional centres of innovation.

<u>Business Climate</u>
- Fuel cells would benefit from the ‘greening’ of electricity, tax incentives, and measures promoting efficient technologies.

<u>System Linkages</u>
- Network

Funds Required

$20 million per year from governments which would be directly leveraged with $40M by industry. These numbers would not include direct R&D and commercialization expenditures by industry of more than $100M/a (mostly Ballard).

BUILDINGS

Issue

There are both technologies and best practices that can be adopted by the buildings industry to reduce greenhouse gas (ghg) emissions. Because buildings have a long life, the time horizon for effecting reductions of ghgs is over the long term. Beyond providing a healthy and comfortable indoor environment, future buildings should have a minimal impact on local, regional and global environments;. Means of achieving this include optimal building design, construction and renovation that utilize high efficiency building systems, maximum use of recycled and recyclable construction materials with low embodied energy; minimal use of non-renewable heat and electricity; effective of use heat recovery, heat cascading, waste water cleaning/recycling and waste management.

Technological Overview and Status

New and improved practices and technologies for future buildings include:

- Computer based integrated building design and optimization including efficient design for reconstruction/demolition/recycling
- Advanced building envelope systems, fully integrated with the building structure, including manufactured wall systems with integrated super-insulation and efficient windows
- “Superwindows” orientated to take advantage of solar energy for heat and natural lighting
- Integrated natural and artificial lighting systems
- Low energy cooling systems (night-time cooling, desiccants for humidity control, strategic positioning of trees, etc.)
- Highly efficient, multi-functional and integrated appliances
- Air and heat distribution systems with low energy motors and fans and pumps
- Advanced building control systems incorporating “smart” technology, with diagnostics and fault detection, to closely match energy and water supply and ambient conditions with need
- On-site power generation, including fuel cells for power generation and space conditioning: photovoltaic roofs/walls, and micro-turbines, with any excess electricity sold to the grid or used to charge vehicles
- Solar energy for water heating, ventilation air and space heating/cooling using integrated wall and roof collectors
- Advanced district heating and cooling systems
- Energy storage systems
- Technologies to assess long term performance (life cycle) potential to assess financial benefits and provide assurance of durability
- Selection of advanced low GHG construction materials and systems for building construction
- Advanced water, wastewater and fuel delivery systems (buried infrastructure)
- Open and flexible building systems that can be easily adapted over time.

Actions to influence building design, construction, and refurbishment are high leverage activities the provide long-term benefits because the long lifetimes of buildings.

Timeframe to Commercialization: medium to long term (2010 and beyond)

Canadian Innovation Capacity

There is strong innovation capability within the Canadian building industry to capitalize on these technologies where liability and risk associated with the adoption of new technologies has been addressed. The Canadian building industry is well positioned to implement these technologies and best practices and market them internationally – particularly in target, niche markets.

Canadian R&D capabilities are strong – with leading expertise at the NRC Institute for Research in construction and the CANMET Energy Technology Centre. There is strong private sector engineering capability as well as research capacity in universities. The relatively small size of individual construction companies implies the need for collaborative R&D through government/private sector partnerships such as the Forintek for wood products R&D.

Market Potential

The building sector represents one of the largest markets (if not THE largest) for both technologies and services, both domestically and globally.

Barriers to Commercial Opportunities

- Upfront cost of innovative GHG technology
- Resistance to change in building industry
- Disconnect between builder/user interests
- Lack of awareness , education and information
- Professional and trades silos that stifle integrated, innovative solutions
- Lack of incentives in professional fees to save on energy or capital cost
- Lack of life cycle analysis data
- Low cost of fossil fuel supply
- Low acceptance by OEMS
- Banks/investors hesitant to provide risk investment for innovative technology
- Risk and liability of specifying and adopting new technologies.
- Lack of established & credible system to assess payback and durability for new technologies
- Demonstrating that new technologies satisfy the intent of codes and regulations.
- Lack of organized and focused international marketing effort

Suggested Measures to Enhance Innovation

Knowledge Infrastructure
- Analysis of economic benefits
- Further research and development
- Life-cycle analysis information
- International technology and market intelligence

Commercialization, Demonstration
- Demonstrations (CANMET, Canada Centre for Housing Technology, CMHC, PWGSC, NRC, associations)

Business Climate
- Encourage adoption of energy/building codes
- Regulation/performance standards coupled with warranty and enforcement
- Change CCA to be equivalent to competing energy system
- Promotion of CCMC role in advancing new technologies
- Acceptance by OEMS

System Linkages
- Public education and outreach on technologies
- Networks

Market Linkages
- Procurement policy and design showcases to create demand
- Establishing consortia projects
- Realization of added value of advanced technologies
- Tools and technical information to help address risk and minimize liability
- International marketing program for building technologies and services

Human Resources
- Training and education of building industry

Funds Required: $15million/year

TRANSPORTATION AND TRANSPORTATION SYSTEMS: INTELLIGENT TRANSPORTATION SYSTEMS

Issue

Intelligent Transportation Systems (ITS) are viewed as having considerable potential for achieving key transportation objectives among them: reducing congestion in ground transportation (highways, bridges, multimodal terminals and border crossings), improving safety, enhancing the mobility of people and goods, increasing economic productivity and reducing the environmental impacts associated with ground transportation, including GHG emissions. While it is difficult to accurately quantify the GHG reduction potential of these systems, recent studies, including one prepared for the Transportation Table, estimate that results would be positive and additionally ITS generate a range of ancillary benefits such as reduced fuel consumption, reduced delays, reduced collisions and improved operating efficiencies.

Technological Overview and Status

ITS include the application of advanced information processing (computers), communications, sensors and control technologies and management strategies in an integrated manner to improve the functioning of the ground transportation system in both urban and rural areas. These systems offer a variety of transportation improvements including: traffic signal control; fleet, freeway, transit, and incident management; multimodal traveler information services; emergency response services; and electronic payment systems. These applications bring system users, vehicles and infrastructure together into one integrated communication system that enables the exchange of information for better management and use of available resources. Various ITS market packages (see attached table) exist to address a variety of transportation requirements.

Timeframe to Commercialization

These systems are already commercially available in Canada and internationally and some are being deployed but only to a limited degree and primarily in urban areas for traffic control and freeway and transit management. What is required is more intensive and widespread deployment across urban centres, rural areas and for integration of the various ground transportation modes. Considerable advances, using existing technologies, could be achieved in the short term (2000-2008) if adequate funding were made available. In the medium-term a critical mass of ITS deployment is achievable and new applications could be deployed for greater integration of ITS systems across modes and jurisdictions. In the long term (beyond 2012) highly advanced applications such as fully automated highway systems and intelligent vehicles could begin to appear in the marketplace.

Canadian Innovation Capacity

Canada currently has a small but growing ITS industry. Given Canada's established capabilities in communications and information technologies, we have the potential to build a dynamic and competitive ITS industry in Canada. Already, a few Canadian firms are world leaders in niche markets e.g. MARK IV Industries (Mississaugua) are leaders in the world's supply of transponder technologies; International Road Dynamics - IRD (Saskatoon) are major suppliers of weigh-in-motion technologies; Nortel Networks is a major provider of fibre-optic equipment for ITS applications. A joint Industry Canada/Transport Canada study (1996) estimated the global annual sales for ITS at US$43 billion by 2006 with Canada's share of this market estimated at US$ 2.9 billion. Canadian firms are capable of building world class ITS systems in Canada, the prime example being the fully automated electronic toll route, Highway 407 in Toronto.

Some ITS R&D work has been undertaken in Canada. The most active participants have included the National Research Council and Transport Canada's Transportation Development Centre, in partnership with U.S. agencies. Several universities across Canada have participated and are increasing their R&D activities for ITS (e.g. University of Toronto). PRECARN is also in the process of establishing a sector initiative targeting intelligent transportation systems.

Barriers to Commercial Opportunities

The Transportation Association of Canada recently conducted a survey of provinces and the cities of Montreal, Toronto and Vancouver to determine barriers to the deployment of ITS within their jurisdictions. The major reasons included: lack of available funding for deployment; lack of adequate human resources with necessary skills and knowledge; lack of planning for ITS as part of broader transportation planning; and lack of national and regional cooperative strategies and frameworks.

Canadian firms need to demonstrate to international clients that they have the expertise to engage in ITS deployments. Building a national capability and market is essential for Canadian firms to showcase their successes and seize international opportunities.

Suggested Measures to Enhance Innovation

Canada needs a national plan to promote the wide-spread and aggressive deployment of ITS in all ground transportation modes across the country. Transport Canada has already begun to develop such a plan but its success will depend on available funding. This national ITS Plan proposes the following activities:

1. Partnerships for Knowledge - Establish concrete partnership arrangements with the private sector, other jurisdictions, academia and the U.S. to building awareness and knowledge of ITS and to contribute to the implementation of this plan. *[Knowledge infrastructure & Human Resources]*.
2. Development of an ITS Architecture for Canada - The architecture is of critical importance for ensuring that products and services are seamlessly integrated and inter-operable. It is the communications and information backbone that supports and unites key ITS technologies enabling them to work together and communicate with each other. *[System linkages]*
3. A Multi-modal ITS R&D Plan - Industry-oriented R&D is essential for developing new technologies and demonstrating emerging capabilities in ITS. *[Commercialization, Demonstration]*
4. Deployment and Integration of ITS Across Canada - The establishment of a new mechanism to accelerate the deployment, integration and interoperability of ITS across all modes, on a

cost-shared basis with other public and private sectors. *[Market linkages and Human Resources]*

5. Strengthen Canada's ITS Industry - The federal government would work collaboratively with the ITS industry on an export development strategy to promote Canadian expertise to the world and conduct trade mission to those regions demonstrating greatest potential for ITS export opportunities. *[Business Climate]*

Funds Required

New funding is required to undertake the above-noted R&D and deployment activities. For R&D, $2 million per year over 5 years for a total of $10 million to be matched 50/50 by the private sector. For deployment $15 million per year over 5 years, for a total of $75M to be matched 50/50 by other public sectors (provinces and municipalities) and/or the private and non-for-profit sectors.

ITS USER SERVICE BUNDLES			
USER SERVICE	DEPLOYMENT FEATURES		
	FUNCTIONS 1	FUNCTIONS 2	FUNCTIONS 3
TRAVEL AND TRANSPORTATION MANAGEMENT			
En Route Driver Information	General in-vehicle display of static sign information along with driver advisories for current congestion, incident, conditions, etc.	Sign information tailored to current conditions and driver advisory information filtered/tailored to meet driver's specific needs	Sign information tailored to vehicle and current conditions along with predictive driver advisories integrated with route guidance service
Route Guidance	Autonomous route guidance supplying static directions	Real-time route guidance based on current conditions	Coordinated real-time route guidance to achieve network-wide optimizations
Traveler Services Information	Fixed " Yellow pages" service optimized for traveler queries	Mobile service providing information based on location/need (e.g. gas stations in range)	Integrated electronic reservation/payment service
Traffic Control	Enhanced freeway control	Enhanced network control	Integrated area-wide control
Incident Management	Automated incident detection. May rely on traffic monitoring, direct reports, or both	Automated detection, verification, response plan recommended to operator	Complete incident management automation. Minimal man-in-loop operator control
Emissions Testing and Mitigation	Roadside pollution assessment	Area-wide pollution monitoring	Integrated area-wide air quality strategies
Highway-Rail Intersection	Standard traffic control devices at Highway-Rail Intersections	Coordination with railroads to enhance traffic management	Immobile vehicle detection and emergency notification
TRAVEL DEMAND MANAGEMENT			
Demand Management Operations	Demand monitoring and public awareness information	HOV and parking facility administration	Dynamic user fee based on time, route, number of passengers, emissions, etc.
Pre-Trip Travel Information	Real-time information available to travelers at home, office, etc.	Integrated data for all modes available in one repository	Route, time, and mode recommendations made
Ride Matching and Reservation	Match private vehicle owners/operators with potential riders	Include commercial transit providers as match options	Include support for ride share financial transactions
PUBLIC TRANSPORTATION OPERATIONS			
Public Transportation Management	Centralized schedule monitoring and management	Add off-line analysis/planning and personnel management support	Integrated with traffic control to enhance real-time schedule adherence capability
En Route Transit Information	Current route/schedule information available. Limited interaction	Integrated multi-modal information with decision support	Integrated with electronic payment service (ticket/fare card purchase)

Personalized Public Transit	Reservation-based rider request capability	Vehicle assignment with optimized vehicle schedule	Real-time vehicle assignment
Public Travel Security	Physical security, surveillance, screening, and alarm systems	Driver/traveler initiated silent alarm (vehicle-based)	Alarms capability integrated with personal communications services

ITS USER SERVICE BUNDLES (CONTINUED)			
	DEPLOYMENT FEATURES		
USER SERVICE	FUNCTIONS 1	FUNCTIONS 2	FUNCTIONS 3
ELECTRONIC PAYMENT			
Electronic Payment Services	Electronic toll collection	Electronic fare collection/Electronic parking payment	Integrated electronic payment service supporting all modes
COMMERCIAL VEHICLE OPERATIONS			
Commercial Vehicle Electronic Clearance	Use historical data and WIM to preclear carriers with annual registration	Extended service which preclears those with temporary permits	Vehicle and driver condition automatically monitored and considered in preclearance
Automated Roadside Safety Inspections	On-line access to historical safety records for identified vehicles	Vehicle-based diagnostics collected and monitored	Driver status and condition monitored and considered
On-Board Safety Monitoring	Safety monitoring with automated driver notification	Extended to supply notification to carrier	Extended to supply notification to enforcement agencies
Commercial Vehicle Administrative Process	Electronic purchase of annual credentials from base state	Add purchase of temporary credentials/permits from other states	Automated mileage and fuel reporting
Hazardous Material Incident Response	Enforcement and HAZMAT response teams provided with cargo information	Operational focal point to coordinate with other agencies	Real-time HAZMAT incident response coordination
Freight Mobility	Fleet location and status monitoring	Integrated route guidance	Specific specialized fleet capabilities
EMERGENCY MANAGEMENT			
Emergency Notification and Personal Security	Motorist initiated distress signal	Automated distress signal initiated by vehicle collision	Content added to message for special uses (e.g. HAZMAT)
Emergency Vehicle Management	Vehicle dispatch support	Route guidance directing driver to the scene	Integration with traffic control to optimize travel times
ADVANCED VEHICLE CONTROLS AND SAFETY SYSTEMS			
Longitudinal Collision Avoidance	Driver warning of potential longitudinal collisions	Temporary partial control in collision avoidance situation	Full control, integration with lateral control service
Lateral Collision Avoidance	Blind spot warning and/or partial control	Lane holding warning and/or partial control	Full control, integration with longitudinal control service
Intersection Collision Avoidance	Signalized intersection violation (e.g. run red light) detection and control override	Potential intersection collision warning/partial control	Fully automated intersection control
Vision Enhancement for Crash Avoidance	Independent vision enhancement service	Integrated with in-vehicle signing/other collision avoidance services	
Safety Readiness	Enhanced vehicle	Unsafe road	Impaired driver

	condition monitoring	conditions monitoring	monitoring and control override
Pre-Crash Restraint Deployment	Sensor-based detection and restraint deployment	Vehicle to vehicle coordination and restraint deployment	Personalized restraint based on occupant characteristics
Automated Highway System	In-vehicle collision-avoidance precursors to AHS	Minimum roadside intelligence	Fully automated vehicle operations

GEOLOGIC CO_2 MANAGEMENT

Issue

Geologic CO_2 storage is a promising sequestration technology. It involves capturing the gas and injecting it into subsurface repositories.

Technological Overview and Status

The combined use of membranes and chemical solvents, such as monoethanolamine, have been found to be effective to capture and remove CO_2, for example from large stationary sources such as fossil-fuel fired power stations and natural gas wells. However, the cost of separation of CO_2 from low pressure power plant flue gas streams using conventional solvents is quite high. New formulated solvents used in conjunction with advanced contacting devices can reduce the cost of CO_2 separation significantly. Geologic storage options for CO_2 storage being considered are: deep confined and unconfined saline aquifers, depleted oil and gas wells, deep coal beds, and enhanced oil (EOR) and gas (EGR) recovery. Storage costs ($4-8US/tonne carbon) are low in comparison to separation costs. The technologies required are adaptable from the petroleum industry and include drilling and completion of injection wells, subsurface reservoir characterization, and experience with operating procedures associated with CO_2 injection for enhanced oil and gas recovery. Pipeline infrastructure for CO_2 transportation, including attendant gas compression technology, is already operational. CO_2 management will allow the continued use of low-cost fossil fuels in the Canadian economy.

Timeframe to Commercialization: short to long term (before 2008 to beyond 2012).

Canadian Innovation Capacity

Because of the vast storage potential of Canada's landmass in proximity to major CO_2 stationary sources, especially in western Canada, storage technologies present an important and near-term opportunity for GHG mitigation. Canada has the world's largest CO_2 separation research group at the University of Regina. Strong R&D capability and experience in aquifer disposal and displacement of methane in coal seams exist at the Alberta Research Council (ARC). CANMET is developing O_2/CO_2-recycling technology to burn coal/gas in a pure O_2 stream to deliver a pure CO_2 flue gas. Energy companies, such as TransAlta Utilities, Saskatchewan Power, Pan Canadian Petroleum Co., Wascana Energy, Nova Scotia Power, EPCOR, and Ontario Hydro are supporting efforts to advance these technologies. Program support is also being provided by both federal (e.g. through PERD) and provincial governments.

Market Potential

Because of the current strong capacity in Canada for innovation, development of geological storage and utilization technologies represents a significant opportunity for Canadian firms in markets abroad. Separation cost of CO_2 needs to be reduced before such market potential for geological storage and utilization options can be realized. Thus along with geological storage and utilization technologies, there is also a market potential for CO_2 separation technologies as an enabling technology.

Barriers to Commercial Opportunities

- high CO_2 separation costs ($30-$50/tonne) prior to storage
- uncertainty of storage costs, which could range from -$53/tonne to +$29/tonne
- taxation structure
- perceived need for high-purity CO_2 for enhanced oil recovery projects
- uncertainties in volumes available and capacities of the reservoirs
- long-term integrity of the storage
- lack of CO_2 pipeline infrastructure and transportation costs, especially in the west
- need for environmental assessments for aquifer storage
- Kyoto Protocol does not recognize geological storage as a CO_2 sink

Suggested Measures to Enhance Innovation

Initial focus should be on technologies which can be profitable without GHG credits – EOR, EGR and enabling separation technologies

<u>Knowledge Infrastructure</u>

- R&D to develop better solvents and separation technology
- deployment of technology that generates CO_2 at high pressure
- R&D to maximize CO_2 storage and to understand reservoir characteristics
- network of R&D performers and private sector stakeholders
- bilateral Alberta/Saskatchewan agreement linked to NRCan
- life-cycle demonstration projects, e.g. for storage in deep coal seams

<u>Commercialization, Demonstration</u>

- pilot testing and demonstration of CO_2 capture from power plants
- pilot testing and demonstration of storage in enhanced oil recovery projects and enhanced coalbed methane production

<u>Business Climate</u>

- sufficiently low CO_2 price

<u>System Linkages</u>

- Network

Funds Required: $10 million per year (split 50/50 between government and industry) for 25 years. Current funding is at $3 million level (???) split between ARC, CANMET and U of Regina

CO_2 FROM CEMENT PRODUCTION

Issue

Cement is a mixture of inorganic materials – mainly lime, sand, alumina, iron and gypsum. Cement production emits carbon dioxide at the rate of approximately one tonne of CO_2 per tonne of cement produced. This CO_2 results partly from the conversion of limestone to lime, and partly from the carbon-based fuels used to fire the kilns. Supplementary cementing materials such as fly ash from coal-fired power plants, slags from steelmaking, and others can substitute for cement, thus reducing the associated CO_2 emissions.

Technological Overview and Status

Pozzolanic materials such as fly ash and slag can be incorporated into concrete as a substitute for cement. Most grades of Portland cement contain 60-67% lime by weight. For every tonne of Portland cement produced, around 500kg of carbon dioxide is released in the calcining process of dissociating CO_2 from limestone ($CaCO_3$) to make lime (CaO). About another 400kg is released from the combustion of fuels in the kilns. In order to reduce GHG emissions from cement production, supplementary cementing materials (SCMs) such as fly ash from coal-burning plants and blast furnace slags from steel plants can be used in place of cement in the manufacture of concrete. The addition of these SCMs can occur at the cement plant or at the concrete mixing plant. At either location the use of SCMs to displace cement results in a reduction in overall CO_2 emissions.

Timeframe to Commercializaiton: short term (before 2008).

Canadian Innovation Capacity

NRCan estimates that SCMs, principally fly ash, met about 8% of Canadian cement demand in 1995. This utilized about 15% of the total fly ash available in Canada. Although not all fly ash is suitable for use as an SCM, there is potential to increase the use of fly ash and other SCMs. When used, SCMs typically substitute for up to 25% of the cement in a given concrete mix. In appropriate applications (e.g., mass concrete in foundations, roller compacted concrete for roads) as much as 60% substitution of cement has been successfully demonstrated, although this level of replacement is not common practice. Factors inhibiting increased use of SCMs include the associated reduction in early strength, availability of suitable SCMs, the need for added plasticizers, and user (or owner) specifications. However, several factors encourage greater usage, including significantly decreased concrete permeability, and hence greater concrete durability, and high long-term strength. Canadian universities (e.g. University of Sherbrooke, University of New Brunswick) and government laboratories (e.g. Natural Resources Canada) presently carry out research and development on cement and concrete products. The National Research Council and the Canada Centre for Mineral and Energy Technology (CANMET) are involved with applied R&D; CANMET in particular has strong expertise in SCMs. The Canadian Standards Association, Levelton Associates, Ortech, Golder, and other engineering and materials testing firms are also involved in cement- and concrete-related technology development.

Market Potential

Key areas for Canadian regional markets of pozzolanic materials are concentrated in British Columbia, Alberta, Ontario and Quebec, with a share of 85% of Canada's building construction. There are an estimated 600 to 700 concrete producers operating at approximately 1,100 mixing facilities across Canada. Canada also has 18 cement plants operating in six provinces across Canada, with the majority of the production occurring in Ontario (40%) and Quebec (25%). Most of the international transport of concrete occurs via low-cost marine routes (the Great Lakes, St. Lawrence River, Pacific Coast). Twenty-five Canadian coal-fired power plants are operated by provincial utilities (such as Alberta Power, Ontario Power Generation, SaskPower, Nova Scotia Power, and New Brunswick Power) which generate fly ash waste. Ferrous and non-ferrous smelting plants across Canada (such as Dofasco, Inco, Noranda) can provide slag, which, along with fly ash, can be substituted within cement and concrete mixtures.

To promote the use of supplementary cementing materials with the intent to reduce GHG emissions, 'low cost', 'free of charge' or even 'credits' would encourage the incorporation of fly ash and slags into cement and concrete mixtures. Substitute materials can offer a low-cost replacement for cement in concrete. For example, whereas cement prices are $110-130 per tonne, fly ash and slags are only one-quarter to one-half that amount, at $30-60 a tonne (Sept 1998, Ontario prices).

Barriers to Commercial Opportunities

The principal barriers to greater use of SCMs are: lack of knowledge of the suitability of SCMs (and even wrong beliefs about performance); lack of high-profile demonstrations, especially for high-volume fly ash (HVFA) concretes (containing 50% or more fly ash), which would show that the technology is feasible; and conservatism on the part of specifiers of materials for construction.

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of this technology have been identified. These barriers can be overcome through concerted efforts by both user and supply industries, as well as the research community. Some suitable measures are as follows:

<u>Knowledge Infrastructure</u>

There are few R&D issues remaining to be solved. One of these is development of an appropriate de-icing salt scaling test. HVFA concretes perform poorly under the current ASTM test for scaling (i.e., surface deterioration) in the presence f de-icing salt.

However, in practice HVFA concretes perform well. There is a need for research into the mechanisms active in the ASTM test, and to develop a test that better corresponds to actual usage

There is a strong ongoing need for technical support, for several reasons. One is the variation in SCM properties. Although cement itself varies considerably in its make-up, SCMs – particularly fly ash – vary more. Each new concrete mix must be carefully designed and tested to ensure the desired properties are consistently achieved. Further, HVFA concretes require the use of super-plasticizers as additives to ensure good workability and final strength. Sound technical advice, e.g., from CANMET and the manufacturers of these additives, is a prerequisite for good performance, especially until use of HVFA concretes is widespread.

<u>Commercialization, Demonstration</u>

High-profile demonstrations would address all of the above barriers. They would be a clear manifestation that the technology is feasible, and hence also be a source of accurate knowledge; and they would raise confidence on the part of the specifiers that SCMs are valid. Appropriate demonstrations include roads – preferably high profile like the Trans-Canada highway – built with roller-compacted HVFA concrete, and high profile "green" buildings. These would complement existing high-SCM projects, of which the best known to date is the Confederation Bridge linking PEI and New Brunswick.

<u>Business Climate</u>

The issue of specifications can be addressed in part by the knowledge imparted by demonstrations and seminars, and also by federal example. All buildings that have federal support in whole or in part should include a condition that SCMs be used to the maximum level consistent with required performance. Issues such as credit for use of SCMs – and hence reduction of carbon dioxide emissions – should also be addressed.

<u>System Linkages</u>

Seminars across Canada, aimed at the architectural and construction community, would directly address the knowledge issue; articles in the technical and even lay press should support these.

Funds Required: $1 million per year for five years for the measures listed under 'knowledge infrastructure and commercialization & demonstration'. Of this amount, approximately half would be public funds, and the rest would be supplied by industry.

TECHNOLOGIES TO CAPTURE METHANE FROM LANDFILLS

Issue

Landfill gas (LFG) is a naturally occurring product of the anaerobic decomposition of organic wastes in landfills. It is approximately 50% methane and 50% carbon dioxide, both important green house gases. When burned, the methane is converted to carbon dioxide, which has a much lower global warming potential. Solid waste disposal on land accounted for 3% of Canada's GHG emissions (970 kt of CH4, or 20Mt of CO2 equivalent) in 1996.

LFG utilization systems collect and purify methane for use as fuel. Besides directly reducing the GHG potential by use of the methane in landfill gas, the substitution of purified LFG for other fuels such as coal, fuel oil, gasoline, and diesel by cleaner methane significantly reduces GHG emissions.

Technological Overview and Status

There are two main options for reducing GHG emissions from landfills: energy utilization and simple combustion. For the first option, the methane in the landfill gas is collected and treated for use as a fuel in several energy sectors. Low energy content methane can be used on or near the site for heating purposes, medium energy content methane can be used to generate electricity, preferably in co-generation systems offering higher energy efficiencies. High energy content methane can be injected into local pipelines or it can be compressed or liquefied for use as a transportation fuel

Before the methane can be used as a fuel, it must be collected and treated to remove particulates, water, corrosive compounds and other impurities. Several existing techniques can be used but typically are only cost effective for the larger landfills (those with greater than 3 MMscfd of LFG). CO_2 separation technologies include amine scrubbing, cold methanol absorption, pressure swing absorption (PSA), molecular membranes and sieves.

Evolving technology using the solvent capability of CO_2 and cryogenic purification/liquefaction promise to reduce the cost of bulk separation of clean LFG. Further R&D and commercial prototype demonstrations are required to lower the cost of these technologies for LFG treatment. The importance of these evolving technologies is their ability to convert the LFG into a higher value energy form that can be used in various sectors as a replacement for fuels that emit higher amounts of GHG emissions.

The second option for reducing GHG emissions from landfills is to combust the methane in untreated LFG in a flare without any energy recovery. While this is a simple option with limited cost liabilities for landfill owners/operators, it does not reduce emissions by substitution for other fuel usage and it does not create any wealth for Canada by converting LFG into high-value fuel.

Ancillary benefits to the capture of methane gas from landfills can include improved effluent runoff; sale of soil by-products; reduced odor; reduced groundwater contamination, and; reduced toxic and VOC emissions.

Timeframe to Commercialization: Short term: up to 2008

Canadian Innovation Capacity

There are very few Canadian companies in the business of selling products and services in support of landfill gas collection and utilization. Companies participating in this business are typically not solely dedicated to the landfill gas business, as the demand for new landfill systems is very limited. Canadian firms largely distribute products designed and manufactured in the United States, Japan, or Europe.

Market Potential

There is a large market potential for Canadian firms to develop landfill gas technologies and to market them domestically and internationally. Small to medium sized companies require financial support to enter into this market and require opportunities for project demonstration.

Barriers to Commercial Opportunities

The following represent barriers to domestic implementation and to international sales:

- Opportunities to facilitate demonstration projects are lacking
- Grid hook-up and net billing opportunities are lacking
- Lack of networking between suppliers and users
- Cost of technology is expensive for smaller landfill sites
- Difficulty in getting capital particularly for small to medium sized companies
- Lack of international experience
- Cumbersome provincial permitting process
- Not enough people with appropriate skill set (i.e. Biotechnology)
- Safety issue

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of this technology have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. Such a process must involve both user and supply industries as well as the research community with competence in this technology area. A suggested listing of potential measures to enhance innovation include:

<u>Knowledge Infrastructure</u>
- Need knowledge of safety equipment and procedures
- Need for R&D funding at Universities to encourage new idea development

Commercialization, Demonstration
- Small to medium sized companies need access to capital

Business Climate
- Deregulation of electricity sector
- Tax credit for innovative commercial development of "lower GHG fuels"
- Make returns on investments by individuals into qualified ventures that reduce GHGs and produce wealth for Canada tax free

System Linkages
- Need to engage governments at the municipal level

Market Linkages
- Need to support networking opportunities between suppliers and users
- Greater access to information and awareness programs
- Incentives for use of LNG as a heavy duty vehicular fuel

Human Resources
- Targeted training programs in international business
- Need to have more micro-bioengineering based courses
- Graduate level scholarship programs in targeted areas that will reduce GHGs.

Funds Required: $1 million/year over the next ten years split between the federal government (50%), the provincial governments (25%) and the private sector (25%).

METHANE FROM MANURE MANAGEMENT

Issue

Anaerobic digestion of livestock manure is a technology which captures methane emissions from organic animal waste to use as a fuel or to generate electricity, thereby offsetting carbon dioxide emissions at the farm and at fossil-fuel fired power plants. When burned as fuel, the methane is converted to carbon dioxide, which has a much lower global warming potential. Manure management accounted for 0.7% of Canada's GHG emissions (210kt of CH_4, or 4.4Mt of CO_2 equivalent) in 1996. An estimated 30% of manure-related CH_4 emissions in Canada could be reduced from the application of anaerobic digester technology.

Technological Overview and Status

There are three main types of anaerobic digesters, namely: (i) plug flow; (ii) complete mix systems; and (iii) covered lagoons. Plug flow digesters are constant volume flow through units that decompose high solids (>11%) manure from dairy farms. Complete mix digesters are heated, mechanically-mixed tanks that decompose swine and dairy manure (3-8% solids) to produce biogas and biologically stabilized effluent. Covered lagoon digesters contain a floating impermeable cover placed over the surface of a manure treatment/storage lagoon.

Anaerobic digesters have been operating for many years in the municipal wastewater and agri-food sectors. They have not gained widespread application in the area of manure management. Several Canadian farms installed anaerobic digesters in the late 1970's and early 1980's, however they were not successful because of the poor state of the technology at that time. Currently there are no known farms in Canada that have operating units and only 25 are in operation in the U.S.

One of the primary benefits (beyond a reduction in methane emissions) of anaerobic digesters is that they produce significant quantities of biogas which may be used as an on-farm energy source. In addition, anaerobic digesters can also increase farm revenues from the sale of manure by-products as soil amendments and compost enhancers. Methane recovery also reduces unpleasant odour and helps reduce the chances for surface and ground water contamination.

Timeframe to Commercialization: Short term: up to 2008

Canadian Innovation Capacity

Only five Canadian companies have been identified as developing anaerobic treatment systems: ADI Systems Inc. of Fredericton, N.B.; Aquasol Technologies Inc. of Edmonton, Alberta; NovaTec Consultants Inc. of Vancouver B.C.; Atara Corporation of St-Laurent, Quebec, and; Apollo Environmental Systems Corporation of North York, Ontario.

Agriculture and Agri-Food Canada (AAFC) is the primary organization in Canada conducting R&D with respect to controlling CH4 emissions from livestock manure. AAFC has 18 research centres across Canada of which 5 work in the area of manure management. In addition to AAFC, a number of universities and colleges including McGill, Guelph, University of Manitoba and the N.S. Agricultural College conduct research into manure management.

Outside of pilot projects, the market in Canada for anaerobic digesters is virtually untapped. The same can be said for the U.S. where the U.S. EPA estimates that up to 3000 dairy and swine farms may profit from methane recovery technologies like covered lagoons. The small size of Canadian farms and the colder temperatures, when compared to the U.S., significantly impacts the economics of deploying such systems domestically.

Barriers to Commercial Opportunities

The following represent barriers to domestic implementation and to international sales:

- Lack of availability of turn-key systems
- Operating such systems requires technical training
- Low winter temperatures
- Lack of information and expertise
- Opportunity to feed energy into a grid is lacking
- Lack of networking between suppliers and users
- Cost of technology is still too expensive
- Difficulty in getting capital by farmers

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of this technology have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. Such a process must involve both user and supply industries as well as the research community with competence in this technology area. A suggested listing of potential measures to enhance innovation include:

<u>Commercialization, Demonstration</u>
- Small to medium sized companies need access to capital

<u>Business Climate</u>
- Deregulation of electricity of sector

<u>Market Linkages</u>
- Need to support networking opportunities between suppliers and users
- Greater access to information and awareness programs

Human Resources
- Operator training programs for farmers
- Targeted international training programs in international business

Funds Required: $1 million/year over 10 years split between the federal government (50%), provincial government's (25%) and the private sector (25%).

ANAEROBIC DIGESTION OF MUNICIPAL SOLID WASTE

Issue

Anaerobic digestion technology for municipal solid waste (MSW) accelerates, under controlled conditions, the natural processes that occur in a landfill. The recovered methane becomes a renewable energy. Solid waste disposal on land accounted for >3% of Canada's GHG emissions (970 kt of CH_4, or 20Mt of CO_2 equivalent) in 1996.

Technological Overview and Status

Anaerobic digestion of MSW has been employed in Europe for some time where a landfill ban on organic waste is being instituted. New regulations in Canada relating to protection of groundwater and air resources have greatly increased the overall cost of siting and constructing new landfills and for their long term maintenance.

In addition to accelerating the elimination of MSW, anaerobic digestion technology recovers the methane produced. Potential revenue may be realized from the sale of electricity and a compost-like soil amendment. Other ancillary benefits include reducing the need for landfilling and incineration, thereby reducing discharges to air and groundwater and additional CO_2 credits for displaced fossil fuels.

The US EPA has concluded that the largest source of manmade CH_4 entering the atmosphere is from landfilled MSW. A study of options (Environment Canada) for management of MSW concluded that anaerobic digestion with energy recovery is more effective in reducing net GHG emissions to the atmosphere than any other generic MSW management option (recycling, composting, incineration, landfilling, pyrolysis, fermentation, etc.)

Timeframe to Commercialization: Short term up to 2008 **-** Major urban centers (e.g. Toronto, Montreal) are close to exhausting current landfills. Incentives to encourage this waste diversion technology are required now before large new landfills are sited**.**

Canadian Innovation Capacity

National Research Council - R&D

University of Manitoba Environmental Engineering group - R&D

The Canadian company Eastern Power Ltd. and its affiliate, Super Blue Box Recycling Corp., have developed an enhanced anaerobic digestion process called SUBBOR, which provides more complete MSW digestion and removal of heavy metals and results in maximum recovery of the methane potential of MSW with almost no requirement for landfill. This patented technology gives superior results to European competitors in relation to energy yields and metal removal. Research results indicate a potential to realize 2.8 t CO2 reductions for each tonne MSW treated relative to the landfill option (a 90Mt potential reduction for Canada).

University of Guelph is collaborating (with Eastern Power) on agricultural usage of digestor products (R&D and graduate training).

Market Potential

Technology presents large opportunities for Canadian equipment, construction and services providers

Barriers to Commercial Opportunities (priority ranked)

The following represent barriers to domestic implementation and to international sales:

- No public demonstrations to show both the technical and economic feasibility of the new technology
- Continued acceptance of landfilling (no planned restriction for organics)
- Low tipping fees in certain jurisdictions
- Poor economies of scale for small or remote communities
- *Competing technologies such as recovery and recycling, incineration, fermentation, pyrolysis to produce fuel oils, and gasification to produce fuel gases*
- Lack of information and expertise
- Opportunity to feed energy into a grid is lacking
- Lack of networking between suppliers and users

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of this technology have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. Such a process must involve both user and supply industries as well as the research community with competence in this technology area. A suggested listing of potential measures to enhance innovation include:

<u>Knowledge Infrastructure</u>

- Federal and Provincial Government recognition of technology benefits and verification of results and GHG credits. Workshops with municipalities to provide information in non-commercial forum. Integrated approach to planning that encourages new technologies on an equal footing.

<u>Commercialization, Demonstration</u>

- Canada needs a large scale commercial demonstration (Toronto , Montreal ,etc) where >250,000 t MSW/yr can be treated; this to establish technology on scale similar to European installations and show competitive to conventional high volume alternatives (landfill, incineration). Technology provides an opportunity to tie in with infrastructure funding program to municipalities.

Business Climate
- Deregulation of electricity of sector
- Require utilities to purchase renewable energy
- Introduce disincentives for disposal of organic wastes

System Linkages
- Need to support networking opportunities between suppliers and users
- Greater access to information and awareness programs
- ETV recognition of Climate friendly technology - tie in with USA verification programs

Human Resources
- Need to have more micro-bioengineering based courses
- potential for graduate training through industrial programs in collaboration with University of Guelph etc.

Funds Required: Partial funding for first full-scale demonstration ($5M)

NITROUS OXIDE (N_2O) FROM FERTILIZERS

Issue

Technologies or management practices to reduce N_2O emissions from fertilizer application can be used to achieve short term sequestration. This includes fertilizer management practices; nitrification inhibitors; irrigation water management; organic farming; and substitution among fertilizers. Agricultural soils accounted for 4.5% (100kt of N2O, or 30Mt of CO2 equivalent) of Canada's GHG emissions in 1996.

Technological Overview and Status

Fertilizer management practices involve matching mineral fertilizer to crop requirements. By matching fertilizer input with crop requirements, the demand for fertilizer decreases which in turn decreases the amount of N_2O emissions. This includes, but is not limited to, such activities as using nitrogen testing kits to more closely match crop requirements to nutrient inputs; or paying careful attention to the frequency, timing and appropriate placement of fertilizer applications. Nitrification inhibitors are chemicals applied with fertilizers that slow down the nitrification process and thus the release of N_2O emissions. Water management can reduce N_2O emissions by preventing water-logging (i.e. oxygen depletion) of solid and by reducing leaching of nitrate, some of which may eventually be converted to N_2O. Ancillary benefits are improved water quality and water conservation.

Organic farming does not include nitrogen-based fertilizers. Through crop rotations, organic farmers have a slower release of nitrogen that is evenly spread throughout the growing season as compared to fertilizers which have a large nitrous oxide release directly following fertilizer application. However, these systems rely on N inputs from legumes and manures which can generate high amounts of N_2O. Substitution among fertilizers includes substituting anhydrous ammonia fertilizer with other less N_2O emitting fertilizers such as urea, ammonia sulfate, ammonium nitrate, nitrogen solutions and calcium ammonium nitrate. The farming industry has indicated that individual nitrogen based fertilizers are completely substitutable with each other, however, some scientists have begun to question the validity of substitution.

Each of these technologies/management practices has economic benefits for farmers and are adaptable by the farming community in general. Demonstration projects and awareness programs would ease the transition from present fertilization practices to less N_2O emitting technology practices.

Timeframe to Commercialization: Short term: up to 2008

Canadian Innovation Capacity

Agriculture and Agri-Food Canada (AAFC) have conducted a substantial amount of research with respect to N_2O emissions from fertilizers and soils in general over the last 5 years. AAFC and several Canadian universities have already proven that some of these technologies/management practices are promising (ie. Precision farming, nitrification inhibitors, slow release fertilizers). Research funding for future projects is anticipated to have less funding than previous years. Research to date has shown that net economic benefits are gained by using these technologies and management practices. Canadian farmers need to be encouraged to test these technologies and management practices and begin recognizing the economic benefits that will result from their implementation.

There is a significant market potential for Canadian farmers to implement these technologies and management practices and then market them overseas.

Barriers to Commercial Opportunities

The following represent barriers to domestic implementation and to international sales:
- Awareness among farmers to use alternative technologies and improved management practices
- Lack of opportunities to demonstrate technologies and improved management practices
- Information sharing and networking between users and suppliers is lacking

Suggested Measures to Enhance Innovation

- A number of challenges to the realization of the innovation potential of this technology have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. Such a process must involve both user and supply industries as well as the research community with competence in this technology area. A suggested listing of potential measures to enhance innovation include:

<u>Knowledge Infrastructure</u>
- Develop efficient ways of utilizing the N in animal manures, so it is not released as N_2O

<u>Commercialization, Demonstration</u>
- pilot testing and demonstration of fertilizers and management practices

<u>System Linkages</u>
- create networking opportunities between the users/suppliers, academic/private sector and government
- provide information awareness programs for users and suppliers

Market Linkages
- support the networking opportunities between users and suppliers

Funds Required: $2 million/year over 10 years split between the federal government (50%), provincial governments (25%) and the private sector (25%).

HYDROGEN

Issue

Hydrogen is a carbon-free energy carrier that can be used to fuel transportation vehicles, provide process heat for industrial processes, supply domestic heating needs through cogeneration or heat recovery systems, supply domestic and commercial and cooking and baking needs, and fuel power plants for centralized, distributed or portable power generation.

Technological Overview and Status

Hydrogen as an energy carrier and as a fuel for transportation and other uses offers a long-term, high-reduction mitigation technology, especially if production is based on non-fossil renewable fuel sources such as renewable electricity, biomass and solid wastes, or from non-fossil sustainable energy, such as nuclear fission. Production methods include electrolysis and photoelectrolysis of water, biomass gasification and pyrolysis, and photobiological techniques. If the hydrogen is made from carbon-containing energy sources, such as fossil-fuel based electricity or by steam reforming of natural gas, CO_2 appears as a concentrated by-product, which has to be sequestered.

Lightweight hydrogen storage systems have been developed for safe storage of compressed hydrogen and liquid hydrogen. Other hydrogen storage technologies, which require on-going research, are metal hydrides, gas-on-solid adsorption (including carbon nanotubes), and glass microspheres. Hydrogen can store energy and distribute it as needed and at a significantly lower cost than by electricity transmission when in large quantities and over long distances. Hydrogen is used in small industrial applications and as a feedstock in the refinery, fertilizer, chemical and food industries. However, its use to replace fossil fuels in transportation (e.g. fuel cells to power vehicles with electric power trains and internal combustion engines) and for stationary applications, such as remote power generation systems, has been limited to demonstrations.

Hydrogen is already being used for fuel cell engines in prototype vehicles (transit buses and cars). Hydrogen can also be used in internal combustion engines with significant reductions in greenhouse gas emissions and no carbon dioxide if the hydrogen is produced from a renewable or sustainable energy source. Hydrogen is the cleanest alternative to diesel electric generators for stationary applications in remote areas and makes sense in conjunction with, for example, wind energy or hydroelectricity. With further development of the required technologies, it is possible to achieve energy self-sufficiency in remote areas blessed with indigenous renewable energy sources, using hydrogen and electricity as the only two energy carriers. The required technologies are being developed now.

Timeframe to commercialization: Mid to long term (2008 to beyond 2012)

Canadian Innovation Capacity

The ultimate GHG reduction potential is huge should hydrogen significantly displace fossil fuels as an energy carrier, although account has to be taken of the full life cycle. R&D in Canada has been coordinated by NRCan (PERD and the CANMET Energy Technology Centre) and the NRC. Significant hydrogen R&D programs exist within the Hydrogen Research Institute at Trois-Rivières, University of Victoria, University of Toronto, McGill University, Powertech Labs (Vancouver), Armstrong Monitoring (Ottawa), Tektrend International (Montreal). Use of hydrogen in the upgrading of oil sands to refinery-acceptable feedstocks is studied at the National Centre for Upgrading Technology (NCUT) at Devon, Alberta,

Stuart Energy Systems operates research facilities in Toronto and Grand-Mère, QC. Buses operating in Vancouver use an electrolytic hydrogen generation unit, built by Stuart Energy Systems, to provide pure hydrogen to fuel cells supplied by Ballard Power Systems. This is Canada's first demonstration of a zero emission fuel cycle, since hydroelectricity is used to produce the hydrogen for the fuel cells.

Dynetek Industries Ltd. (Calgary) is developing composite hydrogen storage tanks for compressed hydrogen. These are being used in all of the ballard fuel cell buses and in the Ford P2000 prototype car as well as in about 16 other countries. The Dynetek cylinders are the world's lightest certified containers for compressed hydrogen. The Hydrogen Research Institute (Trois Rivières) is addressing hydrogen storage in carbon materials.

H2T/Hydro Quebec (Montreal) is pursuing hydrogen systems development, including transportation of liquid hydrogen over large distances. GL&V Hydrogen Technologies Inc. of Montreal is developing pressurized water electrolysis systems.

Market Potential

Because of the interest in fuel cells in the transportation sector and because of deregulation of electricity generation, opportunities now exist for commercially viable electrolytic hydrogen production in several countries. Therefore, the deployment of hydrogen in the economy, the domestic and international market potential for hydrogen technologies is considered to be medium to large. For example, Stuart Energy Systems is developing a Personal Hydrogen Fuel appliance that the Ford Motor Company (USA) will test free of charge in conjunction with its prototype P2000 fuel cell car. This hydrogen refueler is equally applicable to internal combustion engines and could be located at a service station, small fleet operation, etc. The electrolytic hydrogen generation unit in Vancouver for refueling fuel cell buses is applicable to larger fleets, etc. Therefore, the potential for sales of hydrogen technologies appears to be large.

Barriers to Commercial Opportunities

- high cost of electricity in some areas when produced by electrolysis of water
- low efficiency when made from non-electrolytic sources, e.g. steam reforming of natural gas
- lack of storage and distribution supporting infrastructure
- vehicle storage capacity
- public perception of safety issues
- lack of competition in energy supply

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>
- increased R&D effort

<u>Commercialization, Demonstration</u>
- demonstration of Stuart Energy Systems electrolysis technology
- demonstration of more efficient fossil-fuel reforming
- demonstration of production from biomass gasification and pyrolysis

<u>Business Climate</u>
- increased effort in the development of standards and codes (national and international)
- rationalization of current codes, standards and practices which impinge on the new hydrogen technologies

<u>System Linkages</u>
- improved linkages and partnerships between stakeholders

<u>Market Linkages</u>
- identification and implementation of opportunities for hydrogen use, both nationally and internationally

<u>Human Resources</u>
- training programs to use the emerging technologies, with emphasis on safety

Funds Required: $10 million/year from governments which would be levered by an equivalent amount by industry. Over and above this, large industry players (Dynetek, Electrolyser/Stuart) will be making marketing and commercialization investments of several 10's of millions of dollars.

ENABLING TECHNOLOGIES

Issue

Enabling technologies help improve the efficiency of energy production, transmission, and utilisation across a broad range of industry sectors. Examples include electrotechnologies, advanced materials, catalysts, biotechnologies, and storage technologies.

Technological Overview and Status

Electrotechnology refers to a system or a piece of equipment that uses electricity to manufacture or transform raw materials into intermediate or finished goods. This represents a broad category and encompasses more than thirty different technologies including motor drives, electrolytics and process heat, drying and curing technologies. Electrotechnologies designed for process heat applications include electric arcs, plasmas, induction, resistance, and lasers for high temperatures, and microwaves, radio–frequencies, infrared, heat pumps, membranes, electrosynthesis and ultraviolet for low temperatures. Another category of electrotechnology is the production of electricity using specialized materials including pyroelectric and thermoelectric conversion of residual industrial heat to electricity.

Advanced materials include new materials, composites, or manufacturing techniques developed to create or ameliorate a desired physical property. Examples include: low-weight materials such as composite materials and aluminum and plastics for transport vehicles; high temperature-resistant materials for nuclear reactors or space vehicles; strong light-weight composites for wind turbine blades; low cost manufacturing techniques to produce semi-conductors.

Catalysts are substances that lower the energy required or increase the production rate for a chemical reaction without being consumed themselves. Catalysts aid in the production of chemicals and fuels and are used in the production of nearly 20% of all consumer products. Advanced catalysts provide improvements in operating environment, productivity, reaction kinetics, specificity, and catalyst life.

Biotechnologies can be employed to replace chemical processes thus reducing reliance on fossil fuels and chemical feedstocks. Examples include:
- bio-catalytic processes that occur at mild conditions as a substitute for energy-intensive processes;
- biomass as a non-petroleum feedstock (i.e. product substitute) for producing industrial chemicals and hydrogen; and
- processes/products in which biotechnology indirectly reduces reliance on fossil fuels in the non-energy sector.

Storage technologies are used to store energy (e.g. thermal or chemical storage), electricity (e.g. batteries, pumped water, compressed air, superconducting magnets, supercapacitors), or mechanical power (e.g. flywheel) on a temporary basis.

Other examples of cross-cutting technologies or tools include systems analysis, modeling, design, and simulation (e.g. life cycle costs and impacts; and process optimization), advanced sensors and control, artificial intelligence and low-energy separation technologies (e.g. membranes). These technologies will not be explored here.

Timeframe to Commercialization: short, medium and long term.

Canadian Innovation Capacity

There is a limited amount of domestic suppliers of and research into *electrotechnologies*. In fact, the LTEE is the largest RD&D laboratory in Canada on electrotechnology. There are others actors in the area: others utilities, universities and research organizations.

There is a significant amount of Canadian technological capacity in developing *advanced materials* for the automotive sector. Research is focused on light-weight material, such as plastic raw materials and lightweight finished products, and light aluminum and magnesium alloy castings. The British Columbia Research Institute is one player in this area.

A number of organizations are currently conducting R&D work in the field of *catalysis* in Canada. The National Centre for Upgrading Technology (NCUT) is a Canada-Alberta research alliance formed to advance technologies for converting heavy oil and oil sands to value added products, and transportation fuels in particular. The NCUT fulfills a critical need for Canada's energy sector by providing specialized hydrotreating tests as a turnkey operation to catalyst users. Another centre of expertise in catalysis resides at CANMET Energy Technology Centre. It provides catalysis R&D for emissions reduction and the development of carbon and energy efficient conversion processes (e.g. gas-to-liquids technology). The Alberta Research Council, Environmental Science and Technology Canada, Université Laval, University of Calgary, the University of British Columbia and the University of Waterloo are some of the other organizations conducting research into catalysis.

The Canadian *catalyst* market is largely serviced by multinational suppliers. For example, Criterion Catalysts is a major supplier to the Canadian oil and gas industry and Degussa, for the transportation sector. Other suppliers of catalysts to the Canadian market include, but are not limited to, BASF Canada, Bayer, Bryce Industries and Engelhard Canada.

Within Canada, a small *bio-upgrading* research group is forming that involves government, universities and private sector companies. This includes CANMET's Western Research Centre and the University of Alberta. It is not possible to clearly say what Canada's potential capabilities are in terms of researching, developing and supplying other biotechnologies.

BIOCAP is an emerging Centre of Excellence initiative focused on *biological solutions* to the issue of climate change. Important federal government players in the field include Industry Canada and the National Research Council.

There is not much research being pursued in Canadian on *storage* technologies. NRCan has funded flywheel technology since 1994 through PERD, and thermal storage though its passive solar buildings program. Hydro-Quebec/3M and US's partners have an important development program on a lithium-polymer electrolyte battery for use in electric vehicles.

Market Potential

Many *electrotechnologies* represent a relatively mature technology with many of them having been commercialized for many years. However a large number of industrial processes which could reduce emissions and increase efficiency have not yet entered the market as they need to be demonstrated. In particular, many chemical products could be produced using electrosynthesis. The impetus for further expansion of the market could come from regulatory measures on environmental issues.

There is a large and broad demand for *advanced materials*, both inside and outside the energy-related sectors. In the automobile industry, for instance, there will be increasing demand for magnesium (at the expense of aluminum and steel to some degree) and the continued or increased use of plastics. Composites, such as fibreglass, will become prominent in the short-term.

Global demand for *catalysts* is more than C$14 billion year in four major market segments: petroleum refining catalysts; polymerization; chemical processing catalysts; and environmental. Environmental catalysts have been the fastest-growing segment of the market in the 1990s as firms seek to comply with health, safety and environmental legislation to decrease emissions, toxic by-products and chlorinated materials.

Given the importance of the petroleum industry worldwide and in Canada, and the declining reserves of higher quality crude, there is an opportunity to apply *bio-upgrading* on a wider scale. Cost increases in coking and hydrotreating, environmental initiatives to reduce sulfur and greenhouse gas emissions and the increasing costs to meet new environmental standards are likely to foster the development and commercialization of the technology over the long term. Bioprocess technologies may also be applied to Canada's pulp and paper, mining, chemical and other sectors.

There is a misconception that *biotechnology* is still in the laboratory and that it will not be relevant as a technology to address GHG for decades to come. A recent OECD document "Biotechnology for Clean Industrial Products and Processes" indicates that "Industrial biotechnology has come of age" and catalogues a number of applications in major industry sectors where biotechnology is already contributing to increased energy efficiency, utilization of renewable C and to paradigm shifts which save energy and reduce production of waste and hazardous waste in particular.

A little known fact is that Canadian companies (outside those developing biotechnology as their main business) are already using *biotechnology* as one of the technologies in their normal day-to-day business. In a first-of-its-kind study, Statistics Canada (1998) surveyed the use in 1996 of biotechnologies by major Canadian companies (sales >$5M) in a number of key industry sectors. Of approximately 2000 companies about 10% reported using biotechnology, mostly for end-of-pipe cleanup. But a number reported using biotechnology up the pipe for processing purposes.

Storage technologies have greatest potential where there are benefits to matching demand and supply for energy. Remote areas inaccessible to the electricity grid provide a fair market for batteries in wind and solar energy systems. Where electricity pricing has been liberalized and the pool price reflects the marginal cost of supply, utilities and consumers have an incentive to invest in electricity storage. The demand for electrical or more efficient cars will spur the market for other storage technologies.

Barriers to Commercial Opportunities

High capital costs present a significant barrier for *electrotechnologies*, despite the potential to improve productivity. High electricity costs may also inhibit uptake in certain regions.

High costs impede the development and adoption of *advanced materials*. There can also be difficulties in manufacturing a high quality, reliable product at the early stages of development. Low energy costs can mitigate against light-weight materials that help reduce energy consumption.

The major barriers to developing new *biotechnologies and catalysts* are scientific and technological. Scientific research and testing requires significant capital input while immediate applications may be limited when equipment changes or redesign of the manufacturing plant is required. Only the largest industry players will be able to absorb these higher development and implementation costs, and these may be delayed for the long-term until a new plant is required.

Cost is also a major barrier for *storage* technologies. There are also technical barriers, including: improved reliability and extended life are key challenges for batteries; safety concerns for flywheels; favourable geology and proximity to a transmission grid for compressed air facilities; greater system integration and simplification for superconducting magnets; reduced component defects and increased inductance of ultracapacitors.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>

- Encourage joint ventures, research collaborations and partnerships, including with universities.
- More strategic research required, with appropriate protection of intellectual property for the benefit of Canada.

<u>Commercialization, Demonstration</u>

- Technology transfer. Pilot testing and demonstration programs required to develop and refine biotechnologies, catalysts and newer electrotchnologies such as electrosynthesis, pyroelectric conversion and membranes technologies.

<u>Business Climate</u>

- Provide appropriate economic incentives, especially for capital investments and through 'Green' tax credits.

Funds Required: $50 million per year.

BIOTECHNOLOGIES

Issue

Biotechnologies can be employed to replace chemical processes thus reducing reliance on fossil fuels and chemical feedstocks. Examples include:

- biocatalytic processes as a substitute for energy-intensive processes;
- biomass as a non-petroleum feedstock (i.e. product substitute) for producing industrial chemicals; and
- processes/products in which biotechnology indirectly reduces reliance on fossil fuels in both the energy and the non-energy sector.

Biotechnologies have much to offer to the Canadian resource industries in terms of increased productivity and lower environment impacts/costs. In many cases [they] biotechnology companies are emerging as suppliers of novel process technologies and strategic alliances and acquisitions are beginning to occur. The interest of major user firms is important not only from the resources flowing from alliances but also in terms of validating the value of the sector for the investor community.

Technological Overview and Status

A growing number of companies are involved in using biotechnology and biological systems to develop products and services which either solve environmental problems or result in a net benefit to the environment. The distinctive feature of biotechnologies is that they utilize or mimic aspects of natural ecosystems and thus they offer the best potential for developing long term sustainable solutions to problems of environmental biodegradation resulting from growth of human populations and industry.

Given the importance of the petroleum industry worldwide and in Canada, and the declining reserves of higher quality crude, there is an opportunity to apply bio-upgrading on a wider scale. Cost increases in coking and hydrotreating, environmental initiatives to reduce sulfur and GHG emissions and the increasing costs to meet new environmental standards are likely to foster the development and commercialization of the technology over the long term. Bioprocess technologies [may also be] are already being applied [to] in Canada’s pulp and paper, mining, chemical and other sectors [e.g. food processing].

Canadian companies (outside those developing biotechnology as their main business) are already using biotechnology as one of the technologies in their normal day-to-day business. In 1996, Statistics Canada surveyed the use of biotechnologies by major Canadian companies (sales >$5M) in a number of key industry sectors. Of approximately 2000 companies about 10% reported using biotechnology, mostly for end-of-pipe cleanup. But a number reported using biotechnology up the pipe for processing purposes.

The environmental bio-industry in Canada consists mainly of specialized SMEs which are focused on specialized niche markets and which are located in most regions of Canada. These SMEs account for approximately 11% of the companies and 3% of employment in the overall Canadian bio-industry. In addition, there are a number of larger consulting engineering firms which are active in the market sometimes forming alliances with the SMEs and sometimes competing with them. The industry is largely focused on remediation markets with only a few firms focusing on cleaner production and renewable feedstocks. However, with major companies such a Dupont Canada moving to incorporate biotechnology into their future operations, the level of activity relating to cleaner production and renewables is expected to increase significantly in the short term.

Timeframe to Commercialization

There is a misconception that biotechnology is still in the laboratory and that it will not be relevant as a technology to address GHG for decades to come. A recent OECD document "Biotechnology for Clean Industrial Products and Processes" indicates that "industrial biotechnology has come of age". It catalogues a number of applications in major industry sectors where biotechnology is already contributing to increased energy efficiency, utilization of renewable carbon and to paradigm shifts which save energy and reduce production of waste and hazardous waste in particular. In this light, biotechnologies are ideally positioned both short term (up to 2008) and long term (post 2012) application.

Canadian Innovation Capacity

The Canadian biotechnology sector is a rapidly growing but still nascent industry in which three quarters of the businesses are small or medium-size companies. It is a research-based industry, characterized by a mixture of firms, made up of those dedicated solely to biotechnology, and of those using it as a tool to develop more traditional products and services.

Strategic alliances are an important issue for Canadian biotechnology companies. Most of them have formed R&D partnerships (e.g., with universities and research centres) and later-stage manufacturing, marketing or distribution alliances (often with large MNEs). These later-stage alliances can enable biotechnology companies to retain their product development focus and build on existing competencies, rather than vertically integrating all of the functions required for successful commercialization of their product research.

A small bio-upgrading research group is forming that involves government, universities and private sector companies. This includes CANMET's Western Research Centre and the University of Alberta. It is not possible to clearly say what Canada's potential capabilities are in terms of researching, developing and supplying other biotechnologies.

BIOCAP is an emerging Centres of Excellence initiative focused on biological solutions to the issue of climate change. Important federal government players in the field include Industry Canada [and] the Canadian Forest Service, Agricuture and Agrifood Canada and the National Research Council.

Barriers to Commercial Opportunities

The major barriers to developing new biotechnologies are scientific and technological. Scientific research and testing requires significant capital input while immediate applications may be limited when equipment changes or redesign of the manufacturing plant is required. Only the largest industry players will be able to absorb these higher development and implementation costs, and these may be delayed for the long-term until a new plant is required.

Many of the firms in the industry are generating relatively little sales because of the long product development cycles and regulatory approvals that are often required. But this will change as products move through the research pipeline and clear the regulatory hurdles. As a result, a unique characteristic of this industry is the heavy reliance on capital provided by outside investors and alliance partners.

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of biotechnologies have been identified. These need to be confirmed and a roadmap for moving ahead needs to be developed. Such a process must involve both user and supplier industries as well as the research community with competence in this technology area. A suggested listing of potential measures to enhance innovation include:

<u>Knowledge Infrastructure</u>
- Encourage joint ventures, research collaborations and partnerships, including with universities
- More strategic research required, with appropriate protection of intellectual property for the benefit of Canada

<u>Commercialization, Demonstration</u>
- Technology transfer. Pilot testing and demonstration programs required to develop and refine biotechnologies.

<u>Business Climate</u>
- Provide appropriate economic incentives, especially from capital investments and through ‘green’ tax credits.

Funds Required:

Incremental funding required = $[20] 30 M over 5 years
Public sector = $[10] 15 M
Private sector = $[10] 15M

Current level of effort on biotechnology and climate change
Public sector = (CBS, CEIS, EC-ETAD, IC-LS, BRI, PBI) (est. $2-3M/y)
Private sector = ??? (est. $ 2-3 M/y)

CATALYSIS

Catalysts can speed up chemical reactions by as much as one million fold by lowering the activation energy required. Catalysts also improve product selectivity. Because of the ability of catalysts to speed up reactions, processes can be accomplished at much lower temperatures which results in increased, productivity and energy efficiency as well as reduced GHG emissions.

Catalysts are widely used in the refining of transportation fuels (hydroprocessing, reforming, alkylation) and in the petrochemical, polymer, pharmaceutical industries and energy conversion processes. Catalytic processes are routinely utilized in pollution abatement systems for vehicles and stationary units. Catalytic processes are responsible for about 75% of chemical and petroleum processing products by value. Between 1930 and 1990, more than 60% of product innovations and 90% of the process innovations were based on catalysis.

Catalytic Technologies that impact on GHG emissions

Hydrogen demand will increase because of the increasing need for hydroprocessing to meet the low sulphur demands, for fuel cell applications and for use as a fuel. Technologies based on catalysis can offer hydrogen production at mild conditions and from non-fossil sources avoiding the enormous amounts of GHG emissions associated with conventional hydrogen production. For example, photo-catalysis relies on light as the energy source for the production of hydrogen from water.

Bio-catalysis and bio-mimetics (synthetic catalytic systems that mimic natural enzymes) offer enormous potential for achieving synthesis at mild conditions with high selectivity for targeted products. Similarly, homogeneous catalysis that is based on organometallic systems is an emerging technology that has potential for high selectivity and mild conditions for processing.

Opportunities exist for greater benefits via the development of energy-efficient catalytic processes for applications such as fuel processors for fuel cells (fuel cell technology itself is based on catalysis), the production of cleaner transportation fuels (low S diesel fuels and oxygenated fuel additives), more energy-efficient processes (for gas –to-liquids and advanced hydrogen production) and NOx reduction to nitrogen. These nitrogen oxides produce not only ground-level ozones but are also considered greenhouse gases.

Catalytic membrane reactors is a technology that combines reaction and separation simultaneously, offering high efficiency and reduced GHG emissions as well as improved economics. Catalytic processing combined with process optimization/simulation aiming at tri-generation of power, chemicals and heat is another option that should prevail in the 21st century to achieve reduced GHG emissions.

Canadian Innovation Capacity

In terms of universities, the expertise resides at: University of New-Brunswick, Université Laval, Concordia University, Ecole polytechnique,, University of Ottawa, Royal Military College, Kingston, Queen's University, University of Toronto), University of Waterloo, University of Western Ontarion, University of Saskatchewan, University of Calgary, University of Alberta, University of British Columbia.

Government research centres the CANMET Energy Technology Centre (CETC), the National Center for Upgrading Technologies (NCUT), Alberta Research Council and the Saskatchewan Research and Atomic Energy of Canada Limited (AECL).

In terms of industrial expertise, most of the basic research in catalysis is done outside Canada (at multinationals' R&D facilities in United States and Europe), some work is done in the development/improvement of catalytic processes. For example, at Calgary R&D centre of Nova Chemicals, Uniroyal Canada, Inco, Questor Industries, H Power Canada, Environair SIPA, etc.

Market Potential

High. Opportunities in clean transportation fuels, more energy-efficient processes (lower CO_2 emissions), emission control (diesel NOx removal).

Barriers to Commercial Opportunities

Too few industrial champions for commercializing novel catalytic processes. The investment for commercialization is usually high; therefore, the paradigm shift takes longer.

The routes with high potential for GHG reduction require longer term R&D and patient capital.

What needs to be done to enhance technology implementation.

Concerted, aggressive and steady R&D efforts from bench scale to pilot scale in order to be able to attract joint venture funds for large-scale demonstration and commercialization. Coordination and leadership from government centres to ensure synergy nationwide.

Funds required: $ 20 million per year in order to make a difference.

MEMBRANE-BASED SEPARATIONS

Issue

Manufacturing operations, for example, in the chemical process, agri-food and pharmaceutical industries utilize separation for recovery, purification and refining of valuable products. These separation operations are estimated to account for more than 5% of the total national energy consumption in Canada.

Technological Overview and Status

Many separations that are in use in the industry are not very energy efficient. For example , removing water in a by-product recovery operation in a fish processing plant by thermal evaporators consumes many times higher energy than that of a membrane-based technology. Adoption of membrane-based technology in 40 plants in Atlantic Canada in the above operation alone would be able to reduce annual CO_2 emissions by 24,000 tons. There are many other opportunities for membrane-based separation technology in the resource sector for recycling greenhouse gases.

For many applications membrane-based technology is ready to be used in industry whereas in other areas additional development for industrial applications is in progress. It is encouraging to note that newer products and applications are coming on-stream every year. A large number of applications have a short-term commercialization cycle. However, applications requiring approval by health and regulatory agencies might be commercialized on a medium-term basis. Applications involving the replacement of capital stock, such as oil refinery operations, would have longer term implications.

Timeframe: short, medium and longer term.

Canadian Innovation Capacity

In the area of membrane manufacturing and development, Canada has a few companies geared to the environmental and chemical process industries. There is much more industrial activity through a network of many system developers, distributors and suppliers (examples are Serval, Calgary; Zenon, Burlington, Liumar, Ottawa, Seprotech, Ottawa) of this technology representing products and processes from offshore companies throughout Canada. There is good capacity of research and development in this technology in government research laboratories (NRC, ARC, NRCan, Environment Canada), universities (Ottawa, McMaster, Waterloo, Victoria, McGill, Laval, Guelph) and other organizations (WTI, Burlington).

Barriers to Commercial Opportunities

An important barrier to commercial opportunities for Canadian companies relates to offshore domination of membrane manufacturing business. The current trend in this industry is for consolidation through mergers/takeovers, which has narrowed down the opportunities only to limited areas of customized products for niche markets.

Suggested Measures to Enhance Innovation

The way forward for Canadians in this technology area is to focus on developing new products and process systems for targeted markets.

Knowledge Infrastructure

- Encourage industry and R&D provider collaborations targeted on specific applications most relevant to Canadian needs.
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Commercialization, Demonstration

- Encourage industrial consortia to undertake first commercialization projects

Funds Required: $5 million per year

ELECTROTECHNOLOGIES PROFILE

Issue

The use of electrotechnologies , which have applications in industrial, commercial and residential sectors, has a great potential to reduce the GHG's emissions. Moreover, their use in industrial and commercial sectors contribute to the increase of productivity, product quality and working conditions.

Technological Overview and Status

Electrotechnology refers to a system or an equipment that uses electricity to power the process. The electrotechnologies can be classified as electro-specific and non electro-specific; the former need electricity to power it, e.g. dielectric heating and motors.

Electrotechnologies encompasses a large number of technologies including motor drives, electrolysis, heat pumps, and processes such as heating, drying, curing and electrosynthesis. They are known to be very flexible and facilitate the use of advanced sensors and control, and artificial intelligence.

Electrotechnologies offer opportunities for finding solutions to environmental problems by providing processes which could be more energy efficient, producing less waste or could simply replace more efficiently a fossile fuel process. A few typical exemples are as follow:
Recycling process: The use of electric-arc technology in the steel production in replacement of the blast furnace. Similarly the melting of aluminum residue and the extraction of aluminum from dross , have increased the aluminum recovery and eliminated the use of additives which reduce the quantity of waste.
Manufacturing :Electrochemical processes have the advantage of being highly selective and producing less byproducts or waste.
Heat Recovery: In commercial buildings, heat recovery using heat pumps combined with building management has reduced the energy requirements from 30 to 50%

In 1995, electricity accounted for 25% of the total energy used by Canadian industry.[1] Where electricity is generated by hydro or nuclear, the use of electrotechnologies has a significant contribution to in reducing GHG emissions. Even, in the case of electricity generated by fossil fuels, there is a benefit in using electrotechnology since fossile power plants have, in general, greater efficiency than most fossile fuel process used in industrial plants.

Timeframe: short, medium and long term.

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[1] Marbek Resource Consultants, *Climate Change Mitigation and Canadian Industry Sectors*, a report prepared for Industry Canada, March 1998.

Canadian Innovation Capacity

There is a limited amount of domestic manufacturers, but some are very active. Their R&D is rather restricted to adapting and integrating the technology to meet the client request or need.

In the last 10 to 15 tears, most of the R&D related to electrotechnologies has been done by few canadian utilities: Hydro-Québec, Ontario Hydro , British Columbia Hydro and Manitoba Hydro. In the last four years, the efforts have greatly been reduced.
Today, the LTEE of Hydro-Quebec, is the largest R&D Laboratory in Canada and probably in North America, dedicated to electric end use technologies. It has an annual budget in excess of 15M$.

There are also others actors in the area: universities and research organizations.

Barriers to Commercial Opportunities

Although, many electrotechnologies have been commercialized for many years, a large number of new or improved industrial processes which could reduce emissions and increase efficiency have not yet entered the market as they need to be demonstrated.

High capital cost is the major barrier despite the potential to improve productivity. High electricity costs may also inhibit uptake in certain regions.

The lack of consistent applications of the regulations concerning environment issues discourage enterprenors to develop new technology. The impetus for further expansion of the market could come from regulatory measures on environmental issues.

Suggested Measures to Enhance Innovation

A number of challenges to the realization of the innovation potential of this technology has been identified. Suggested measures to enhance innovation include :

<u>Knowledge Infrastructure</u>

- Information network to dissiminate results of new R&D and demonstrations..
- Expert network to bring together various experts across Canada, including equipments suppliers.
- Encourage joint ventures, research collaborations and partnerships, including with universities

<u>Commercialization, Demonstration</u>

- Pilot testing and demonstration are needed for industrials to implement new applications. From the time the technical feasibility has been shown at laboratory scale, it remains a number of technical and economic evaluations to be performed at scale-up models depending on the complexity of the process, before deciding on a First Commercial Plant.

- Technology transfer: If governments offer financial support for a demonstration project, they must ensure that the results could be made available to future potential users. This information will help to attract new users/suppliers in Canada, and will be equally very usefull for the sale on the international market.

Business Climate
- Since SME accept to invest only when ROI is short (less than 2 years), a "Green" tax incentive to encourage GHG reduction technologies would make the investment more attractive
- Governments financial support in the form of garanty loan will reduce the burden and encourage the SME to invest.
- Harmonization of federal and provincial regulations related to GHG's reductions will create a larger market bassin (canadian wide).

Linkages (System and Market)
- Linkages among climate change technology players could be achieved either a) by a Network sponsored by various industrial associations, such as the CCE, (Canadian Council on Electrotechnologies); b) by a « Technology Roadmap Initiative »; these networkings should focus on GHG-mitigation technologies.
- There is a need to harmonize the various government programs and regulations.

Human Resources
- The linkage refered above should permit to share expertise and to regroup a more efficient and qualified team of experts.

Funds Required : $35 million per year

Justifications : A laboratory like LTEE has an annual operating and capital budget between 15 M$ to 20 M$.

Each industrial scale demonstration project cost from 0.5 M$ to 10 M$.

GAS TECHNOLOGIES

Issue

"Gas technologies" is a term referring to a group of technologies specifically designed for natural gas. These technologies, by taking full advantage of the physico-chemical properties of natural gas, achieve a very high overall energy efficiency. The cleanliness of the combustion of natural gas is one of the pillars on which these technologies are based. For these reasons, gas technologies cannot operate properly when using other fuels. It is worthwhile to note that the same holds for hydrogen technologies. Gas technologies are designed specifically to burn a high methane content product such as natural gas.

Technological Overview and Status

As a substitution fuel, natural gas allows to achieve a substantial reduction of GHG emissions. On the other hand, natural gas used specifically with "gas technologies" ensures overall energy efficiency levels resulting in minimum amounts of released CO_2 by useful joule of energy.

Many gas technologies are already commercially available. To name a few, there are submerged combustion, immersed combustion, regenerative burners, condensation boilers and infrared drying systems represent some of those technologies, and are described in more details below.

<u>Infrared drying systems:</u>
Drying of goods such as paper by infrared waves is more rapid and efficient than other drying modes such as conduction or convection. Moreover, the specific characteristics of infrared radiation generated from natural gas, ranging between 0.8 and 6 microns matches more accurately the absorption coefficient of water, hence it results in a more efficient use of the energy. Infrared drying also finds a very efficient use in the textile industry and the plastic thermoforming industry.

<u>Submerged combustion:</u>
In the industry, the water heating requires an important share of the overall consumed energy. Submerged combustion is a gas technology which fulfils this industrial need in the most efficient way as the combustion products (mostly water and carbon dioxide) are in direct contact with the fluid to heat. The bubbling of combustion products in the liquid produces a considerable heat exchange surface (1 m^3 of combustion produces an exchange surface of 1000 m^2). This is why for a bath temperature of 60 C, the energy efficiency is 90 % based on the high calorific value of natural gas. Submerged combustion also results in a very rapid heat-up time due to the absence of thermal inertia. The potential markets are the chemical industry, the agri-business, metallurgy, pulp and paper, textile and many others.

Immersed combustion

This gas technology is used to heat liquid without direct contact of the combustion products with the liquid. Combustion of natural gas occurs in a heat exchanger which come in a number of shape and which adapts to various tank forms. This system, which is compact, is built to optimise the heat transfer to the bath. The energy efficiency of this technology reaches 75 to 80 % based on the high calorific value of natural gas as opposed to 50 % for the usual technologies.

Regenerative burners

The clean combustion specific to natural gas allows the use of regenerative burners. Those offer a means to increase the overall energy efficiency in the metallurgical industry. For old systems, thermal efficiency of 25 % is not unusual in this industry, the major fraction of heat being lost through the chimney. Regenerative burners is a gas technology which reduces the energy consumption by 50 to 70 % at these sites by recovering the energy otherwise lost through the chimney in order to preheat the combustion air. This technology is possible because of the physico-chemical characteristics of natural gas combustion products.

Timeframe: short term: up to 2008

Canadian Innovation Capacity

The industrial capacity required to develop new gas technologies is not beyond reach of Canadian means.

An important point in gas technologies is the need to characterise and establish the optimum conditions for optimum performances of new gas technologies. There is also the need for specific expertise and facilities to certify these new technologies. To this end we need laboratory facilities. Once the lab work is complete, entrepreneurs can commercialise these technologies. In Canada, the main labs working on gas technologies are: the Natural Gas Technology Centre (Boucherville, Qc), the Canadian Gas Research Institute (Richmond Hill, Ont.), the Centre for Advanced Gas Combustion Technology (Queen, Univ., Ont.), and CANMET.

Market Potential

The market potential is vast as it is composed of new industrial plants and of equipment replacement of old processes with gas technologies.

Barriers to domestic implementation and international sales

Economic barrier:

Gas technologies do improve productivity; nonetheless, users are reluctant to replace equipment not yet at the very end of their useful life.

Information barriers:
Gas technologies are still new to the mass of consumers, as such, we need support to inform consumers that there are alternatives using natural gas which allow to increase their productivity and reduce the pollution. The credibility of the government would help to pass the message to the Canadian industry.

Government incentives for renewable energy.
Government programs promoting renewable energy go sometimes against natural gas. For instance, subsides should be granted according to the amount of CO_2 reduced. For instance, if a high carbon fuel is displaced, then subsides should be maximal, otherwise it should be minimal when it is to displace the lowest carbon content fuel (natural gas).

Government regulations and guidelines.
Regulations and guidelines are devised in a way which hamper the environmental advantage of natural gas. Indeed, the allowed pollutant emission rates are higher for liquid and solid fuels. Such environmental guidelines neutralise the environmental advantage of natural gas over the other fuels.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure
- Devise an information program from coast to coast to inform the community of the gas technology alternative for an immediate reduction of GHG.

Commercialisation, Demonstration
- Devise an information program from coast to coast to inform the community of the result of gas technology demonstration projects.

Business Climate
- R & D targeted tax measures. Subsides for replacement of old technology by gas technologies. More operating funds for private research centres.

Estimated Incremental Level of Effort Required: $10 million a year.

SIMULATION AND MODELING

Issue

There are significant opportunities to reduce greenhouse gas emissions through improved energy efficiency by application of computational technology in energy conversion and use in manufacturing and industrial processes. With the shift from an experience based to knowledge based design, computational technology can be used to design and substitute products or processes to improve energy and material efficiency over the life cycle of a product.

Technological Overview and Status

Simulation and modeling to improve product or process design cover a wide range of scales. At the atomic scale, identification and synthesis of new materials with targeted properties is guided by molecular modeling and combinatorial methods. Catalysts designed through simulations guide selection of manufacturing processes. At the nanoscale, material composition and physical chemical properties can be designed; macroscale simulations target mechanical and chemical behaviour of manufactured materials as well as process diagnostics, optimization, and control. At the enterprise level, systems modeling targets overall systems efficiency and broad scale environmental management issues as embodied in ISO14000, for example.

Examples include computer technology to enable rapid prototyping and concurrent engineering. With associated virtual environment technology, it is possible to eliminate physical prototypes, resulting in increased productivity, higher cleanliness, lower energy and materials consumption, and faster time to market. A combination of data mining and simulation provide a route to development of system functionality based on material properties. Advanced diagnostics, data analysis, and simulation can optimize equipment maintenance schedules for maximum performance and efficiency. Modeling of relative energy efficiencies over life cycles of materials and processes provides technical assessments of alternative technologies.

Timeframe: short, medium and longer term.

Canadian Innovation Capacity

Computational technologies for simulation and modeling of processes are applied in virtually every economic sector. These include environmental models used to study climate change and ecosystem effects, capability which exists in the Canadian government and private sector.

Computational technology includes ab initial and higher level molecular modeling, data mining, computational fluid dynamics of heat and mass transfer, chemical kinetics, steady state and dynamic simulations of unit processes, mechanical analysis, artificial intelligence, combinatorial methods, data and coding standards to facilitate interchange of information. A number of Canadian engineering companies have strength in computational fluid dynamics (RWDI, Jacques Whitford, AEA) and in simulations of unit processes (Hyprotech, Crechem). NRC's Integrated Manufacturing Technologies Institute is leading the Canadian effort for data standards in computer aided design.

Barriers to Commercial Opportunities

While some sectors have already adopted computational tools for design of products and processes, others still use an experience based approach. Although this includes large companies as well as SME's, the latter face a larger challenge in accessing the technology given the barriers of cost and expertise required to use the technology. Engineering service companies can provide the expertise, but the cost can remain a significant barrier for SME's. Further developments in computational technologies are expected to involve hybrid combinations of previously developed technologies, for example combining steady state analysis of unit operations or detailed chemical kinetics with computational fluid dynamics. An ongoing critical requirement is experimental validation of computer models, a demanding and often expensive task in the case of large scale industrial processes.

Suggested Measures to Enhance Innovation

<u>Knowledge Infrastructure</u>

- Encourage research provider – industry consortia to validate models and applications critical to Canada.

<u>Business Climate</u>

- Provide appropriate economic incentives, especially to SME's, to adopt these technologies.

Level of Funds Required: $5 million per year

STORAGE TECHNOLOGIES PROFILE

Issue

The six technologies that are addressed here under energy storage for use at a later time are: Batteries; Flywheel; Pumped Storage; Superconducting Magnets; Thermal Energy Storage; Compressed Air Energy Storage; and Supercapacitors.

For electric utilities, energy storage is an energy management tool permitting to reduce peak power generation by energy generated during the period of excess power.

The reduction of GHG's emissions resulting from this use depends: a) on the energy source to perform the off-peak activity as compared with the fuel which would have been used to generate the peak power; and b) on the total efficiency of the process of storing the energy and its restitution.

For use in electric vehicles, there is a high reduction of GHG emissions, since the energy efficiency of gasoline or diesel motors is very low.

Technological Overview and Status

Storage technologies have greatest potential where there are benefits in matching demand and supply of energy. Remote areas inaccessible to the electricity grid provide a fair market for batteries in wind and solar energy systems. Where electricity pricing has been liberalized and the pool price reflects the marginal cost of supply, utilities and consumers have an incentive to invest in electricity storage.

The demand for electrical or more efficient cars will spur the market for storage technologies.

Timeframe: short, medium and long term.

Canadian Innovation Capability

There is limited research being pursued in Canada on storage technologies in general. However, Canada has an influential position within USABC through Hydro-Quebec participation in an important development program on a lithium-polymer electrolyte battery for use in electric vehicles. Over 159 man/year of specialists are presently working on that project in Quebec. Also, NRCan has funded flywheel technology since 1994 through PERD, and thermal storage though its passive solar buildings program.

Barriers to Commercial Opportunities

Cost is often a barrier, which depends on the maturity of the manufacturing processes and the volume of production, for some storage technologies such as new batteries and thermal storage. There are however major technical barriers, including: improved reliability and extended life are key challenges for batteries; favourable geology and proximity to a transmission grid for compressed air facilities; greater system integration and simplification for superconducting magnets; reduced component defects and increased inductance of ultracapacitors.

Suggested Measures to Enhance Innovation

A number of challenges to the realization of some of these technologies have been identified. Suggested measures to enhance innovation include:

Knowledge Infrastructure

- Encourage joint ventures, research collaborations and partnerships, including with universities

Commercialization, Demonstration

- Due to the wide diversity of these technologies, it is necessary to investigate and evaluate the needs of the end-users in order to select the most appropriate technologies. It is suggested to use the approach of the Technology Roadmap which regroups all the actors: potential users and manufacturers, research people and university researchers.
- For EV and HEV(Hybrid) batteries, on-vehicle performance demonstrations are required.

Business Climate

- Provide appropriate economic incentives, especially for capital investments and through 'Green' tax credits on the most promising technologies.

Linkages (System and Market)

- Due to the wide diversity of actors involved in these technologies, maybe an approach of a Technology Roadmap regrouping the clients (users), the manufacturers, the R&D could identify and help to focus on the appropriate actions.

Funds Required: (Estimated Incremental Level of Effort Required): $10 million per year on selected technologies.

SYSTEMS INTEGRATION TECHNOLOGIES

Issue

These are broadly applicable technologies that help improve the energy and materials efficiency of industrial and manufacturing processes. Process integration, intelligent control systems, life cycle assessment and industrial ecology are examples of system integration technologies.

Technological Overview and Status

"Process integration" is an information-based technology**.** The term describes the application of methodologies for system-oriented and integrated approaches to the design of a process in an industrial plant (both new and retrofit applications). Typical technologies are pinch analysis for heat recovery, wastewater minimization, energy analysis, optimization, and heuristics and knowledge-based systems. Life-cycle assessment and industrial ecology are growing areas in the systems integration toolbox.

The pinch point method for heat recovery has been used in chemical and process industries to achieve energy savings of up to 50%. Pinch analysis is used to identify areas where internal transfers of heat can be used to avoid the addition of external energy (i.e., energy purchases).

Smart sensors and advanced control systems aid in optimizing energy consumption and other factors in industrial processing systems. Sensors are devices with the ability to detect and adjust/optimize important process parameters as they change. Advanced control systems are linked to computerized algorithms to control and optimize industrial processes. Intelligent controls incorporate a knowledge-based system (also known as artificial intelligence) for predictive signaling and control.

Industrial ecology involves the development of synergies between parts of the production system for improved energy and materials efficiencies. Efficiencies are found in such areas as waste utilization, raw materials preparation and delivery, the transportation of finished goods, and in SME services.

Similarly, the sustainable development or urban neighborhoods and cities is facilitated by technologies and techniques which better design and integrate energy, transportation, water and waste systems, and land use.

Life-cycle assessment considers the impacts of a product's entire life cycle (including human health, environmental and the use of natural resources) from raw material acquisition through production, to subsequent transportation, use and disposal.

Timeframe: short, medium and long term

Canadian Innovation Capacity

Canada has the strength in niche areas through its engineering consulting companies. There is considerable effort to increase the application of information and predictive technologies.

NRCan's CEDRL research facility in Varennes, QC, has an Energy Systems Analysis and Modelling group which supports research into process integration. New methods of process optimization, which merge computer software and analytical methods, are being developed. Several Canadian engineering companies can provide pinch analysis.

The sensors and controls market is dominated by American suppliers and researchers. Canadian suppliers, especially in the sensors market, tend to be small and specialized. Canada has a well developed knowledge of comprehensive building control systems, because of the demands our climate places on building performance.

Life-cycle assessment is increasingly seen as a competitiveness issue by large Canadian exporters, such as those in the pulp & paper and metals industries. Suitable capability has been and is being developed to meet this need.

A CANMET study identified 10 to 15 Canadian companies selling artificial intelligence tools or services to industry. It was also noted that Canadian companies are recognized as North American leaders in predictive modeling, classification and database "mining" tools. Toth Information Systems Inc. is an NRC spin-out which provides predictive capabilities for materials properties. Research on artificial intelligence is being conducted at a number of Canadian universities and CANMET works with industry partners to develop expert system technologies that will optimize and control combustion systems.

Barriers to Commercial Opportunities

Process integration using pinch technology has considerable potential to increase energy efficiency in process industries, which consume a significant share of energy in Canada. The market potential for Canada and abroad is high.

The growth in intelligent control systems for heavy industry is occurring at a rate of 20% per year worldwide. If the trend continues, there is considerable market potential for these systems, particularly expert systems. Given that Canada lags behind other industrialized countries in their use, the domestic potential is strong.

Industrial ecological approaches and life-cycle assessment has considerable market potential for engineering consulting firms as the acceptance of environmentally benign approaches grows.

Barriers to the development and implementation of process integration and advanced sensors and controls in industry include: low fuel costs; limited funds and time; difficulty in quantifying payoffs; lack of support from management or operating personnel; lack of expertise; and difficulty in integrating into existing operations.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure

- Research is needed to produce sophisticated sensors and controls that are cost-effective to implement and to develop computer-based analysis tools and methodologies.

Commercialization, Demonstration

- Create awareness of benefits. Technology transfer.

Business Climate

- Provide appropriate economic incentives.

System Linkages

- Information programs and networks between sectors (supplier, user, transport, services, etc.) need support.

Funds Required: $10 million per year.

USE OF LESS CARBON-INTENSIVE ENERGY SOURCES (INDUSTRIAL SECTOR)

Issue

The use of less carbon-intensive energy sources is examined in the context of end-use industrial applications. The primary measure will be fuel switching, either in part or in whole.

Fuels as less carbon-intensive energy sources

The amount of CO_2 resulting from the combustion of a fuel is a direct result of its chemical composition. Chemical composition of usual fuels involves carbon and hydrogen atoms. By using fuels with a minimum amount of carbon, we prevent right from the start the production of CO_2. From this point of view, the quality of fuels could be rated in function of their hydrogen content. In this rating, hydrogen is the perfect fuel because it does not lead to the production of any CO_2. Hydrogen is a fuel which is, however, very difficult to get in a usable form from the environment. This being taken into account, the least we can do is to resort to hydrogen rich fuels easily available which emits a minimum amount of CO_2.

Less carbon-intensive fuels are those which lead to the minimum amount of CO_2 per liberated joule. For instance, coal leads to 92 grams of CO_2 per gross MJ. Another common fuel is wood (maple) for which we get close to 93 grams of CO_2 per gross MJ. In the case of liquids such as diesel, we will find close to 73 grams of CO_2 per gross MJ. Another common liquid fuel is methanol, which results in 61.5 grams of CO_2 per gross MJ. Finally, the case of natural gas (methane), a substance in a gaseous state, whose combustion results in 49.6 grams of CO_2 per gross MJ. One has to conclude that from their chemical composition, all fuels are not equal when it comes to the necessity to release a minimum of CO_2. Natural gas, because of its chemical composition, is the best fuel to use while at the same time reducing the CO_2 release.

Another point to take into account is that being in a gaseous state, natural gas will also efficiently burn with a minimum of CO, ash, carbon particulate, and unburned hydrocarbons emissions.

Technologies

Two technical possibilities allow the reduction of the total CO_2 emitted.

As mentioned above, one aspect to the reduction of CO_2 released in the environment is to use a less carbon intensive fuel. Many plants already have multiple-fuel capability, in order to take advantage of the lowest-price fuels possible and/or to ensure security of supply. Where multiple fuel capability does not exist, the cost of conversion is generally low, compared to process technology re-investment and other means of reducing emissions.

The second aspect is to use a technology allowing the extraction of a maximum of the energy from a fuel. On-site power generation is a form of fuel substitution, where industrial on-site primary fuel (or natural gas obtained through a distribution network) is substituted as an alternative marginal source of grid power. In many heavy industries, the main purpose is to provide direct heat or steam to industrial processes from the power generation heat cycle, since those processes consume the greatest amount of energy. The unused electric power is sold to the grid to provide additional economic benefits.

Timeframe: short and medium (now to 2012)

Canadian Innovation Capacity

Canadian research and development activities are centred on various governmental and business organisations. These include CANMET's Advanced Combustion Technology Program, the Development and Technical Assistance Program (Datech), the Natural Gas Technologies Centre (NGTC) and the Canadian Gas Research Institute (CGRI).

Market Potential

Natural gas technologies will play a dominant role in fuel switching from oil and coal because it is a cleaner fuel. This trend will be favoured by the current gas flow increase from western Canada due to many new pipeline projects approved by the NEB. Moreover, the pressure on the price of electricity due to a demand increase and a lack of new facilities constructed should confirm this trend in the mid-term. This lack of electrical supply will encourage new entrances to install highly efficient natural gas fired "cogen" or combined cycle facilities. The eventual production from the major gas pool in Sable Island should allow to stabilise the price of natural gas in the Northeast markets. Also, with the major pipeline projects natural gas will become available in all the Northeast area. Fuel switching to natural gas is a broad phenomenon, occurring as well in electricity production and buildings and residential sectors.

Barriers to domestic implementation and international sales

- Low electricity prices and high investment costs deter investment in fuel switching to lower carbon-intensive energy source.
- Monopoly control over electricity production in certain provinces may limit the ability of industry to use less carbon-intensive technologies for on-site electricity production.
- Gas supply network may not reach some industrial customers.
- Foreign ownership of an research into gas and other low carbon-intensive fuel technologies limit Canada's capacity to compete in the equipment market.
- Some less carbon-intensive fuels may have a negative safety perception by the public.
- Regulations. Governmental bodies regulating emissions of CO_2 (and other pollutants) are adjusting their requirements on the type of fuel used. The result is

that less strict emission levels at the chimney are requested for all other fuels than natural gas. This reduces the environmental edge of natural gas over other fuels.

Suggested Measures to Enhance Innovation

Knowledge Infrastructure

- Develop R&D capacity for gas technologies and, to a lesser extent, strategies for co-firing of low carbon fuel across different sectors. Flexible, multi-level fuel switching technology is already well known.

Commercialisation, Demonstration

- For new energy sources in industrial applications.

Business Climate

- R & D targeted tax measures.

System Linkages

- Relative price of fuels most important.

Market Linkages

- Green market incentives that promote use of less carbon-intensive fuels.

Coherence in the approach

- There should be coherence within the governmental programs and we should avoid subsidising the use of green energy against less carbon-intensive energy. For instance to subsidise solar energy against natural gas, where it could be more effective for a more carbon intensive fuel.

Human resources

- Training/awareness of technologies and opportunities.

Estimated Incremental Level of Effort Required: $10 million per year.

Appendix 5

Methodology For Assessing Broad International Technology Needs

In contrast to the methodology used for the domestic needs assessment, it was clearly infeasible to survey potential technology users internationally given the limited time and resources available. Such an endeavour would be a significant larger undertaking than this study. Most OECD countries have not yet begun to explicitly assess their technology needs in the same way that Canada has through a multi-stakeholder process. Information available on the needs of developing countries is available from studies conducted with multilateral or bilateral technical assistance funds. The data are, however, of a much more general nature. The study team therefore decided to assess international technology needs from a variety of possible perspectives so as to build both a top-down and bottom-up assessment of needs. Three different, but complementary, approaches were therefore used to assess international needs for greenhouse gas mitigation technology. The first two approaches enabled the team to assess the overall potential needs on a country-by-country basis. The third approach enabled us to take a technology-specific perspective.

- The first approach involved compiling baseline greenhouse gas emissions data for all countries based on available data from 1989-96, as well as forecast emissions data for the years 2000-50. These data were used as initial quantitative proxies to determine the current and future absolute sizes of the potential international markets for greenhouse gas mitigation technology.

- The second approach identified and assessed various parameters that would likely impact the market dynamics and scale of need in each country such as commitments under the Kyoto Protocol and evolution in the existing market for environmental goods and services.

- The third approach involved a detailed literature review to identify known technology needs for various non-Annex countries.

- Finally, the quantitative and qualitative data obtained from the various approaches were integrated to provide an assessment of international needs by technology that includes an indication of which countries have specific needs.

Each of these approaches, their inherent limitations, and results obtained are presented below.

5.1 Compilation of Overall and Sector-specific GHG Emissions

Baseline GHG Emissions

Baseline greenhouse gas emissions data were obtained for sixty-three countries. These data originate from national country studies that are available from the UNFCCC website[1]. Data was also acquired from the World Resources Institute's Guide to the Global Environment.[2]

The countries included in this study represent all major regions in the world. Some regions have greater representation simply because more data, in terms of greenhouse gas emissions, exists. Overall, data were compiled for 23 industrialised countries (i.e., OECD countries), 9 countries with economy in transition, and 31 developing countries.

Strengths and Limitations

It is recognized that current GHG emissions data is an imperfect indicator for identifying a need for greenhouse gas mitigation technology. However, in the absence of other detailed data, the study team believed it is useful for assessing where there might be a potential international market for specific GHG mitigation technologies. Unfortunately, sectoral data on greenhouse gas emissions were not available for all countries so a complete sector-based analysis is not possible. In addition, emissions data on methane and nitrous oxide were not available for all countries.

An additional limitation is the variation in availability of data by year. Although the Kyoto Protocol uses 1990 as its baseline, this study's baseline data are drawn from a 7 year period, 1989 to 1996, mainly because of the unavailability of data from 1990 for all countries. In spite of these limitations, the data used are the most accurate and complete data currently available on GHG emissions.

5.2 Modeling Assessment of International GHG Emissions Forecasts

Greenhouse Gas Emissions Forecasts

In order to assess future trends in GHG emissions and their possible impact on technology needs, greenhouse gas emission projections were drawn from the latest available modelling results produced from the Atmospheric Stabilisation Framework (ASF). The ASF is a linked system of models developed and maintained by ICF Kaiser Consulting Group that was used to generate the IS92 scenario (the second set of the emission scenarios generated for the Intergovernmental Panel on Climate Change). A series of greenhouse gas emissions forecasts have been completed, peer reviewed, and published in W. Pepper et al., (1998). The ASF makes certain assumptions about population growth, economic growth and energy efficiency for its IS92 model runs.

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1 www.unfccc.de/

2 WRI (1998), "A Guide to the Global Environment"

The emission projections used in this study are based on the US EPA - Climate Policy and Program Division's moderate projection scenario (using the ASF system of models.) This model assumes moderate population and economic growth as well as a moderate rate of improvement in energy efficiency.3 The model also represents a no-policy (business as usual) scenario, which assumes that no measures, or policies to reduce GHG emissions are in place. Exhibit 3-2 projects the growth of GHG emissions in 7 regions. The following table lists the countries that comprise these regions.

Region	**Country**
Middle East (MEAST)	All Middle Eastern Countries including Iran, Iraq, Kuwait, Qatar, Saudi Arabia and UAE
South East Asia and Oceania (SEASIA)	Afghanistan, Bangladesh, Bhutan, India, Indonesia, Malaysia, South Korea, Burma, Pakistan, Philippines, Singapore, Thailand and other countries in the region
Latin America (LAMER)	All Latin American countries (including Mexico, Central and South America)
AFRICA	All African countries
Centrally Planned Asia (CPASIA)	China, Laos, Mongolia, North Korea, Vietnam
Eastern European and New Independent States (EENIS)	Albania, Bulgaria, Czech Republic, Hungary, Poland, Romania, former USSR, former Yugoslavia
Organisation for Economic Cooperation and Development (OECD)	Australia, Japan, New Zealand, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, US

Strengths and Limitations

The no-policy assumption is an important limitation. One might assume that the commitments made by various countries under the UNFCCC and the Kyoto Protocol demonstrate that measures to reduce greenhouse gas emissions will continue to be implemented in a variety of countries.

The baseline greenhouse gas emissions data from1989-96 were presented in thousand metric tonnes as well as by country, sector and gas (where possible). The forecast greenhouse gas emissions data from 2000-50, are presented in billion tonnes of carbon equivalent (with respect to carbon dioxide, methane, and nitrous oxide), and are

3 W. Pepper et al. *Environmental Science & Policy* (1998) 289-312

aggregated by region. Therefore a comparison between the two sets of data is not simple.

5.3 Qualitative Assessment of Market Potential

Assessment of Market Dynamics

For each country where baseline GHG emissions data were available, various parameters that could influence the current and future market for GHG mitigation technologies were identified and assessed.

The analysis provided a means of characterising each potential market. This characterisation helped define, in general terms, the potential demand for Canada's exports of GHG mitigation technologies. These parameters included the countries' commitment to reducing GHG emissions, market size for all environmental goods and services (revenues in billions of dollars USD), and environmental market evolution.

In total, seven market parameters were identified:

- **Signatory** - to the Kyoto Protocol. This indicates that a country recognizes that climate change is an important issue
- **Target** - setting a greenhouse gas emissions reduction target to meet the Kyoto Protocol's goal of cutting emissions by 5% from 1990 levels. This indicates that a country is planning to take concrete steps towards reducing greenhouse gas emissions. Non-Annex countries that have made **voluntary commitments** to stabilise or reduce their emissions, such as Argentina and Kazakhstan, are also considered in this category.
- **Activities Implemented Jointly (AIJ) / Joint Implementation (JI) -** AIJ is the pilot phase of JI projects which create discrete emissions reductions through project-based investments between developed countries[4] - involvement in UNFCCC recognised AIJ/JI projects, as well as projects which have been approved by the host country but have not yet been approved by the UNFCCC[5]. This indicates that a country is taking, or planning to take concrete steps towards reducing greenhouse gas emissions, although the country may not have set an official target.
- **Environmental Market Size -** the absolute size of the country's environmental market in US$billions. This indicates the current size of a country's market for all environmental products and services. We have assumed that there is a fairly strong correlation between the overall market for environmental goods and services and the market for GHG emissions technologies, one of the subsets of this market.

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4 Kyoto Mechanisms Table. 1998. *International Flexibility Mechanisms Table Foundation Paper.*

5 U.S. Environmental Protection Agency, Office of Policy. 1998. *Activities Implemented Jointly: Third report to the Secretariat of the UNFCC.* EPA 236-R-98-003 (Vol. 1)

- **Environmental Market Evolution Factor –** The determination of a country's environmental market evolution is based on public awareness, stated government policy, existing environmental legislation, existence and relative strength of the central regulatory agency, level of enforcement and compliance, status of proactive environmental efforts and pollution prevention initiatives and an indication of economic instruments to provide incentive for environmental quality and sustainable development initiatives[6]. The scale used to characterize the market evolution factor for a given country ranges from 1 to 4, where 4 corresponds to a high market evolution factor.
- **Rank –** for the largest 50 environmental markets, this parameter indicates the relative ranking of the country in environmental markets in the world.
- **Canadian presence –** the degree to which Canadian companies exporting environmental goods and services are already present in the market.

Strengths and Limitations

For non-Annex countries, signing the Kyoto Protocol does not necessarily represent a need for greenhouse gas mitigation technology. Developing countries could have signed the Protocol without any plans for reducing GHG emissions. Clearly, the choice of factors is normative. Other factors can easily be added.

5.4 Analysis of Overall Market Potential

In order to assess the overall market potential of each country, a multi-attribute analysis was devised where weightings were assigned to the parameters described above. The various market parameters were assigned the following values:

Net CO_2 Emissions (thousand metric tonnes) :	<100,000	0
	100,000-200,000	2
	200,000-400,000	4
	400,000-900,000	6
	900,000-1,500,000	8
	>1,500,000	10
GHG Emissions Reduction: Target/Voluntary Commitment	No commitment	0
	Voluntary commitment	2
	Emissions reduction	3
	Stabilise emissions	3.5
	Increase emissions	4
AIJ/JI :	Not involved	0
	Involved	2

6 Environmental Business Journal. 1995. *The Global Environmental Market and US Environmental Industry Competitiveness*.

Market Size (billions of US$)7:		
	<1	1
	1-7	2
	7-25	3
	>25	4
Market Evolution Factor8 :	No data	0
	Data exists	Calculated value (1-4)
Existing Canadian Presence9:	Low	1
	Medium	2
	High	3

The countries were ranked according to the total score derived from the above methodology.

Countries that have a total score of 17 points or more are considered markets with *outstanding* potential. Countries that have a total score between 13 and 16.99 are considered markets with *considerable* potential. Finally, countries that have a total score of 12.99 or less are considered markets with *limited* potential. This analysis represented the state of the *current overall* market potential.

Strengths and Limitations

The weightings for specific factors are somewhat arbitrary, however this approach enabled the study team to make sense of the data we have obtained and provides us with a method of analysing and presenting the results. This methodology can also be refined and the weighting can be modified. Furthermore, additional factors can be added to the analysis, such as market barriers that might impede access by Canadian firms. Again, it must be reiterated, this analysis provides only an overall assessment of market potential. It is not a good indicator of technology-specific needs.

5.5 Literature Review to Identify International Technology Needs

Known Technology Needs

Prior to conducting a comprehensive literature review, a "technology identification template" was designed to track the known technology needs of various countries. The identification template was used to record the technology needs that were identified for or by various countries.

7 Environmental Business Journal. 1995. *The Global Environmental Market and US Environmental Industry Competitiveness*.
8 Ibid.
9 This assessment is based on various sources including Industry Canada, DFAIT, and Canadian Environment Industry Association reports.

This template organised various examples of climate friendly technologies into technology groups, and each technology group was placed into a broad technology category based on the following classifications: Fossil Fuel Supply, Energy Production, Energy End-Use, CO_2 Management, Non-Energy Related sources, and Enabling cross-cutting technologies.

In compiling the list of known technology needs by country, a considerable amount of country studies were used in which staff from ICF Kaiser Consulting Group have participated first-hand. The following is a list of studies that were employed for this exercise:

- *Initial Priorities for Energy Sector Mitigation Measures Identified by Countries Receiving U.S. Support for the Preparation of Climate Change Action Plans*. This document lists the technology needs of 13 countries and indicates the sectors that they are needed for.
- Asian Development Bank funded project *Asia Least-Cost GHG Abatement Strategy* reports on country-specific GHG mitigation strategies in Bangladesh, China, India, Indonesia, Korea, Mongolia, Myanmar, Pakistan, The Philippines, Thailand, and Viet Nam
- *National Climate Change Action Plans* funded by US Country Studies Program providing support on climate change in more than 50 developing countries and countries with economies in transition provides an analysis of technology needs in Bolivia, Bulgaria, Czech Republic, Egypt, The Gambia, Hungary, Kazhakstan, Mexico, Russian Federation, Tanzania, and Thailand
- *The List of Chinese Government Needed Technologies* prepared by Energy Research Institute of SPC. This list identifies 15 sector specific technologies that are necessary for China to decrease its GHG emissions. For each technology identified, detailed information on the general characteristics of the technology, cost information, its environmental effects, and Chinese market potential were provided
- *Impact of improved Technology on Industrial Greenhouse gas emissions in Developing Countries* funded by UNIDO. This document examines industrial options for GHG abatement in Brazil, Egypt, India, Senegal, Thailand, Venezuela, and Zimbabwe
- *Second synthesis report on activities implemented jointly* produced by the UNFCCC documents 95 activities implemented jointly by investors in developed countries in host countries located in the African, Asian and Pacific, EIT, and the Latin American and Caribbean regions
- *United States Government Support for Climate Technology Cooperation Projects and Activities: 1998* documents activities that support climate change mitigation in the African, Asian –Pacific, European and the New Independent States, and Latin American regions.
- *Activities implemented jointly: Third report to the Secretariat of the UNFCCC (Volume 1)* provides information on 20 AJI projects that are planned or currently

underway between the US and the Czech Republic, Ecuador, Honduras, Indonesia, Mexico, Nicaragua, Panama, Russian Federation, and Sri Lanka

The inclusion of Joint Implementation (JI) projects and Activities Implemented Jointly (AIJ) pilot projects are useful in this portion of the study because from the projects described, we can infer that there is a need for specific GHG abatement technologies within the sector the project or activity is being conducted.

Strengths and Limitations

In some cases the country study literature did not provide sufficient detail about the type of technology that is needed by a certain country. For example, renewable energy technologies were identified as a need but the type of renewable energy was not specified. One key limitation from the literature review of existing studies is that much of the data have been compiled from the assessments made by climate change focal points in developing countries rather than potential users of GHG mitigation technology. While the focal point can be expected to have a broad range of knowledge concerning the need for technologies to reduce GHG emissions, one might reasonably expect the potential users to have a more definitive sense about their specific technology needs.

Appendix 6

Integrated Summary Of Domestic And International Technology Needs

Scale:
0: Overall market size insignificant
1: Overall market size less than 1 billion USD
2: Overall market size between 1 – 7 billion USD
3: Overall market size 7 – 25 billion USD
4: Overall market size greater than 25 billion USD
* Denotes where there is a **Likely** need for GHG mitigation technologies

Note that this exhibit is an attempt to organise countries by their <u>overall</u> market size for environmental goods and services. It is not intended to present the market size for each type of technology. This level of analysis is beyond the scope of the study.

Types of technologies	**Overall Market Size for Environmental Products and Services**				
Scale	**0**	**1**	**2**	**3**	**4**
A) Fossil Fuel Supply					
1. **Increased energy and carbon efficient processing of fossil fuels**			Ukraine		
Energy efficiency for crude oil refining	*Kuwait *Nigeria *Oman *UAE	*Iran *Saudi Arabia *Venezuela	*China *Mexico *Norway Russian Fed *Turkey Poland	*U.K.	*U.S.
Natural gas to liquid fuels	*Algeria *Malaysia *Turkmenistan *Uzbekistan	*Indonesia *Saudi Arabia	*Australia *Netherlands *Norway *Russian Fed	*U.K.	*U.S.
More efficient recovery of oil sands, upgrading	*Kuwait *Nigeria *Oman *UAE	*Iran *Saudi Arabia *Venezuela	*China *Mexico *Norway *Russian Fed *Turkey	*U.K.	*U.S.
More efficient recovery of natural gas	*Algeria *Bangladesh *Turkmenistan *Uzbekistan	*Indonesia *Malaysia *Saudi Arabia	*Australia *Netherlands *Norway *Russian Fed	*U.K.	*U.S.
Coal bed methane		*Indonesia *South Africa	*Australia China India *Kazakhstan Poland, Rep Russian Fed Ukraine		*Germany *U.S.

Types of technologies	**Overall Market Size for Environmental Products and Services**				
Scale	**0**	**1**	**2**	**3**	**4**
Underground coal gasification		*Indonesia *South Africa	*Australia China *Kazakhstan *Poland, Rep *Russian Fed Ukraine		
2. **Reduced fugitive gas emissions**					
Improved flaring	*Algeria *Turkmenistan *Uzbekistan	Indonesia *Malaysia	Russian Fed		
Mine ventilation air		*Indonesia	*China *India *Kazakhstan		
Pipeline losses	*Algeria *Turkmenistan *Uzbekistan	*Indonesia *Malaysia	Russian Fed.		
Low leak valves, fittings, etc.	*Algeria *Turkmenistan *Uzbekistan	*Indonesia *Malaysia	Russian Fed.		
B) Energy Production					
1. More efficient conversion of fossil fuels in electrical generation	Bangladesh Mongolia Tanzania Viet Nam	Egypt	Mexico Ukraine		
High efficiency coal based power generation		Hungary Indonesia Philippines *South Africa	*Australia China India Poland, Rep Russian Fed	*U.K.	*Germany *Japan *U.S.
Integrated gasification combined cycle		*Iran *Saudi Arabia	China *Netherlands *Russian Fed *Thailand India Brazil	*Italy *U.K.	*Germany *Japan *U.S.
Fuel cells			China India		
2. Switching to lower carbon fuels			Thailand		
Substituting natural gas for coal and oil	Bolivia Bulgaria Tanzania	Czech Rep Egypt Hungary Venezuela	*Australia Kazakhstan Mexico Poland, Rep Russian Fed. Thailand		*U.S.
Substituting coal with fuel oil			India		

Types of technologies	**Overall Market Size for Environmental Products and Services**				
Scale	**0**	**1**	**2**	**3**	**4**
Biomass cofiring		*South Africa	*Australia Brazil *China India *Russian Fed Mexico	*U.K.	*Germany *US
Hydrogen					
3. Increased use of nuclear	*Pakistan	Czech Rep	*China *India *Korea, Rep *Turkey		*Japan
4. Increased use of integrated energy systems (cogeneration)	Bulgaria Myanmar Tanzania Viet Nam	Czech Rep Egypt Hungary Philippines	India Kazakhstan Latvia, Rep Mexico Thailand Poland		
5. Upgrade/replace existing power plants	Bulgaria Moldova Tanzania	Egypt Hungary Romania	Brazil Kazakhstan Mexico Poland India		
6. Increased use of renewable resources	Bhutan Bolivia Bulgaria Gambia Lithuania Tanzania	Czech Rep Egypt Hungary Indonesia South Africa	Kazakhstan Latvia Mexico Thailand Ukraine Poland India		
Biomass electric	Belize Honduras Mongolia Myanmar Slovak Rep	Indonesia Philippines	China India Russian Fed. Poland		
Biomass transportation fuels			China		
Hydroelectric power	Costa Rica Mongolia Nepal	Indonesia Philippines *Venezuela	*Brazil China India *Norway Russian Fed. *Sweden Thailand		*Japan
Tidal energy					
Wind energy	Costa Rica Mongolia Pakistan Tanzania	Egypt Indonesia Philippines	China India Mexico Russian Fed.		
Geothermal energy	Nicaragua		Russian Fed.		
Solar thermal	Tanzania	Egypt	China		

Types of technologies	Overall Market Size for Environmental Products and Services				
Scale	0	1	2	3	4
Solar photovoltaics	Bangladesh Bolivia Fiji Honduras Mongolia Sri Lanka Tanzania		China India Russian Fed Brazil		
Solar advanced photoconversion	Bangladesh Bolivia Honduras Micronesia Mongolia Tanzania	Venezuela	China India Mexico		
Ocean thermal energy	Micronesia		India		
C) Energy End-Use					
1. Industry					
Improved industrial processes *(for cement manufacturing)	Bolivia Ghana Tanzania Viet Nam	*Egypt *Indonesia	China Russian Fed. Thailand *Ukraine Brazil	*Italy	*Germany *Japan *U.S.
Reduced carbon intensity			Ukraine		
Reduced energy intensity		Venezuela	China Mexico Russian Fed.		
More efficient industrial equipment	Bolivia Bulgaria Myanmar Viet Nam Zimbabwe	Czech Rep Egypt Hungary Indonesia Philippines South Africa Venezuela	China Estonia Rep India Latvia, Rep Mexico Russian Fed. Thailand Ukraine Brazil		
Improved industrial process energy management	Burkina Faso				
Electrotechnologies					
2. Transportation					
More efficient vehicles	Bangladesh Bolivia Bulgaria Mongolia Myanmar Tanzania	Czech Rep Hungary Indonesia Philippines	China India Mexico Russian Fed. Thailand Ukraine		
Next generation drive systems					
3. Buildings (residential and commercial)					

Types of technologies	Overall Market Size for Environmental Products and Services				
Scale	0	1	2	3	4
More efficient appliances and equipment	Bangladesh Bolivia Bulgaria Micronesia Myanmar Solomon Islands Tanzania Viet Nam	Czech Rep Egypt Hungary Indonesia Philippines S. Africa Venezuela	Brazil China Estonia Rep India Korea, Rep Mexico Russian Fed. Ukraine		
Improved envelope and architecture design	Bulgaria Mongolia	Czech Rep Egypt Hungary Venezuela	China Russian Fed. Ukraine		
4. Municipalities					
Urban design	Tanzania				
District Energy		Czech Rep Hungary	Estonia Rep Latvia Rep Russian Fed.		
Public transport and traffic management	Bangladesh Bulgaria Tanzania	Czech Rep Egypt Hungary Indonesia Philippines	China Mexico Russian Fed.		
D) CO_2 management					
1. Separation, capture and transport	Croatia			*US *Norway *Japan	
2. Sequestration/storage					
Agricultural sinks	Mongolia		India Mexico Russian Fed.		
Forest sinks	Belize Bolivia Costa Rica Ecuador Myanmar Nepal Panama Vietnam	Indonesia Philippines	China Mexico Russian Fed. Thailand		
Geological storage			Mexico	*US *Norway	
Ocean storage				*US *Norway *Japan	
3. Use					
Enhanced oil recovery					
Value added products from CO2 and carbon					
E) Non-energy related sources					

Types of technologies	**Overall Market Size for Environmental Products and Services**				
Scale	**0**	**1**	**2**	**3**	**4**
1. Improved ways of addressing non-energy emissions		Czech Rep Indonesia	Brazil Mexico Thailand *Russian Fed Ukraine	*Italy	*Germany *U.S.
Landfill gas capture and use					
Alternative compounds to SF6 and HFCs					
Flyash in concrete			China		
Reducing CH4 emissions in dairy and livestock system	Bangladesh Costa Rica *Ethiopia *Iceland Myanmar Nepal Pakistan *Slovak, Rep Uruguay	Indonesia *Ireland *New Zealand Romania *Venezuela	*Australia China India Mexico *Kazakhstan *Poland, Rep *Russian Fed *Spain Ukraine	*France *U.K.	*Japan *Germany *U.S.
Reducing CH4 emissions from rice fields	Viet Nam	*Indonesia Philippines	*China *India		
F) Enabling cross cutting technologies					
1. Fuel cells			China India Mexico		
2. Energy storage					
3. Hydrogen technologies					
4. Advanced materials					
5. Bioprocessing					
6. Advanced separation methods			China		
7. Systems integration					
8. IT and control technologies			Russian Fed		

Appendix 7A

Brief Descriptions Of Country Needs Assessments

The United States

The United States is perhaps the country with the most outstanding market potential for Canadian suppliers of GHG mitigation technologies. This potential is a result of a combination of factors. The United States is the largest emitter of GHG, and has committed to a 7% reduction in GHG emissions relative to its 1990 baseline emissions. In addition, the United States has initiated various domestic climate change programs that are enhancing the demand for climate-friendly technologies. As many Canadian firms have already come to appreciate, the United States is, by far, the largest and most evolved environmental market in the world. The potential rewards as well as the level of competition are both immense.

Australia

Australia is a country with outstanding market potential for suppliers of GHG mitigation technologies. This is partly due to its high level of GHG emissions and the fact that it appears to be actively engaged in developing a national strategy for mitigating climate change.

Although Australia is the world's fifth largest producer of coal, Australia's overall emissions are small and only account for 1.4% of global GHG emissions. However, Australia is the sixth largest emitter of CO_2 from the energy sector on a per capita basis behind Canada, the US, Kazakhstan, the UAE, and Singapore.[10]

Energy production accounts for over half of Australia's greenhouse gas emissions and will continue to be the principle source of future emissions. Australia's total CO_2 emissions for 1995 were 289.8 million Mt. Of this, 178.5 million Mt came from the burning of fossil fuels. Total CH_4 emissions, based on 1990 data, were 6.2 million Mt, almost half are emissions from livestock while only one sixth were attributed to fossil fuel extraction.

Other principle sources of emissions include the energy use in industry and the transportation sector. A small amount of emissions result from fugitive releases of CO_2 and CH_4, which escape during the extraction of fossil fuels**.** [11]

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[10] www.dfat.gov.au/environment/climate/cc_aus_approach.html (March 26th 1999) "Climate Change: Australia's Approach"
[11] ibid.

The Russian Federation

Russia has considerable market potential for Canadian suppliers of GHG emissions mitigation technologies. This potential derives from the fact that Russia is among the world's largest emitters of GHG. Furthermore Russia is a signatory to the Kyoto Protocol and has set a GHG emissions reduction target. It is clear, however, that given the immense economic problems currently facing Russia, an important impediment to Canadian suppliers of climate-friendly technology will be securing financing for technology exports.

Poland

Poland has considerable market potential for Canadian suppliers of GHG emission mitigation technologies. In part, this potential derives from Poland's considerable emissions of GHG and their status as an Annex B country under the Kyoto Protocol that has a GHG emissions reduction target.

China

Of all developing countries, China is widely considered to be the one with the greatest market potential. China's potential derives primarily from its rapidly expanding industrial base, and the fact that China alone accounts for more than half of Asia's total emission of greenhouse gases and approximately 10% of the world's total.[12] China is also the largest emitter of CO_2 among developing nations.

Emissions data for 1990 indicate that CO_2 emissions from fossil fuel combustion was 2.4 billion Mt, industrial processes 106 million Mt, and net CO_2 emissions were 2.5 billion Mt. CH_4 emissions from fossil fuel extraction was 5.7 million Mt, livestock 8.9 million Mt, and waste 0.8 million Mt, and total methane was 33.8 million Mt.

China's primary sources of GHG emissions are from energy production processes, inefficient industrial boilers, and motor vehicle emissions in the transportation sector. China's heavy dependence on coal for 75% of its energy needs has been a major contribution to the country's large GHG emissions. In 1994, 80% of CO_2 emissions were attributed to coal combustion. Annual coal consumption is projected to rise from a current 1.2 billion tons to over 1.4 billion tons by 2000.

Air quality is also affected by the growing use of motor vehicles. There are an estimated 9.3 million cars and trucks in China[13]. By 2020, the urban vehicle

[12] www.dfait-maeci/gc (March 23rd 1999), "China: Air Pollution Control Market"
[13] US Department of Commerce (1996), "China: Environmental Technologies Export Market Plan"

population is expected to be 13 to 22 times higher than it is today. Chinese vehicles emit 2.5 to 7.5 times more hydrocarbons, 2 to 7 times more nitrous oxides, and 6 to 12 times more carbon monoxide than foreign vehicles.

India

Like China, India is one of the countries with considerable market potential for Canadian suppliers of GHG mitigation technology. Again like China, this potential could become even greater if developing countries eventually take on GHG emissions reduction commitments under the Kyoto Protocol. In general, India's market potential derives from the fact that it is one of the largest emitters of CO_2 in Asia after China and Japan. In 1995, India's net GHG emissions of CO_2 were 908.7 million Mt[14].

India's primary sources of GHG emissions originate from industrial units involved in the generation of thermal power, steel and cement manufacturing.[15] Industrial emissions result from inefficiencies in industrial processes and equipment. In terms of electricity generation, India's efficiency for the production of thermal energy is comparatively low in comparison to western standards. The generating efficiency of coal-fired stations is only 30%, compared with the OECD average of 37%.[16]

India's rapidly growing energy demands cannot be met by the expansion of generation and transmission capacity alone. India will also have to improve efficiency at every point in its energy cycle from production to consumption. Energy efficient measures can potentially add as much as 30% to the country's power output.[17] By the year 2010, India plans to add 115 GW to its current installed capacity of 82 GW. Of this total, the International Energy Agency expects 50-65 GW to be coal-fired, 11 GW gas-fired, and the remainder is expected to originate from primarily hydropower.[18]

Mexico

Mexico has considerable overall market potential for Canadian suppliers of GHG mitigation technologies. This potential derives from a variety of factors such as the fact that Mexico is a signatory to the Kyoto Protocol, it has participated in several AIJ projects, and the Mexican environmental market is among the top 25 markets for environmental goods and services in the world.[19]

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[14] World Resources (1998), see op. cit.
[15] www.dfait-maeci/gc (March 22nd 1999), "India :Environmental Market Report"
[16] www.dfait-maeci/gc (March 22nd 1999), "India: Power Sector Market Report"
[17] ibid.
[18] ibid.
[19] *Environmental Business Journal* (1995), see op. cit.

Brazil

Brazil was a country with limited market potential for Canadian suppliers of GHG mitigation technology. However, there is a possibility that Brazil will become a market with considerable potential should it commit to voluntarily reducing GHG emissions under the Kyoto Protocol as other non-Annex countries have (e.g. Argentina and Kazakhstan). Nonetheless, good niche opportunities presently exist for specific climate-friendly technologies.
In 1994 Brazil's total CO_2 emissions were 3.4 million metric tonnes of which 2.2 million was attributed to fossil fuel combustion.[20]

With more than a 160 million people, and an installed power capacity of 55 000 MW, Brazil is the most attractive market for energy efficient technologies in Latin America. Brazil's rapid population and economic growth is increasing energy consumption at a rate of 6 to 7 % a year. Approximately 95% of Brazil's energy needs currently come from hydroelectric power. The remainder of energy is derived from diesel oil, charcoal and wood, natural gas, and nuclear power. Most opportunities for hydroelectric development in Brazil have already been exploited, and therefore, over the next several years Brazil plans to increase energy output from natural gas-fired thermal generation and small-scale renewable energy sources.

Brazil's goal is to increase the supply of natural gas to 10% of the energy sector's matrix by the year 2005. By this time, natural gas output will increase from the present rate of 9 million m^3/day to approximately 50 million m^3/day. From January to September 1997, the number of gas-fired power plants in Brazil increased from two to fourteen[21]. From 1996 to 2005, Electrobrás the former state owned utility has planned for an additional 27 GW increase in installed capacity, representing a 4.9% annual increase in demand for electricity. Petrobrás the national oil and gas company, is spending $2 billion US annually to double its production of crude oil over a five-year period from 1998-2003. The hope is to significantly reduce imports by the year 2001. As a result, an additional concession of six thermal plants is anticipated with a total capacity of over 2GW.

Spain

Spain has considerable overall market potential for Canadian suppliers of GHG mitigation technology. This potential is attributed to a combination of factors; Spain is the world's ninth largest industrial power, among the world's top ten importers of crude oil (55 Mt in 1996)[22], and coal is one of Spain's primary sources of energy as well as a significant contributor to the country's overall

[20] World Resources (1998), see op. cit.
[21] www.dfait-maeci/gc (March 19th 1999), "Brazil: Energy Market"
[22] International Energy Agency. 1998. *Key World Energy Statistics*.

GHG emissions. Although a country-specific target has not been set, Spain is contributing to the European Union's (EU) overall effort to reduce GHG emissions by 8% to meet the Kyoto target for the first budget period.

In 1990, Spain's net CO_2 emissions were 204.2 million Mt. Fossil fuel combustion accounted for 209.4 million Mt and 17.7 million Mt were from industrial processes. Land use changes resulting in CO_2 removal reduced CO_2 emissions by 23.2Mt. Spain's methane emissions are relatively low in comparison to other EU countries at 2.2 million Mt in 1990. The major sources of methane emissions are fossil fuel combustion, which accounts for 76,000 Mt, livestock, and landfill waste emissions.

Imported crude oil and Spanish coal are the main fossil fuels that are burned for energy. Spanish coal is very expensive, energy-inefficient, and subsidised to compete with imported coal. The sector produces 18 million tons of coal per year, 95% of which is used in electricity generation. Natural gas production is negligible, making Spain a net importer of natural gas. However, the Spanish Government is experiencing mixed success in promoting the use of natural gas to replace other higher carbon fossil fuels as a primary energy source.

Ukraine

Ukraine's overall market potential for Canadian suppliers of climate-friendly technology is considerable. Ukraine is the world's eighth largest emitter of greenhouse gases and is characterised by inefficient industrial processes and an economy dependent on energy intensive industries. Ukraine is a nation that contains 1% of the world's population, yet consumes 2% of the world's energy.[23] For these reasons, Ukraine is considered to be a significant player in the global climate change arena.

In 1990, Ukraine's net carbon dioxide emissions totalled approximately 648.2 million Mt, with the energy sector being the primary source. Fossil fuel combustion accounted for over 90% of CO_2 emissions and industrial processes accounted for approximately 31.8 million Mt of CO_2. Ukraine's energy sector is also a principal source of methane emissions. In 1990, total CH_4 emissions were 9.5 million Mt. Of this, approximately 6.3 million Mt originated from the extraction and combustion of fossil fuels. Methane emissions from livestock only accounted for 2.2 million Mt. Nitrous oxide emissions totalled 25,000 Mt. In 1996, energy related carbon emissions were an estimated 1.6% of world carbon emissions.[24]

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[23] Pacific Northwest National Laboratory. 1997. *Cities in a No Regrets Climate Strategy: Lessons From Transition Economies.* October.
[24] United States Energy Information Agency. 1998. *Ukraine.* September.

The Ukraine has extensive supplies of fossil fuels. There are six oil refineries in the Ukraine, including the Lysychansk Oil Refinery in eastern Ukraine, which is the largest in Eastern Europe.[25] Ukraine has vast coal resources. Donbass, the main coal mining basin, contains metallurgical coal, anthracite, and high grade thermal coals, as well as coal bed methane gas. There are 14 large fossil fuel plants and 10 hydroelectric plants. The country also has a sizeable nuclear electricity generating capacity as well as significant uranium reserves. Ukraine also receives nuclear fuel extracted from warheads of dismantled missiles from Russia.

The Ukraine has signed the UNFCCC, and is participating in the US Country Studies Program (CSP)[26]. In addition, the Ukraine is a signatory to the Kyoto Protocol and has set an emissions reduction target for the first budget period of 0% (i.e., stabilisation) based on 1990 emission levels. Although the country is currently not hosting any JI programs, officials from Ukraine 's Ministry of Environmental Protection have expressed interest in participating in energy efficiency, use of new energy resources (such as coal bed methane), and GHG emissions reduction JI projects. Participation in such projects is viewed as a means of alleviating Ukraine's economic and energy crisis, both of which are currently top priorities for the government.[27]

The Czech Republic

The Czech Republic presents Canadian suppliers of climate-friendly technology with good market potential in specific niches. The Czech Republic is Europe's ninth largest emitter of greenhouse gases and is signatory to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. It has begun to assess how it can reduce its GHG emissions. It is currently hosting 3 pilot JI projects that involve energy efficiency, reforestation, and fuel switching in partnership with the U.S. & Denmark, the Netherlands, and France.

In 1990, the Czech Republic's net carbon dioxide emissions totaled approximately 136.3 million Mt, with 97% of the emissions originating from the energy sector.[28] Fossil fuel combustion and industrial processes accounted for 157.4 million Mt and 8.4 million Mt of the Czech Republic's CO_2 emissions respectively. The energy sector is also a principal source of methane emissions. In 1990, total CH_4 emissions were 0.9 million Mt, of this, approximately 0.6 million Mt originated from the extraction and combustion of fossil fuels. Methane emissions from

[25] DFAIT. 1998. *A Guide to Doing Business in Ukraine*. May.
[26] Pacific Northwest National Laboratory. 1997. *Cities in a No Regrets Climate Strategy: Lessons From Transition Economies*. October.
[27] 1995.*Joint Implementation in Countries in Transition: An Analysis of the Potential and Barriers.* March. (www.pnl.gov/aisu/jiforweb.htm) April 25, 1999.
[28] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.

livestock only accounted for 0.2 million Mt. Nitrous oxide emissions totaled 26 thousand Mt in 1990.

Electricity is produced from fossil, nuclear, and hydroelectric sources. The Czech Republic contains approximately 95% of the former Czechoslovakia's coal reserves, mainly comprising of hard (bituminous) coal. Most hard coal is produced from 16 underground mines in the Ostrava-Karvina Basin, located in the eastern region of Silesia. Coal accounts for approximately 88% of the energy produced in the Czech Republic as well as nearly all of the country's net energy exports.

The Czech Republic has only one operable nuclear power plant located at Dukovany that provides 13% of the country's energy. The plant is equipped with four relatively new 440 MW generators. The Temelin nuclear plant in southern Bohemia is still under construction and will have 2,000 MW of installed capacity upon its completion in late 1999.

The Czech Republic’s GHG emissions, and most of its air pollution problems, are mainly due to high levels of energy end-use consumption and energy inefficient processes. Throughout the Czech Republic, there are over 9,000 installed boilers and 550 cogeneration units. Approximately two-fifths of these units are over 30 years old.

In order to improve air quality, the government has developed an energy plan to reduce pollution from dirty brown coal power plants, particularly in the southern Bohemia region.[29] According to the plan, by the year 2000, 54 % of energy will be produced from steam power plants, 11% from hydroelectric power plants, and 35% from nuclear power plants.[30] The government is also implementing several projects related to GHG emissions mitigation in order to achieve energy efficiency in the industrial and municipal sectors. The biggest changes in the Czech Republic's fuel consumption over the next several years will result from switching from various fuel sources (primarily coal) to natural gas. The Transgas company estimates that the demand for natural gas will double from 1993 to 2005.[31] Therefore, although reducing GHG emissions is not a major priority for the Czech Republic, its efforts to increase energy efficiency will indirectly result in reduced GHG emissions.

For these reasons, the Czech Republic is considered to be an ideal export market for energy efficient technologies.

[29] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.
[30] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.
[31] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.

Argentina

Argentina's emerging environmental and energy markets holds vast potential for Canadian suppliers of GHG mitigation technology. In less than a decade, Argentina has transformed itself from a country unable to meet its own electricity needs to one that now not only meets all its domestic needs, but also partially meets the demands of its neighbours. Argentina has a sufficient energy resource base to accommodate growing energy needs well into the future. The country is rich in natural energy resources, including coal, hydroelectric potential, oil and gas.

As a result of energy sector reforms, the total production volumes of hydrocarbons and reserves have doubled over the past decade, and total installed generation capacity has increased by one-third. Total consumption of energy has risen by more than 30% since 1990, and has almost doubled since 1980.[32] As a result, Argentina is Latin America's third largest emitter of greenhouse gases and the country's primary source of emissions originates from the newly privatised energy sector. Private utility operators are in the process of implementing energy conservation measures and technologies in order to minimise energy loss due to inefficient processes.

In 1994, Argentina's carbon dioxide (CO_2) emissions, not including land use and change, and forest growth, totalled 114.3 million Mt. Fossil fuel combustion accounted for 109 million Mt, approximately 95%, while industrial processes accounted for 4.2 million Mt of CO_2 emissions, approximately 4%. Argentina's methane (CH_4) emissions for the same year totalled 3.2 million Mt. The primary source of CH_4 emissions is the Argentine agricultural sector where 82% of emissions are attributed to livestock fermentation and manure treatment. Emissions of nitrogen oxide (NO_x) in 1994 were approximately 623 thousand Mt, with fossil fuel combustion accounting for 99% of emissions.[33]

In 1996, Argentina's energy matrix comprised of 47% thermal, 44.1% hydropower, 5.5% nuclear, and 3.2% renewable energy. Of the 3.2% that was attributed to renewable energy, 87.1% of energy was generated from biomass, 10.6% from small hydro, 1.6% from wind power, 0.6% from solar photovoltaic, and 0.1% from geothermal.[34]

In November 1998 at the Fourth Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC) held in Buenos Aires, the Argentine Government pledged to lead other developing nations in efforts to reduce greenhouse gas emissions.[35] Argentina is also a signatory to the Kyoto

[32] US Energy Information Administration. 1998. *Argentina*. November.
[33] Government of Argentina 1997. *Final Report of the Project Study of Climate Change in Argentina Greenhouse Gas Inventory*. December.
[34] US & Foreign Commercial Service and US Department of State. 1997. *Argentina Solar Energy Equipment Market Research Report*.
[35] US Energy Information Administration. 1998. *Argentina*. November.

Protocol and has made a voluntary commitment to reduce GHG emissions. Although the details of the commitment are still being worked out, Argentina has already begun negotiations to host pilot joint implementation projects involving combined cycle power generation and landfill gas capture and use.

Thailand

The Kingdom of Thailand may provide good niche opportunities for Canadian suppliers of GHG mitigation technologies. Efforts to refine data on Thailand's GHG emissions are ongoing and will provide a more complete picture as the quality of data improves. At present, most of the published data on emissions come from the fuel combustion sector. In 1996, CO_2 emissions from fuel combustion were 175,220 Mt.[36]

In 1998 Thailand had 161 generating units and a total installed capacity of approximately 18.2 GW. The types of fuel used by power plants include natural gas (34.7%), fuel oil (19.7%), lignite (18.1%), hydro (6.4%), light oil (1.3%), and purchased power (19.8%).[37] Electricity consumption by sector, in 1998, was as follows: industrial (49%), residential (23.3%), commercial (22%), and other (5.7%).[38]

The transportation sector is Thailand’s fastest growing contributor to GHG emissions. The average annual growth rate for registered motor vehicles in Thailand has fluctuated between 6.6% and 32.5% through the first half of the 1990s[39]. Despite the lack of road space, severe air contamination, and high oil prices, the number of registered motor vehicles could double within the next 10 years. To combat the environmental impacts of this growth in the size of vehicle fleet, the Royal Thai Government (RTG) is planning on reducing transport-related oil imports, mitigating the severe urban air pollution problems, and to a lesser extent reducing GHG emissions.

Thailand is among the original signatories of the United Nations Framework Convention on Climate Change and ratified the agreement in December 1994 to reduce GHG emissions. Thailand has not yet signed the Kyoto Protocol but has shown a willingness to undertake pilot projects that demonstrate the viability of technologies to reduce GHG emissions. For example, it is implementing a pilot phase AIJ project with Japan involving efficiency improvements for coal-fired power plant. Three electric power generating companies from Japan are collaborating on this project with the Electricity Generating Authority of Thailand (EGAT). EGAT is a state-owned enterprise that produces virtually all of the

[36] International Energy Agency. 1998. *Key World Energy Statistics*.
[37] US Department of Commerce. 1999. *Thailand Electric Power Overview*. April 23rd.
[38] US Department of Commerce. 1999. *Thailand Electric Power Overview*. April 23rd.
[39] The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.

electricity in Thailand. This project will use energy conservation technologies for a 310 MW power plant.[40]

Other efforts in the energy sector, undertaken with objectives other than to reduce GHG emissions, suggest that Thailand already offers significant market potential for niche GHG mitigation technologies. In 1991, Thailand became the first Asian nation to formerly incorporate a comprehensive Demand Side Management (DSM) Program. EGAT, in cooperation with the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA) are responsible for implementing the US$189 million program. The program has achieved considerable success in its efforts to promote energy efficient processes. At the end of 1997, initial estimates of the DSM program showed a cumulative energy savings of 1 427 GWh, a peak capacity reduction of 238 MW, and GHG emissions reductions of 1.16 million tonnes of CO_2 per year. According to The World Bank, Thailand's DSM project is the best in Asia, and ranks in the top 8 of the 110 worldwide programs.[41]

[40] JI Online: www.ji.org/maps/htm/thailand.shtml (May 12, 1999)
[41] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

Appendix 7B

Detailed Country Assessment of International Needs

7.1 The United States

7.1.1 Technology Needs

The United States has significant needs for climate-friendly technology in the energy sector. It is the world's largest producer of commercial energy as well as the world's largest consumer of energy.[1] Much of the energy is produced from solid fuels.

Net carbon dioxide emissions in 1994 were 4.6 billion metric tonnes (Mt), the highest in the world. The bulk of these emissions are from fossil fuel combustion which accounts for 5.1 billion Mt. The emissions from fossil fuel combustion are offset, to a small degree, by land use changes which enhance the capacity of carbon sinks by 532,000 Mt. The rest of the carbon dioxide emissions are from industrial processes, mainly cement production. Total methane emissions in the United States in 1994 are 28.1 million Mt mainly from waste, livestock, coal mines and natural gas systems. Nitrous oxide emissions were 359,000 Mt.[2]

Overall, the main sources of GHG emissions in the United States are electric power plants, transportation, heavy industry and waste.[3] Current projections suggest that a carbon emissions reduction of 390 million metric tons per year (MtC/year) is required to stabilize US emissions in 2010 at 1990 levels. The target that the US has committed to by the first budget period of the Kyoto Protocol represents approximately a 23% reduction in GHG emissions over the business-as-usual scenario.

[1] US EPA (1996), "Inventory of US Greenhouse Gas Emissions and Sinks, 1990-96"
[2] World Resources (1998-99), "A Guide to Global Resources"
[3] www.dfait-maeci.gc (March 26th, 1999), "United States"

The highest demand for technologies comes from energy production, renewable energy and energy end-use. Given the current state of the US economy, investing in energy-efficiency is the most cost-effective way to reduce carbon dioxide emissions.[4] Therefore the most important technologies needs for the United States are energy-efficiency technologies. Specific demands for GHG mitigation technologies include those for:

Fossil fuel supply

- *Coal bed methane*: The most recent US Climate Action Plan[5] calls for increased spending on research and development for methane recovery from coal mining.[6]
- *Reduced fugitive gas emissions:* The Natural Gas STAR program, a voluntary program, sets an industrywide performance benchmark for leakage and emission control throughout the entire natural gas system. The US EPA plans to expand the existing partnership to include additional transmission, distribution and production companies.[7]

Energy production

- *More efficient conversion of fossil fuels in electrical generation.* The US electric power industry seeks to improve the thermal efficiency of its power plants.
- *Clean coal - high efficiency coal based power generation*
- *Fuel cells*: The US plans to accelerate the commercialization of high-efficiency gas fuel-cell technologies through joint ventures with utilities, research organizations and technology developers.[8]
- *Cogeneration - increased use of integrated energy systems.* With increased state by state deregulation of the electricity industry, opportunities for cogeneration technology are expected to increase.
- *Substituting natural gas for coal and oil:* The US Action Plan proposes to increase the use of natural gas. The Clean Air Act encourages the use of natural gas as a pollution control strategy. The US government also plans to increase the rate at which high-efficiency gas fuel-cell technologies are commercialized. The government will also continue to implement regulatory reforms which will increase the availability and use of natural gas.[9]
- *Switching to lower carbon fuels:* Utilities participating in the Climate Challenge voluntary program can utilize a number of emission-reduction measures to reduce GHG emissions. Switching to lower carbon fuels is one such measure.
  In the biofuels area, cellulosic ethanol, a promising biofuel made from agricultural and forestry wastes, produces no net carbon emissions; the US Department of energy projects cutting the cost of ethanol to under US$0.70/gallon by 2010.

[4] US Government (1995), "US Climate Action Report"
[5] US Government (1995), see op. cit.
[6] ibid.
[7] ibid.
[8] ibid.
[9] ibid.

- *Biomass cofiring:* Biomass cofiring with coal at some plants could product significant emissions reductions. A study for the US EPA has developed detailed cost estimates that indicate biomass cofiring is potentially viable in several parts of the US.[10]
- *Increased use of renewable resources*: The Energy Policy Act of 1992 (EPAct) includes incentives to promote the use of renewable resources. These incentives have given rise to the Renewable Energy Technology Consortium which is being formed with utilities to emphasize the commercialization of *wind power*, *photovoltaic, biomass* and *geothermal energy* programs. The US DOE will facilitate mass-purchasing of these technologies which will enable the manufacturers to increase their production capacity and reduce their units costs. This will increase the competitiveness of these technologies in the market.[11]
- *Wind energy:* Development of wind turbines are expected to enable production of power at less than US$0.03/kilowatt-hour by 2010. Several areas of the US are promising markets for wind energy.
- *Hydroelectric power:* Significant technological potential exists for increasing generation at hydroelectric facilities, but, in the past, institutional barriers prevented efforts to make these profitable upgrades. The recent Profitable Hydroelectric Efficiency Upgrade initiative eliminates some of these barriers and will enable non-federal developers to invest in upgrading existing hydroelectric facilities and sell the additional power generated at market rates.[12]
- *Upgrade/replace existing power plants:* There are approximately 50 million distribution transformers in the US, and 40 million units are on the utility side. Approximately 61 billion kWh are lost per year during electricity delivery from utility transformers. There is, therefore, a strong and immediate need to improve the efficiency of the transmission and distribution networks. The US EPA is implementing an "Energy Star" identification program to encourage electric utilities to invest in high-efficiency transformers. The US DOE is also providing Integrated Resource Planning (IRP) assistance to utilities to consider all options before developing their resource plans such as renewable generating technologies, improving efficiency of generation, transmission and distribution equipment. This program will also increase federal support for removing regulatory barriers to the *increased use of natural gas and renewable energy*.[13]

Energy end-use

<u>*Industry*</u>

- *Improved industrial processes:* The Motor Challenge initiative is a voluntary based program which is being implemented by the US DOE. The US DOE will work with industry to test, verify and disseminate information on the cost-saving

[10] ICF Kaiser Consulting Group (1996), "An Assessment of the Potential for Biomass Cofiring In the US."
[11] US Government (1995), see op. cit.
[12] Ibid.
[13] ibid.

potential of energy efficient industrial motor systems and then obtain commitments from industry to use them.[14]

- *More efficient industrial equipment:* In addition to the Motor Challenge, the "Golden Carrot" program for industrial appliances is being implemented. This program is similar to the "Golden Carrot" program for residential appliances.[15]

<u>*Transportation*</u>

- *More efficient vehicles:* The Climate Change Technology Initiative includes a plan to provide tax credits for purchasing highly fuel efficient vehicles.[16] The US Climate Action Plan also includes initiatives aimed at reducing the amount of miles travelled and encourage the population to use public transport.[17] The Partnership for a New Generation of Vehicles is developing advanced automobiles that will be three times more fuel-efficient than today's vehicles but still safe and affordable.
- *Buildings (commercial and residential):* The US government has stated that it plans to reduce energy use per square foot by 30% by 2005 (base 1985 levels). The State Buildings Energy Incentive Fund was created to finance the design and start-up of energy management programs for public buildings. There are efforts being made to review and revise the Residential Building Code. The Cool Communities program encourages the planting of shady trees around buildings to reduce the demand for air-conditioning during the summer.[18]
- *More efficient appliances and equipment:* The US has developed a "Golden Carrot" program, similar to the industrial program, which creates a financial incentive for developing more efficient appliances. In addition, the schedule for reviewing and revising the National Appliance Conservation Act of 1987 to include new standards for residential appliances is being accelerated.[19]
- *Public transport and traffic management:* The US EPA has implemented a Transportation Partners Program designed to identify measures that could promote GHG emissions reduction.

Carbon dioxide management

- *Forest sinks*: The US is implementing actions to protect carbon sequestered in forest. One initiative is lower harvests of old-growth forests. In addition, efforts are being made to recycle forest products, thereby reducing the demand of new products and consequently enhancing forest carbon sinks. The US Department of Agriculture's (USDA) Forest Service will provide technical and economic assistance to non-industrial forest landowners to help them make silviculturally and financially sound investment decisions. The US government is also involved in accelerating tree planting in non-industrial forests through providing free technical consultations and management plans for forest landowners.[20]

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[14] US Government (1995), see op. cit.
[15] ibid.
[16] www.dfait-maeic/gc (March 26th 1999), "United States"
[17] US Government (1995), see op. cit.
[18] ibid.
[19] ibid.
[20] US Government (1995), see op. cit.

- *Non-energy related sources*
  - *Landfill gas capture and use:* The US EPA is formulating a more stringent rule to reduce methane emissions from landfills under the Clean Air Act. The rule is expected to affect the largest 10% of over 6,000 landfills in the US.[21]
  - *Alternative compounds to SF_6 and HFCs:* The US EPA, under the umbrella of the 1990 Clean Air Act Amendments, will narrow the scope of uses allowed for HFCs with high global warming potential where better alternatives exist. The US EPA will also establish partnerships with chemical manufacturers to support efforts to limit by-product emissions.
  - *Reducing CH_4 emissions in dairy and livestock systems:* AgSTAR is a US pubic-private partnership effort designed to assist dairy and swine farmers to utilize methane produced from manure to produce energy to the farm. The US EPA and the USDA are also involved in an outreach program focusing on production efficiency and reducing methane emissions per unit beef, pork or milk produced.[22]

7.1.2 Factors Influencing Technology Needs

The United States has signed the Kyoto Protocol and has committed to reducing GHG emissions by 7% below 1990 levels to be achieved by 2008-2012. While some demand for GHG mitigation technologies will be enhanced through the scores of voluntary programs and measures include in the US Climate Action plan, significant demand for technologies will likely only emerge if and when the US government ratifies the Kyoto Protocol.

The need for some climate-friendly technology will likely be enhanced through regulatory requirements associated with other environmental and energy issues where certain technologies can address both local as well as climate related issues. For example, ground-level ozone is still a problem in many cities and many states are out of compliance with requirements under the Clean Air Act. Technologies that can reduce air pollution and GHG emissions will be in high demand. In addition, the move towards further deregulation of the electricity market in the US may provide increasing opportunities for Canadian exports of low- and no-carbon electricity to displace high-carbon US generated electricity.

The first US Climate Change Action Plan, developed in 1993, includes market incentives, research and development, improved regulatory frameworks and intensifies existing programs to achieve the United States GHG emissions reduction commitments.[23] The Action Plan has established opportunities to reduce the GHG emissions in all major sectors.

In addition, the Climate Change Technology Initiative (CCTI) was announced by US President Clinton in 1997. This is a nine-point plan which proposes increased funding of US$6.3 billion through to US government fiscal year 2003. The CCTI is designed to

[21] ibid.
[22] ibid.
[23] US Government (1995), see op. cit.

encourage energy-efficiency and to help develop low-carbon energy sources. It consists of a package of tax incentives and research and development spending. The CCTI covers four major carbon-emitting sectors of the US economy: buildings, industry, transportation, and electricity.[24]

Demographic factors may also contribute to an increased need for GHG mitigation technologies. The US has the most powerful, diverse, and technologically advanced economy in the world, with a per capita GDP of US$28,600, the largest among major industrial nations. In 1998, the population of the US reached 273.74 million. The estimated average annual population change between 2005-10 is 0.8 %.[25] Although some significant energy efficiency achievements have been made, the US's demand for energy and mobility is increasing as population increases and as average income levels continue to rise. As a result, it is projected that transportation will be the fastest growing source of carbon dioxide emissions through the year 2000.

An increase in the United States' GHG emissions may also occur as a result of increased economic growth. Real GDP, in the United States, increased 6.1 % in the fourth quarter of 1998, according to the preliminary estimates of the national income and product accounts (NIPAs). This 6.1 % increase, is the largest increase since the second quarter of 1996 and is nearly double the 3.1 % average annual growth rate for real GDP over the current expansion that began in the second quarter of 1991.[26] GHG emissions can be expected to increase as industrial energy demands increase.

Although the US electricity market is already relatively competitive, the Clinton Administration is proposing to restructure the market to achieve greater competition which would translate into economic incentives for generators to produce more electricity with less fuel and to improve energy efficiency.[27] This may enhance demand for cleaner fuels and for energy efficiency technologies. The net impact of restructuring on GHG emissions is, however, still unclear. Energy costs will likely decrease and may in fact increase industry and consumer demand for electricity.

7.1.3 Factor Influencing Market Access

Since the implementation of the Canada-United States Free Trade Agreement (FTA) on January 1, 1989, two-way trade of goods, services and investment income has grown by 83%. After a growth of 22% in 1994, two-way merchandise trade expanded by a further 12.5% in 1995 to C$370.7 billion as a result of the North American Free Trade Agreement (NAFTA) which was implemented in 1994. Currently, NAFTA, together with the World Trade Organisation (WTO), governs the trading relationship between Canada and United States. The expansion of trade with the United States has continued

[24] www.dfait-maeic/gc (March 26th 1999), see op. cit.
[25] World Resources (1998), see op. cit.
[26] www.doc.gov (March 26th 1999), "Bureau of Economic Analysis"
[27] US EPA (1996), see op. cit.

strongly under NAFTA which further reduced trade barriers that affect Canadian exports to the United States.

Although the vast majority of Canadian trade with the United States proceeds unimpeded, there still remain obstacles to the free flow of goods, services and investment between Canada and the United States.

There are numerous US federal laws and regulations that limit foreign investment in the United States. For example, there are restrictions to Canadian investment in US radio and television, air carriers, ship building, banking and insurance, maritime transport and fisheries, natural resource industries, communications and defence-related sectors. Federal and state research and development programs sometimes contain regulations that prevent Canadian firms from becoming members of consortia.

Although a significant amount of government procurement is covered by the WTO Agreement on Government Procurement and NAFTA, many barriers to Canadian exports remain. The Buy American Act still affects some federal contracts, and related legislation creates barriers that flow through federal funding to state and local contracts. The Buy American Act also indirectly discourages US distributors from selling Canadian goods, since it might require separate inventories of goods eligible for public contracts and those ineligible for such use.

US state and local governments, and private sector entities, often receive federal project funding on condition that procurement be restricted to US suppliers. As a result, the use of Canadian products in such projects, frequently in sectors of significant interest to Canadian exporters such as transportation-related supplies and equipment, may be difficult or impossible.

Regulatory requirements applying to products vary widely under US legislation on consumer protection, public health and safety and the environment. There is considerable variation in procedures for assessing regulatory compliance of products. State, regional and local regulations governing laboratory recognition and accreditation can also impede market access.

During US President Clinton's Ottawa visit in February 1995, Canadian and US immigration and customs agencies signed an accord which establishes common objectives for a joint approach to the management of the Canada-United States border. The objectives are designed to promote international trade; to facilitate the movement of people and goods across the border; to provide enhanced protection against illegal activity and to reduce costs.

According to the Environmental Business Journal, the United States is the largest environmental market in the world at US$165.5bill.[28] This market is expected to grow at

[28] *Environmental Business Journal* (1995), "The Global Environmental Market and US Environmental Industry Competitiveness "

an annual rate of 4%. The projected overall growth in the US environmental market is presented below :-

Year	1997	1998	1999	2000	2001
US$bill	186.2	193.6	201.4	209.8	217.8

The new environmental business generated by greenhouse gas emission reduction activities will result in additional and expanded growth above these projections.[29]

The US is currently interested in low-cost climate change technology and the principal opportunity for Canadian technology suppliers is via collaboration with US firms through contract/sub-contracting in the near term and by collaborative technology development in the long term.[30]

Competition for climate friendly technologies is fierce in the US market. The US economy is very market oriented. Overall, the US' principal trading partners are Canada (20%), Western Europe (18%), Japan (16.5%) and Mexico (8%). Canada and the United States are each other's principal trading partner, and have the largest two-way trading relationship in the world. In 1995, the value of goods, services and investment income flowing between Canada and the United States totaled C$454.1 billion. Given the success to date of Canadian environmental firms in accessing the US market, The prospects for an increase in exports of climate-friendly technology are promising.

7.2 Australia

7.2.1 Technology Needs

Australia's technology needs include the following:

Energy Production

- *High efficiency coal based power generation:* Given Australia's heavy reliance on coal, there is a need for technology to improve the thermal efficiency of coal plants.
- *Substituting natural gas for coal*: The Australian government is currently implementing reforms to the gas industry. Gas is therefore projected to account for 21% of fuel inputs for thermal electricity generation in 2010, compared with 9% in 1995-96.[31]
- *Renewables including biomass cofiring, hydrogen, hydroelectric power, tidal energy, geothermal energy, solar photovoltaics, and ocean thermal*: The Australian government is actively engaged in a variety of efforts to develop and promote renewable energy production technology. For example, it continues to provide support for renewable energy technology through the Renewable Energy

[29] www.dfait-maeic.gc (March 26th 1999) see op. cit.
[30] ibid.
[31] Ibid.

Initiative, which is aimed at strengthening the development of this industry. Additional support is given to Cooperative Research Centres with a primary objective of developing technologies to assist climate change abatement with renewable energy.[32] Australia is imposing a mandatory target with electricity retailers to source an additional 2% of their electricity from renewable sources by the year 2010. Australia will be providing A$60 million for the commercialisation of renewable energy technologies[33]. Other government supported measures for the development of renewable energy technology include Showcase -an A$10 million competitive grants program for large-scale renewable energy applications, Renewable Energy Commercialisation Program -an A$30 million competitive grant program to support the demonstration and commercialisation of innovative renewable energy equipment and services, and the Renewable Energy Equity Fund -an A$20 million venture capital fund for small innovative renewable energy companies.[34]

- *Biomass electric*: The Rocky Point Green Energy Corporation received a A$3 million grant to install the latest biomass technology at the Rocky Point Sugar Mill. A 30MW electrical biomass cogeneration plant will operate year round using local wood waste to provide electricity to the Queensland grid.[35]
- *Wind energy*: Western Power Corp. and Powercorp Ltd. received a grant to install an additional two variable speed wind turbines and energy storage system in Denham.[36]
- *Solar thermal energy*: The International Centre for Application of Solar Energy promotes and facilitates the sustainable application of solar and renewable energy in developing countries (this program is run by the Western Australian Government and the Commonwealth Government under the patronage of the United Nations Industrial Development Organisation). Additional initiatives include a consortium comprising of ANUTECH Pty Ltd, Pacific Power, and Transfield Pty Ltd. received a A$2 million grant to install eighteen "Big Dish" solar thermal collectors at the Eraring Power Station. The output of the dishes will provide 2.1 MW of electrical solar energy to the New South Wales electricity grid.[37] Another grant to the Austa Energy Corp. and to Stanwell Corp. will allow them to build a 5MW plant.

Energy end-use

<u>*Industry*</u>

- *Improved industrial processes*: The Australian government is working closely with industry to improve industrial energy efficiency. Australia's Greenhouse Challenge works with the private sector to encourage voluntary reductions in GHG emissions.[38] The Victorian Energy Smart Companies is a government

[32] Ibid.
[33] www.dfat.gov.au/environment/ (March 26th 1999) see op. cit.
[34] www.greenhouse.gov.au/pubs/factsheets/fs_solar.html (March 26th 1999) “Solar, Wind, Oceans, and Rivers - Renewable Energy”
[35] www.greenhouse.gov.au/ (March 26th 1999), “Renewable Energy Showcase”
[36] ibid.
[37] ibid.
[38] www.dfat.gov.au/environment/(March 26th 1999), see op. cit.

initiative that provides assistance to industries in Victoria to improve energy efficiency and reduce GHG emissions.[39]

Transportation

- *More efficient vehicles*: A broad range of university research programs exists to build solar vehicles. Australia is also aiming to improve the fuel efficiency of vehicles by imposing a 15% fuel efficiency improvement target for the automotive industry by 2010.[40] Establishing a more efficient transportation system by upgrading public transport improved infrastructure and reforms in rail and coastal shipping.[41] Voluntary agreements with transportation manufacturing industry.

Buildings (residential & commercial)

- *More efficient appliances and equipment*: The "Green Lights Consortium" was established to implement the Energy Smart Homes program. The program is designed to improve energy efficiency and reduce GHG emissions in the domestic sector. Australia has a National Appliance and Energy Efficiency Committee. Standardised test procedures and energy efficiency standards in new buildings. Efficiency: Improve energy efficiency of electric appliances, equipment and building, energy consumption labeling, adoption of standardised test procedures and energy efficiency standards in new appliances. Voluntary agreements with producers and importers. All Commonwealth departments are required to undertake annual energy audits of their buildings and operations, reporting on specific performance objectives and progress on implementing energy-efficiency measures.

Carbon dioxide management

- *Forest and Agricultural sinks*: Australia will plant forests and revegetate certain areas to enhance forest sinks. This program is supported by Australia's Natural Heritage Trust which will receive A$1.25 billion over five years from 1997 to support initiatives such as Landcare, Bushcare, the National Vegetation Initiative, and the National Reserve System to minimise vegetation loss and increase the uptake of CO_2.[42]

Non-energy related sources

- *Landfill gas*: Australia plans to reduce CH_4 emissions by adopting a national strategy to minimise waste and encourage reuse and recycling.
- *Reducing CH_4 emissions in dairy and livestock system*

7.2.2 Factors Influencing Technology Needs

Australia is a signatory to the Kyoto Protocol and is committed to increasing its GHG emissions by 8% above 1990 levels. According to Australian estimates, this will

[39] ibid.
[40] ibid.
[41] ibid.
[42] www.dfat.gov.au/environment/ (March 26th 1999), see op. cit.

represent a reduction of about 20% from business-as-usual scenarios by 2008-2012. Additionally, Australia has an overseas aid program that is currently funding projects that contribute directly to abating greenhouse gas emissions. These projects are mainly in the Africa and the Asia-Pacific region. For example, Australia is currently participating in an air conditioner energy conservation AIJ project with the Solomon Islands.

Australia has a relatively small population, 18.4 million in 1996. The country's average annual population increase is projected to be 1% for the time period 2005-2010.[43] Compared to other OECD countries, this represents a rapid increase in population. Australia's increasing population will be a contributing factor to increasing energy demands, increasing GHG emissions, and subsequently increasing demand for GHG mitigation technology.

Australia is the fourteenth largest industrial economy in the world. In 1996-97 Australia's GDP was $US 400 billion[44]. Economic growth for the fiscal year 1995-1996 was 4.1%. The ongoing region-wide Asian financial crisis, which began in 1997, has created uncertainty and instability in Australia's economy. Over the long term, Australia's economic prospects generally are bright. The integration of the Australian economy into the rapidly growing Asia-Pacific region and increasing emphasis on using the Asia-Pacific Economic Cooperation (APEC) forum to advance regional economic liberalization should also boost future growth.

On going energy market reforms have reduced some of the barriers to the penetration of new energy supply technologies for electricity generation. Reducing the cost of gas will increase its competitiveness against coal usage and will likely promote fuel switching. In the medium term, greater penetration of gas will offer a significant opportunity to reduce the greenhouse intensity of energy supply in a cost competitive way.

7.2.3 Factors Influencing Market Access

The Australian Government welcomes foreign investment congenial to the Australian community, particularly if it is for export-oriented industries and creates employment opportunities. Some restrictions on foreign ownership exist for the media, civil aviation, mining, and certain kinds of real estate. In 1998, cumulative US investment in Australia--the single-most important source of direct foreign investment in that country--totaled more than US$72 billion and accounted for 24% of total foreign investment.

Since 1984, successive Australian governments have reduced or eliminated tariffs and sectoral-assistance measures. All tariffs were reduced to 5% or below in 1996, except for textiles, clothing, and footwear (TCF), and certain automotive products. In May 1996, the Australian Government reduced the value of tariff relief available to importers of goods through changes to the Tariff Concession Scheme (TCS). The TCS applies to goods imported into Australia for which there is no substitutable good produced

[43] World Resources (1998), see op. cit.
[44] www.dfat.gov.au/environment/ (March 26th 1999), see op. cit.

domestically. The TCS waives any duties payable on imported business inputs and consumer goods, but requires that minimum 3% concessional duty be paid.

Australia has a world class research base with demonstrated achievement, especially in the areas of solar, thermal photovoltaics, and biomass. Renewable energy technologies and manufacturing in Australia are well positioned to take advantage of export markets.[45] Now that privatization and deregulation are realities, Australia need for renewable energy and energy efficiency technologies is increasing. Therefore, although opportunities exists to enter the Australian environmental market, competition from domestic suppliers of environmental technology limit these opportunities.

Many utilities are moving into energy service businesses, where there will be more involvement in end-use technology, particularly where electro-technologies can provide a competitive edge to manufacturers. Opportunities exist for Canadian companies for the following services and equipment: energy audits, energy efficient products (lighting, heating, air conditioning), testing equipment, design, maintenance of energy efficient systems, intelligent motor controller systems, cogeneration, renewable energy, energy management systems, equipment associated with emission controls, process control instrumentation, engineering and construction, ventilation, environmental technologies and services, equipment such as boilers, compressors, piping, pumps and fans, tanks, electric actuators, valves, power transformers, fabric flue filters and many other products to reduce greenhouse emissions.

Australia's links with the Asia-Pacific region which accounts for over half of Australia's trade flows are particularly strong. In 1997 Australia's exports were US$56 billion. The majority of exported goods went to the United States (US$5.5bill), Japan, South Korea, New Zealand, Singapore and Taiwan. In 1998, imports to Australia were valued at US$59 billion. Goods were mainly imported from the US ($13.7 billion), Japan, Germany, U.K., China, New Zealand, Taiwan and Singapore.[46]

7.3 The Russian Federation

7.3.1 Technology Needs

Russia has some of the highest GHG emissions in the world. In 1990, net carbon dioxide emissions were 1.8 billion Mt. Although 2.3 billion Mt of carbon dioxide comes from fossil fuel combustion, land use changes absorb 587 million Mt of carbon dioxide thereby reducing Russia's net carbon dioxide emissions. Methane emissions in 1990 were 27 million Mt mainly from fossil fuel extraction and to a limited degree, livestock and waste. Nitrous oxide emissions were approximately 225,000 Mt.[47]

[45] www.dfat.gov.au/environment/ (March 26th 1999) see op. cit.
[46] www.dfait-maeci/gc (March 26th 1999), "Australia"
[47] World Resources (1998), see op. cit.

In Russia's urban centres, carbon dioxide and nitrogen oxide levels are 12 times higher than maximum permitted levels during rush hours. Although the level of air pollution is reportedly down 30% from 1990, due to economic decline and reduced industrial production, some 16,000 deaths each year are still attributed to suspended particulates in the air.[48] Russia's fuel and energy industry, particularly oil and gas facilities, is the main contributor to this pollution. The industry suffers from a wide range of problems including leaky pipelines and inefficient and heavily polluting refineries. Nearly 60% of Russian companies are believed to be severely impacting the environment due to the use of outdated equipment and technology.[49] The outdated and inefficient district heating systems currently operating also represent a major source of GHG emissions.

The Russian Federation has one of the world's largest energy industries. Russia is the world's third largest producer of crude oil producing 303 million tons. In addition, Russia produces 196 474 Mm^3 of natural gas making it the world's largest producer of natural gas. Russia is also the world's largest producer of brown coal, producing 85 Mt, and it is the world's sixth largest producer of hard coal, producing 157 Mt.[50] Despite the enormous significant of Russia's energy sector, the industry is facing serious difficulties since the Soviet era. The contribution to GHG emissions is but one of the many problems facing this sector.

Russia's oil sector is currently under intense pressure to improve production efficiency. Low industrial demand and environmental concerns related to pipeline deficiencies have produced an overall industry stagnation. The Russian government is implementing various measures to increase production such as removing oil export ceilings and reducing the oil export tax by 20%. In 1994, the World Bank estimated that Russia requires 15 to 20 new fields by 2000. Western industry experts predict that if the right conditions are met for market economics and foreign investment, Russian oil output could rise moderately to 350-370 million tons by 2010.

The highest demand for GHG emissions technologies relate to the energy industry, with the greatest needs in the oil sector, and then the gas and coal sectors. Specific demands for GHG technologies include those for:

Fossil Fuel Supply

- *Energy efficiency for crude oil refining:* Russian oil firms are under pressure from the government to increase efficiency.
- *Coal bed methane:* The US EPA is working on projects to recover methane from coal mines.[51] ICF/EKO, a consulting firm in Moscow is preparing a UNDP funded feasibility study for coal bed methane technologies in Russia.
- *Reduced fugitive gas emissions and pipeline losses:* The US EPA is working with Russia to recover fugitive methane emissions from gas pipelines

[48] www.worldbank.org (March 24th 1999), "Countries and Regions : Russia"
[49] www.dfait-maeic.gc (March 24th 1999), "Russia"
[50] IEA (1998), "Key World Energy Statistics"
[51] US Government (1998), "US Government Support for Climate Technology Cooperation Projects and Activities"

(particularly in the GAZPROM system). The GAZPROM working group is also working with the US to identify opportunities to reduce methane emissions from Russia's natural gas system through the application of US technology.[52]

The World Bank is currently implementing a project funded by the Global Environmental Facility to reduce pipeline emissions of natural gas.

- *Improved flaring:* Russia has expressed a need for gas-flaring system upgrades.[53]
- *Low leak valves, fittings:* Russia and the US are involved in an AIJ project to capture fugitive gas emissions at 2 compressor stations. The project involves sealing leaking valves at the stations.[54]

Energy production

- *High efficiency coal based power generation:* Russia is interested in new coal-fired generation technologies with higher thermal efficiencies.[55]
- *Wind energy:* The US DOE is providing technical assistance to demonstrate the huge potential for wind technologies in off-grid locations in Russia's Northern Territories. 40 wind-diesel hybrid systems were installed in 21 sites in the Northern Territories in 1997-8.[56]
- *Solar photovoltaics:* The US DOE and the Russian Ministry of Fuel and Energy have launched demonstrations of rooftop PV generators in Fili Park in Moscow. Assistance is also being provided to start a PV manufacturing facility in Moscow.[57]
- *Biomass electric*: The World Bank has authorized a loan of US$3 million to build a 470 kW wood-waste biomass electric facility.[58]

Energy end-use

<u>*Industry*</u>

- *More efficient industrial equipment:* Firms in the energy sector are facing increasing pressure to upgrade the environmental component of their operations, namely outdated pipeline infrastructure and equipment.[59] There is an overwhelming need to improve current levels of energy intensity and upgrade industrial processes.

<u>*Buildings*</u>

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[52] US Government (1998), see op. cit.
[53] www.itaiep.doc.gov.BISNIS (March 24th 1999), "Country Reports : Russian Federation"
[54] US EPA (1998) "Activities Implemented Jointly:Third Report to the UN Framework Convention for Climate Change - Vol.1"
[55] www.itaiep.doc.gov.BISNIS (March 24th 1999), see op. cit.
[56] US Government (1998), see op. cit.
[57] ibid.
[58] ibid.
[59] www.dfait-maeci/gc (March 24th 1999), "Russia"

- *More efficient appliances and equipment:* The US EPA is working with Russia to develop new energy efficient building codes and an energy "passport" system to improve and monitor energy use in buildings.[60]
  The US DOE is cooperating with US window manufacturers to disseminate energy efficient window technologies and window rating systems to Russia. The Russian Ministry of Construction has issued new, higher energy efficiency requirements for windows as a result.[61]
- *Public transport and traffic management:* The World Bank is engaged in negotiations with the Russian Government to fund improvements to public transportation infrastructure in several urban areas.
- *District energy:* The US DOE and the Russian Centre for Energy Efficiency (CENEf) are working with municipalities to identify, design and finance district heating retrofits. In 1997, US$645,000 in efficiency improvements were made. The World Bank is considering a US$200 million district heating loan program to support these projects.[62] Projects in 3 districts are already underway as AIJ projects between Russia and the US.[63]

Carbon dioxide management

- *Forest and Agricultural sinks:* Russia and the US participate in an AIJ project where 2000 hectares of collective state farm land will be converted from hay fields back to forest in Vologda, 300 miles northeast of Moscow.[64]
  Another Russia/US AIJ project involves 900 ha of marginal agricultural land and previously burned forest stands which are being converted to plantations to serve as forest sinks.[65]

Enabling (cross-cutting) technologies:

- Russia and the Netherlands are involved in an AIJ project to reduce CO_2 emission by reducing heat losses from installing modern greenhouse structures and using of energy saving technology to grow tomatoes. Specifically the project will involve using a modern heating installation (efficiency 90%) and/or a cogeneration unit; on-farm heat production (no transport loss); computer controlled heat production based on actual demand.[66]
- *IT and control technologies:* Russia and Germany are involved in an AIJ project where Gazprom and Ruhrgas will pool their know-how in pipeline system control optimization. For this cooperation project, Gazprom selected a section of the Volgotransgaz pipeline system as a pilot project. The optimization software is provided by LIWACOM Informationstechnik GmbH, a Ruhrgas affiliate.[67]

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[60] US Government (1998), see op. cit.
[61] ibid.
[62] ibid.
[63] US EPA (1998), see op. cit.
[64] ibid.
[65] ibid.
[66] www.unfccc.de (March 24th 1999) "UNFCCC-CC:INFO/AIJ - List of AIJ Projects"
[67] ibid.

7.3.2 Factors Influencing Technology Needs

The Russian Federation is a signatory to the Kyoto Protocol and has committed to stabilising GHG emissions by the first budget period.

Russia faces enormous environmental problems caused by extensive industrialization and the lack of adequate technologies to deal with the ecological consequences. There is severe pollution of air, water and soil in many regions of the country, caused by spills and routine discharges. While Russia has committed to reduce its GHG emissions over the business-as-usual scenario, climate change is not a top priority among environmental issues. The possibility of technology transfer through Annex B country Joint Implementation (JI) is, however, of interest to the Russian government. At present, however, the modalities for JI under the Kyoto Protocol have not been finalised. In theory, however, JI could offer Russia the opportunity to obtain technologies that reduce emissions of GHG and ameliorate local environmental issues.[68]

Although on a daily basis, the most serious problem facing Russians is the poor quality of water supplies, air pollution has received considerable attention in the last year, and demand for treatment equipment should improve. The most serious environmental problem in Russia's cities is pollution from cars, which are responsible for about 85% of air pollution. In addition, 40% of Russia's population live in some 200 cities where the air pollution level exceeds permissible levels. In 120 of these cities air pollution levels exceeded government standards by five times.

Russia is beginning to focus attention on the environment and to make progress toward cleaning up the ecological disasters left over from the Soviet era. The Russian population has become relatively well informed about the environmental problems facing the country. Despite this awareness, and certain actions taken by the federal and local governments, progress toward achieving environmental protection is very slow.

The main impediments are:

- lack of financing,
- the need for export revenue, which has encouraged the development of environmentally unhealthy industries such as the chemical and petrochemical industries, and ferrous and non-ferrous metallurgy,
- the inconsistency or misuse of environmental legislation and lack of enforcement, and
- the lack of modern techniques and equipment for environmental site assessment and remediation.

[68] Karmali, A (1997), “Lessons Learned from Technology Transfer and the Pilot Phase of Activities Implemented Jointly”. IEA Conference on AIJ Technologies.

If anything, demographic factors may reduce demand for GHG mitigation technologies. The Russian Federation has a population of 147.3 million.[1] According to 1996/7 United Nations data, almost 78% of Russia's population is urban. Currently Russia is in the midst of a demographic crisis. The estimated average annual population change between 2005-10 is -0.4% and the expected population by 2025 is 131.4 million.[1] Therefore, as Russia's population decreases, its impact on GHG emissions could actually be positive since there would not be any significant increases in the demand for household electricity or for mobility.

Russia's fuel and energy industry, and the oil and gas sector in particular, is the backbone of Russia's economy. Oil and gas is responsible for more than a quarter of the country's industrial production, and over half of its exports. Oil accounts for 5% of Russia's GDP, 20% of foreign exchange earnings, and 10% of all fiscal revenues.

Although some marked improvement was visible in Russia's economy in 1997 when the economy showed signs of consolidating macroeconomic stabilization, things changed by 1998. The two main reasons for the downward turn of events were the East Asian financial crisis at the end of 1997 and a change of government in Russia in early 1998. The fiscal situation continued to worsen resulting in an unsustainable accumulation of public dept although attempts were made to improve tax collection. In addition to protecting the ruble, these events meant that real interest rates remained high, thereby inhibiting growth.

Since then, the financial crisis has not abated and Russia has been actively involved in dealing with the financial volatility and the increasing macroeconomic instability through structural reform in key areas with help from the IMF and the World Bank.[71] The process of making the transition to a market-based economy has not yet provided Russia with an enduring basis to sustain growth. Without a significant increase in economic growth in the near future, Russia's GHG emissions will probably stabilise at current levels, which are extremely high.

7.3.3 Factors Influencing Market Access

Although environmental protection is not a top priority in Russia, Russian industry is facing growing pressure to upgrade the environmental component of their operations, namely outdated pipeline infrastructure and equipment.

For a brief period in 1990-1992, officials attempted to shut down chronic polluters. However, the economic and political impact of these actions quickly overruled environmental concerns. At present, Russia's system of pollution charges and fines provides the only incentives for industrial enterprises to make environmental investments. Although Russia has relatively stern environmental standards, enforcement is extremely weak. As a result, Russian private enterprises and government authorities

[69] www.worldbank.org (March 24th 1999), see op. cit.
[70] World Resources (1998), see op. cit.
[71] www.worldbank.org (March 24th 1999), see op. cit.

currently devote only limited resources toward meeting environmental standards. There are discussions about revising environmental laws and enforcement, but the topic is a low legislative priority.

Important economic reforms are being implemented to abolish state monopoly on foreign investments and to privatise state owned companies. The Ministry of the Economy is responsible for promoting foreign trade and has created the Russian Foreign Trade Promotion Centre whose mandate is to:

- encourage foreign investment,
- advocate laws and regulations to improve Russia's investment climate, and
- study investment projects and bring together potential partners.

Russia has also formed a Foreign Investment Advisory Council whose objectives are to initiate cooperation in improving the investment climate through:

- image enhancing,
- reducing internal barriers, and
- reducing external barriers.

Aside from administrative and competitive factors there are no significant barriers to exporting environmental products to Russia. Although these barriers have been substantially reduced, they have not been eradicated. The Russian government actively encourages the purchase of locally made equipment where possible in order to help its balance of payments.

The value-added tax (VAT) in Russia is 20%. Duties on imported equipment can vary from 0% to 30%, depending upon the product. Many import taxes are waived on environmental equipment, which must be certified to meet Russian standards. In the past, these standards have been used to protect domestic industry from foreign competition.

The agreements that Canada and Russia made in 1992 for closer economies ties and political ties, bilateral cooperation on environmental and northern issues have set the stage for Canada's entry into the Russian market.

The market for environmental technologies in Russia is somewhat depressed at present due to the economic crisis and the collapse of heavy industry. The general lack of enforcement of environmental regulations only exacerbates the problem. The US Embassy in Moscow estimated the environmental equipment market was worth US$190 million in 1997, with imports accounting for 58% of the total market. The market has experienced an average annual decline of 14% since 1994.

There is, however, considerable potential in the long run, when the Russian economy improves. Prior to the financial collapse of August 1998, the German consulting group Helmut Kaiser Unternehmensberatung (HKU) reported that the Russian environmental market offered the greatest potential in Central and Eastern Europe. They estimated the market was worth US$8.715 billion in 1997 and would rise to US$18.046 billion in 2010. They also indicated that Russia would have to spend approximately US$288.83 million by 2010 in order to bring its environmental technology up to par with Western European standards. While these long-term forecasts will be affected by Russia's current economic situation, they nonetheless indicate an huge potential market.

The stimulus for environmental market growth will come from outside Russia, through projects funded by international financial institutions (IFIs) such as the World Bank and the European Bank for Reconstruction and Development (EBRD), as well as foreign direct investors. IFIs are the largest source of environmental market demand, through specific environmental projects and through non-environmental activities such as industrial development projects that require environmental protection activities.

Russia's oil and gas sector has massive environmental needs, and is likely the only industrial sector in Russia that has the capital and foreign currency to buy western equipment. Therefore it appears to be the most attractive market for GHG emissions mitigation equipment and services in Russia.

Price is the most important competitive factor in selling to Russian buyers. Domestic equipment and service providers have a significant cost advantage over foreign producers, and are able to sell at a much lower price.

Strong home government support has given European firms, trading with Russia, a competitive advantage. The funding of tied-aid projects is a common strategy used by European governments to help their firms gain a foothold in the market.

Germany is the largest exporter of environmental equipment and services to Russia. Scandinavian companies also have a strong presence, particularly Norway. Other former Soviet bloc countries such as Ukraine also supply the Russian environmental market. The US is the third largest exporter of environmental equipment to Russia after the Ukraine and Germany.

There are between 400 and 1000 Russian firms involved in the production of environmental technologies. While Russian-made equipment is the first and often only choice of Russian customers, this equipment does not meet most international standards for quality and performance. As such, domestic manufacturers are not particularly competitive when selling to international companies operating in Russia. Foreign companies and IFI-funded projects are more likely to require better performing equipment.

Canada has already established a presence in the Russian environmental market. There are a number of Canadian firms selling oil and gas equipment to Russia. Canadian companies were early investors in Russian joint-ventures, but all original investors have since pulled out, except Canadian Fracmaster, Norex-Yugraneft, and Bitec.

7.4 Poland

7.4.1 Technology Needs

Carbon oxides (dioxide and monoxide) emissions are among the highest in Europe. This is due mainly to the country's heavy reliance on coal for electricity production and heating. Emissions of nitrogen oxides per capita are similar to those of other EU countries.[72] In 1992, total carbon dioxide emissions were 371.6 million Mt, 360.9 million Mt of which are from fossil fuel combustion. Methane emissions were 2.47 million Mt mainly from fossil fuel extraction, livestock and waste.[73] Total emissions of GHGs are lower than 1990 because of the tremendous restructuring that the Polish economy has gone through after it changed its economic system from central planning to a more market-based approach.

The main sources of stationary emissions are power and heat-and-power plants, chemical plants, iron and steel mills, and lead and zinc smelters. Small district heating plants and residential furnaces are the largest source of local emissions. District heating companies own about 16 GW coal fired boilers, consuming about 6 million tons of coal per year.[74] Power is generated in 56 thermal power plants, 33 of which are combined power and heat plants. The installed capacity of the power stations is 33,000 MW. Modernization is need to replace 16 gigawatts of obsolete installed capacity and to satisfy additional stricter environmental standards.[75]

Mobile sources of emissions account for 31% of nitrogen oxide, 37% of carbon monoxide, 24% of hydrocarbons, 25% of carbon dioxide and 30% of lead released into the atmosphere. These figures should improve since Poland now requires that all cars produced or imported be fitted with catalytic converters.

The highest demand for environmental technologies relates to the energy sector and water and wastewater treatment, followed by waste management. This demand pattern is due mainly to current Polish environmental policy and regulations, whose major priority areas are air pollution control and protection of water resources. Specific demands for GHG mitigation technologies include those for:

Fossil fuel supply

- *Coal bed methane:* In order to reduce their dependence on imported gas, Poland intends to develop exploration and production of methane gas from hard coal deposits in Silesia.[76]
- *Energy efficiency for crude oil refining:* Major problems faced by the petroleum industry in Poland include obsolete technology, poor energy efficiency, excessive use of raw materials and low utilization of existing capacity (below 80 %). The two largest refineries, Plock and Gdansk, are

[72] www.worldbank.org (March 23th 1999), “Countries and Regions : Poland”
[73] World Resources (1998), see op. cit.
[74] www.unfccc.de (March 23th 1999), see op. cit.
[75] www.tradecompass.com/library/books/com-guide/ (March 23th 1999), “Country Commercial Guides : Poland”
[76] ibid.

embarking on modernization programs worth more than USD 1.5 billion.[77] Specifically, Poland is interested in heat recovery systems and coal-fired fluidized bed combustors.

Energy production

- *Substituting natural gas for coal and oil:* Poland's energy industry is dominated by coal. About 3.2 GW of this capacity is considered, by the World Bank, suitable for replacement with gas fired boilers.[78] Poland is exploring various avenues for fuel switching. For example, Poland participates in a fuel switching AIJ project with Norway. The project involves switching from coal to gas. The conversion of coal to gas is not financially attractive without taking into account the global warming considerations and/or local pollution effects.[79]
- *Increased use of integrated energy systems (cogeneration):* Poland has expressed significant interest in cogeneration.
- *Upgrade/replace existing power plants*: State-of-the-art systems are needed to reduce emissions of sulphur dioxide, dust and particulates, nitrogen monoxides and hazardous chemicals. Many of these technologies reduce local air pollutants and subsequently reduce GHG emissions.
- *Increase use of renewable resources:* Poland's National Environmental Policy Program proposes replacing some coal-fired power generation with alternative sources of energy.
- *Biomass electric:* One alternative energy source proposed by the Program is waste conversion.
- *Hydroelectric power:* Another alternative energy source proposed by the Program is small hydro.

Non-energy related sources

- *Landfill gas capture and use*: Composting and biomass conversion technologies are in high demand for dealing with municipal waste. For example, the city of Szczecin has recently signed an agreement with the United States to design, build and operate a 15 to 20 megawatt waste-to-energy power plant.

7.4.2 Factors Influencing Technology Needs

Poland has signed the Kyoto Protocol and has set a GHG emissions reduction target of 6% from baseline levels, 1990. Climate change is, however, not a major environmental priority. The need for climate -friendly technology will likely be enhanced since it would enable Poland to reduce its GHG emissions as well as address other local air pollution issues.

[77] ibid.
[78] www.unfccc.de (March 23th 1999), see op.cit.
[79] ibid.

Poland suffers from some of the most severe environmental problems in Central and Eastern Europe. Two of the most polluted areas in Europe, Upper Silesia and the Black Triangle (Central Europe's brown coal depression), are located in the south and southwest of Poland. Considerable environmental damage has occurred in the past and continues to take place. Damage includes the contamination of water and soil and the deterioration of air quality. The continuing development of heavy industry and an energy sector based mainly on coal are among the key causes of severe pollution.

The main goals of the government's 1994 National Environmental Policy Program to the Year 2000 are to reduce environmental pressures on the air, water and soil; develop waste treatment and disposal facilities; develop water resources; and expand and/or enlarge nature conservation areas. In terms of air quality, the following priorities have been set out in the Program:

- reduce sulphur dioxide emissions from stationary sources by 1 million tonnes between 1995 and 2000 -- the main focus is on the coal-fired power sector and the mining industry;
- achieve major reductions in carbon monoxide, hydrocarbons, lead and noise from transportation-based sources over the same period;
- modernize technological processes through the use of cleaner technologies;
- replace some coal-fired power generation with other electrical generation technologies, such as small hydro and waste conversion; and apply alternative sources of energy.

Demographic factors are not likely to drive demand for GHG emission mitigation technologies. Poland's population is currently 39 million. According to 1997 World Bank figures, 64% of Poland's population is urban and 24% live below the poverty line. The estimated average annual population change between 2005-10 is 0.2%.[80] Therefore, population growth will likely not significantly contribute to a growth in Poland's GHG emissions.

Poland's continually improving economic performance may, however, result in an increase in the growth of GHG emissions. Poland adopted radical economic transformation policies in 1990 and by 1992 the Polish economy started recovering. Poland's economy has been growing positively since then with a record GDP growth in 1995 at 7%. The 1998 budget made several assumptions about GDP growth and inflation. GDP is expected to grow at 6.5% and inflation is expected to reach 9.5%. One can anticipate a growing increase in the demand for energy and a concomitant increase in GHG emissions.

Electricity prices are relatively low in Poland. For example, the price for electricity for industry in Poland is US$0.0352 kWh compared with an average of US$0.0407 in the US. Similarly, the price for household electricity is US$0.0598 in Poland and US$0.0831 in the US. The prices for natural gas for industry and households are much higher in Poland than in Canada. The industry prices are US$123 in Poland and US$72.31 in

[80] World Resources (1998), see op. cit.

Canada while household prices are US$220.77 in Poland and US$170.57 in Canada.[81] The high prices for natural gas indicate Poland's dependence on imported gas, although there are some domestic sources.[82]

The differences in electricity prices between the United States and Poland indicate that the Polish government intervenes quite heavily in the energy market to distort energy prices. The lower electricity prices indicate that electricity for households and industry is subsidized. Changes are occurring however, Poland's Parliament passed a new Energy Law in April, 1997. This law creates a solid legal framework for a competitive energy market.[83] Subsidies will gradually be removed to ensure that distortions are phased out of the energy market. This should cause the price of previously subsidised energy to rise. Energy producers will then have two choices; increase efficiency to bring the price down to more competitive levels or reduce production and allow lower priced imports into the market. Either option presents opportunities for Canadian exporters of GHG emissions mitigation technologies.

7.4.3 Factors Influencing Market Access

Poland's desire to enter the European Union has caused it to move environmental issues to the top of its political agenda. Consequently, Poland has demonstrated the most impressive commitment to environmental protection of all the countries with economy-in-transition. For example, it has the region's most aggressive program of investment in the environment, worth over US$1.4 billion annually (1.3% of gross national product). Government policies are shifting away from the application of end-of-pipe technologies toward more progressive programs to prevent pollution and minimize waste.

Poland also has progressive environmental regulations and a strong commitment to enforcement. Environmental officials have closed down inefficient industries even at the expense of increasing unemployment.[84] The effective regulatory system has been a major contributor to the rapid growth of environmental investment in the post-Communist period. The system of fees and fines imposed on polluting industries and municipalities, coupled with an innovative system for financing environmental expenditures, has caused many polluters to take pollution control (and, more recently, prevention) seriously.

The Polish government, and all major political parties, generally believe that foreign investment is essential for the growth and modernisation of the Polish economy. Although this belief has not translated into specific policies, the government is adopting some measures to boost foreign investment and promote trade. For example, Poland has developed a legal system which provides equal treatment to foreign and domestic firms.[85]

[81] IEA (1998), see op. cit.
[82] www.tradecompass.com/library/books/com-guide/ (March 23th 1999), see op. cit.
[83] ibid.
[84] www.dfait-maeci/gc (March 23rd 1999), "Poland"
[85] www.strategis.gc.ca (March 23rd 1999), "Trade and Investment - *search Poland*"

Although Poland and Canada have signed a Memorandum of Understanding on Environmental Cooperation to facilitate and broaden environmental cooperation activities between the two countries, there are still a number of concerns for Canadian technology suppliers. Specific government supported import programs do not exist. In fact, the Public Procurement Law (1994) gives preference to domestic suppliers, especially if major installations are procured.

In addition, Canadian products face tariff disadvantages compared to European products. The duty on Canadian environmental equipment is generally 11%. The rate for EU countries is between 0% and 6.6%, while equipment from Central European countries enters duty-free. All imported goods are subject to a 22% value-added tax and must comply with EU standards and safety regulations.

Estimates of the overall environmental market size in Poland vary considerably from source to source, since there is no standard definition of what products and services make up the environmental market. According to a study by the German environmental consulting firm of Helmut Kaiser Unternehmensberatung, the Polish environmental technology market is one of the most dynamic in Central and Eastern Europe, averaging an annual growth rate of 8%. The market was worth US$3.1 billion in 1996 and should reach US$7.95 billion by 2010. Total environmental expenditures in 1995 amounted to US$13 billion. Spending on air protection accounted for 53% of total expenditures, while water protection accounted for 37% and waste management for 9%.

The Polish environmental industry has developed at a rapid pace and is quite competitive and there may be opportunities for Canadian firms to find suitable local partners. There are approximately 2,000 local environmental companies, the majority of which are small to medium-sized firms. Local companies supply approximately 34% of the environmental equipment market. In addition to focusing on the water and wastewater market and the waste management, Polish firms also specialize in air quality measurement and analysis, including the design of both air pollution control systems and air pollution monitoring systems.

Foreign business activity in the Polish environmental market is highest in the water and wastewater sector, followed by the waste management and air sectors. Competition for Canadian exports is likely to come from Poland’s largest import partners Germany, Italy, Russia, the U.K., France and the United States. German, Austrian, American, Dutch and Scandinavian environmental technology firms are the most active. Foreign companies from countries that offer financial assistance to Poland (Germany, Denmark, the Netherlands, Italy, the United Kingdom, Austria, France, Switzerland and the United States) are very well represented in the market.

The Canadian environmental industry has only recently begun to make inroads in Poland. Some companies have had success in niches other than climate change technology (Zenon Environmental, Mabarex, ADI, ESI Ecosystem, Agra Earth & Environmental), but the industry remains under-represented relative to its capacities. The success of these firms bodes well for other Canadian companies interested in helping Poland reduce its GHG emissions.

7.5 China

7.5.1 Technology Needs

Fossil fuel supply

- *Coal bed methane*: China is interested in producing energy through coal bed methane recovery. The US EPA is currently conducting pilot projects designed to capture methane emissions from Chinese coal mines.
- *Underground coal gasification:* The Chinese Government has expressed an immediate need in this area. Through the Asian Development Bank (ADB), ICF Kaiser Consulting Group is presently conducting a feasibility study on the viability of coal gasification technologies on behalf of the Chinese State Environmental Protection Agency.

Energy production

- *High efficiency coal based power generation*: China has expressed its need for technologies that desulphurise coal, and that allow for the comprehensive usage of coal gangue for construction materials like brick making or the backfill of mines. In addition, China has also expressed an interest in coal refining equipment for purifying and reusing coal, equipment for the denigration of flue gas from coal burning boilers, and large-scale fluidised bed combustion technology.[86] China also needs modern combustion technologies that remove suspended particulate matter from flue gases and coal-fired boilers through the use of gravity settling chambers, cyclones, spray chambers, bag filters, and electrostatic precipitators.[87]
- *Integrated gasification combined cycle (IGCC)*: China is interested in efficient clean coal combustion technologies which may have the capacity to replace the steam turbine in fossil-fired power plants as China attempts to retro-fit old plants. China has already imported more than 10 sets of oil-fired and gas-fired combined cycle units. IGCC has been classified as a medium to long-term need by the Chinese Ministry of Electric Power. A project is currently underway in China construct an IGCC demonstration power plant that uses 1/3 less water and will reduce CO_2 emissions by 23%.
- *Crude gas production*: CFB coal gasification for ammonia synthesis is a process used to convert a variety of solid fuels (biomass, coal, wastes) into crude gas for fuel and synthesis gas production. China has expressed a need for this technology although it is still in its research and development stage. This technology could replace the low efficient UGI gasification process. If China were to replace 50% of their old UGI gasifiers with CFB gasifiers there will be a 7.8 Mt reduction in CO_2 emissions.[88]

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[86] US Department of Commerce (1996), see op. cit.
[87] Energy Institute of SPC (1996), "The List of Chinese Government Needed Technologies"
[88] ibid.

- *Biomass gasification*: Biomass gasification is a technology used to convert woods, stalks, and other solid biomass fuels into gas fuels. Gasificating one tonne of biomass can reduce CO_2 emissions by about 1.4 tonnes. This technology is intended to provide efficient energy to China's rural areas. China also expressed a need for Rice Husk Energy Transfer Instruments as another method for providing energy to its peripheral areas. This technology will convert the biomass energy of rice husks into usable energy.[89]
- *Wind energy*: China has expressed a need for rural and remote renewable energy electrification.[90] Currently, US Agency for international development (USAID) is providing a wind-mapping service for China to enable China to increase its use of wind energy.
- *Solar thermal energy*: In its list of technology needs, China also expressed a need for solar hot water heater-vacuum tubes.
- *Nuclear power*: China will be increasing its reliance on nuclear energy in order to meet its rapidly growing demand for energy. China plans to increase its nuclear capacity by the year 2003 with the construction of two CANDU reactors.[91]

Energy end-use

<u>Industry</u>

- *Improved industrial processes*: The Chinese government is also interested in Direct Reduction processes for its iron-smelting industry. This process consumes significantly less energy than conventional processes and emits 50 to 60 % less CO_2 emissions per tonne of steel produced.[92]
- *Reduced energy intensity:* The United Nations Industrial Development Organisation's studies suggest that Chinese industry can vastly improve its energy intensity. Various UNIDO demonstration projects are underway to assess the potential improvements in this area.
- *More efficient industrial equipment*: A World Bank/UNDP/Chinese Environmental Protection Agency study in 1996 identified a series of GHG emission control options in the industrial energy efficiency area. The US DOE and China are working on the development and commercialisation of high-efficiency motors and motor speed controls. A Chinese Motor Challenge Program is currently in its developmental stages.

  The Chinese iron and steel industry is interested in converting open hearth furnaces to basic oxygen furnaces, DC electric arc furnaces, replacing outdated copper, lead, and zinc smelters, and in modern technologies for new iron an steel plants. China has also expressed a need for technologies that use industrial wastes such as fly ash and coal washery wastes for its cement industry.

<u>Transportation</u>

- *More efficient vehicles*: The US DOE and the Chinese Ministry of Science and Technology recently expanded technology cooperation to include electric vehicles

[89] ibid.
[90] US Government (1998), see op. cit.
[91] www.can.ca (March 24, 1999) Canadian Nuclear Association.
[92] Energy Research Institute of SPC (1996), see op. cit.

and electric-hybrid vehicle development.[93] Additionally, China has expressed a need for three-way catalytic converters that significantly reduce NO_x, CO_2 and hydrocarbon emissions[94], fuel evaporation control systems (FEC), renovated energy-saving and low polluting carburetors, and electronic fuel injection systems.[95]

<u>*Buildings*</u>

- *More efficient appliances and equipment*: The US DOE is sponsoring an energy efficient office building demonstration project in China in partnership with the Chinese Ministry of Science and Technology. This project involves the demonstration of clean energy building technologies that include the use of solar energy which could potentially reduce CO_2 emissions by 50%.[96]
- *Improved envelope and architecture*: The US EPA has a partnership with the Chinese State Environmental Protection Agency to demonstrate energy efficiency technologies in government buildings.

Non-energy related sources

- *Landfill methane*: China is also participating in a UN / GEF project which involves developing a landfill methane recovery system.

Enabling and cross-cutting technologies

- *Fuel cells*: China is interested in fuel cell technology which is used to transfer chemical energy from fuel into electric energy. This process does not emit GHGs.

7.5.2 Factors Influencing Technology Need

China has not yet signed the Kyoto Protocol or committed to a reduction in GHG emissions. Currently China is also not participating in any AIJ projects. The Canadian CDM/JI office has, however, reached an agreement to set up a framework for such projects. However, China recognises the importance of addressing environmental problems and is committed to improving the air and water quality within its major cities and Special Economic Zones. It is also engaged in a variety of technology transfer projects funded by bilateral agencies and international funding institutions (IFIs) that are aimed at demonstrating technologies to reduce GHG emissions. In general, however, the need for GHG emissions mitigation technologies will only become heightened if China, like some non-Annex countries, takes on voluntary commitments to reduce GHG emissions.

Both demographic and economic factors may increase GHG emissions and contribute to an increased need for climate-friendly technologies. China's estimated total population in 1997 was 1.22 billion with a 0.93% growth rate. China's large population is the leading cause for escalating energy demands and consumption in China. Coal

[93] US Government (1998), see op.cit.
[94] US Department of Commerce (1996), see op. cit.
[95] www.dfait-maeci/gc (March 23rd 1999), see op. cit.
[96] US Government (1998), see op. cit.

consumption is expected to grow dramatically as the country's standard of living increases.

China is one of the fastest growing economies in the world. Its per capita gross national product (GNP) for 1997 was $620 million US[97] and is projected to grow between 8 and 9 percent annually in the short-term[98]. This dynamic growth can be largely attributed to China's reform policies that have substantially opened its doors to the outside world.

China is the second largest producer of electricity in the world after the US. In terms of the country's energy requirements, China will need to increase its installed energy potential to keep up with its rapid pace of economic growth. China is the largest producer of coal in the world and the seventh largest producer of crude oil.[99] This suggests that with such an abundance of coal and crude oil resources, China will continue to use these carbon intense fuels to meet its escalating energy demands and therefore continue to significantly contribute to climate change. China also produces 7.5% of the world's hydropower. In 1995 installed capacity was 48 GW.

Between 1997 and 2005, China plans to add approximately 23.2 GW to its present overall installed capacity. 19.1 GW will be in the form of thermal energy and hydropower will comprise the remaining 4.1 GW.[100]

China's energy prices are far lower than the actual costs. However, great strides are being made to rectify the situation. Over the past three years, the government has raised and partly deregulated coal prices. In most areas coal prices now reflect the cost of production and delivery. The World Bank estimates that the majority of China's GHG emissions reduction could theoretically be achieved with market reform and the industrial rationalisation that would follow.

7.5.3 Factors Influencing Market Access

In 1997 and 1998 China's focus has been on managing the transition of a state-controlled economy to a freer market economy. China's international memberships include the UN, APEC, IMF, ASEAN, and the WTO as an observer.

China's currency convertibility problems hinder the country's the ability to afford significant spending on environmental programs. Therefore, China depends heavily on foreign assistance. The World Bank and the Asian Development Bank (ADB) are the leading sources of international funding, followed by the UN Development Program (UNDP), the Overseas Economic & Cooperation Fund (OECF) of Japan, the Global Environmental Facility (GEF), the UN Industrial Development Organization (UNIDO), and the UN Environmental Program (UNEP).

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[97] World Resources (1998), see op. cit.

[98] www.dfait-maeci/gc (March 23rd 1999), "China: Economic Overview"

[99] IEA (1998), see op. cit.

[100] www.dfait-maeci/gc (March 23rd 1999), "China: Air Pollution Control Market"

About 10% of environmental spending come from thousands of foreign investors in China. There are over 200 000 joint venture companies currently in China. Foreign environmental service and equipment firms may find that there is considerable opportunity for sales growth in projects by joint-venture-companies. For example:

- A joint venture that possesses advanced technology by world standards may apply for a reduction of or exemption from income tax for the first two to three profit-making years.
- A foreign joint venturer that reinvests in China its share of the net profit may apply for refund of a part of the income taxes already paid.

High tariffs on imports are one of the principal impediments to exporting products to China. Tariffs are particularly high on items that compete against domestically produced goods and commodities with a fixed world price.

Another impediment is the lack of transparency in the Chinese market and an inconsistent application of laws, regulations and import practices. These impediments are augmented by the decentralised nature of administration in China and the associated difficulties with ensuring the uniform enforcement of national regulations. For example, it is not uncommon for the same product to be subject to different levies in different ports since each port has its own administrative procedures and fees in addition to the basic import tariff.

The Chinese market for environmental technologies is one of the largest potential markets in the world. The air pollution control market occupies the largest share of China's environmental market after water treatment. According to Sofres Consulting Asia Pacific, between 1994 and 1995 annual imports of air-cleaning equipment increased 44% to US$670 million. In 1996, foreign firms sold US$1.8 billion worth of environmental equipment and services to China. High growth rates for climate friendly technologies are expected to continue in the medium term as China pays more attention to environmental protection.

At present, Shanghai, Beijing and Tianjin, and China's Special Economic Zones and coastal regions represent the best areas of opportunity, since they are the most economically developed and the most open to foreign interaction. Opportunities for climate-friendly technologies is greatest in large cities, which have the greatest demand for environmental protection and the greatest ability to pay in hard currency for environmental projects The US Embassy in Beijing estimates that a total spending in 1994 on the environment in China reached approximately $15 billion and is expected to grow by 30 percent annually in the next 10 years. China’s State Environmental Protection Agency estimates that approximately $4 billion per year will be needed to control pollution and that nearly $40 billion will be needed to clean up existing damage.

Because of financial constraints, it is expected that funding for imports of environmental technologies will most likely come from multilateral development banks.[101]

In general, Canadian companies entering the Chinese market will face strong competition from the United States, Japan, Australia, the United Kingdom and other European countries. Japan, the US and Germany dominate exports in the automobile emissions market. In terms of clean coal technologies, foreign competition primarily comes from Japan, Germany, France, and the UK. Japan is the most active in the emission control market, and Germany has a reputation for possessing advanced technology. A new entry into the market is Finland, which supplied a boiler for a recent project in Dalian. Japan's technology is seen as being convenient to use and service. It is also supported by favourable promotional activities and conditions of trade. France and the UK are preferred mainly for their prices.

7.6 India

7.6.1 Technology Needs

Fossil fuel supply

- *Coal bed methane*: Indian coal is low in both sulphur and heat content, and relatively high in ash. Due to the chemical composition of India's coal there is an urgent need for coal bed methane technologies. US Environmental Protection Agency has worked with Global Environment Facility (GEF) and Coal India on a coal bed methane demonstration project.[102]
- *Clean coal technologies*: About 90% of thermal power is coal-fired. Due to this large dependence on coal, there is a growing demand for these technologies (e.g. stage burners, coal washing[103], reburning and fluidized-bed combustors as opposed to the pulverized coal systems now in use, post-combustion emission control technologies including flue-gas scrubbing systems and fly-ash utilisation programs.[104]

Energy production

- *Integrated gasification combined cycle*: India's energy planners have expressed a need for increased use of gas-fired (combined-cycle) generation due to environmental and thermal efficiency considerations.[105]
- *Integrated energy systems / cogeneration*: As one of the world's leading sugar cane producers, India has tremendous potential for generating power by using refinery waste products (bagasse) as fuel. So far, more than 400 sugar mills have been identified as suitable, with a potential generating capacity of 3,500 MW. Several bagasse cogeneration projects are being sponsored by bilateral donors and

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[101] www.dfait-maeci/gc (March 23rd 1999), see op. cit.
[102] US Government (1998), see op. cit.
[103] www.dfait-maeci/gc (March 22nd 1999), "India : Power Sector Market Report"
[104] www.dfait-maeci/gc (March 22nd 1999), "India : Environmental Market Report"
[105] www.dfait-maeci/gc (March 22nd 1999), "India : Power Sector Market Report"

geared towards key sugar producing states for cane cogeneration. Several private projects are under way and are expected to reduce CO_2 emissions by one million tonnes annually. Furthermore, the state of Punjab is requiring that that all paper-making plants meet 60% of their own power requirements through cogeneration.

- *Fuel cells*: Fuel cells are expected to be long-term energy production need.
- *Biomass cofiring:* The plentiful supply of biomass feedstocks make biomass energy production an appealing technology in India. For example, in Madras, the Tamil Nadu Industrial Development Corporation (TIDCO) has signed an MOU with a British firm to build a 5 MW garbage-to-power plant that will consume 600 of the city's daily 2 000 tonnes of garbage. [106]
- *Upgrade / replace existing powerplants*: Many coal generating plants are more than 20 years old and contain outdate technology. As a result, there are frequent break downs and blackouts. Most of the transmission technology is also outdated, and systems are prone to leakage. Furthermore, in comparison with generating capacity, most transmission and distribution systems are underbuilt and are therefore overloaded.[107] India's National Thermal Power Corporation receives support from bilateral donors such as the US Agency for International Development (USAID) to facilitate the development of advanced power generation technologies. Involves placing advanced technologies in new power plants that will not only reduce CO_2 emissions per unit of power, but will also help decrease the local pollution problems.[108]
- *Increased use of renewable resources*: India is investing in many forms of renewable energy development. Preliminary studies estimate that the generation potential for non-conventional energy sources (wind, ocean, wave, tidal, biomass, and mini-hydro) is 126 GW. India is receiving assistance to commercialise renewable energy systems across a range of technologies, applications, and services. These efforts are catalysing the commercialisation of high potential renewable energy technologies.
- *Biomass electric*: If fully developed, can have a generation potential of 17 GW
- *Small Hydro*: India has an estimated small hydro generation potential of 10 GW. Canada Hydro has successfully pursued several of these projects in India.
- *Wind energy*: India's estimated potential for wind generation is 20 GW. Currently there are several large wind farm projects in the works totaling 1 800 MW. To date, Denmark has dominated the import market for wind harnessing technologies.
- *Solar photovoltaics*: this source of power is already widely used in India and is virtually unlimited in terms of generating potential. There are approximately 150 000 small photovoltaic villages with electricity. US DOE sponsored a Photovoltaics Development Initiative project over 300 systems were installed in seven villages in the isolated Sundarbans area. An additional two thousand systems have been sold in the area following the successful demonstration.[109] In addition, USAID supports the Solar Electric Light Company project. The project

[106] ibid.
[107] ibid.
[108] US Government (1998), see op. cit.
[109] ibid.

aims to improve energy service to those living and earning their livelihood in rural areas through solar-based electric generation systems. One of the state electricity boards in India is currently in discussion with SELCO to use solar home systems in place of expensive grid extensions to remote villages. This will significantly reduce state transmission and distribution losses and CO_2 emissions from the utility.[110]

- *Ocean power (thermal, tidal, and wave)*: The total potential along India's 5 600 km coastline is estimated at 50 000 MW. A US company has proposed the first 100 MW marine thermal conversion project for installation off the coast of Tamil Nadu. A wave power plant of 150 MW has already been installed in Kerala. India is also actively pursuing a proposed 900 MW tidal plant in the Gulf of Kutch.

Energy end-use

- *More efficient industrial & commercial equipment*: USAID and US EPA supports The Sustainable Cities initiative which aims to improve energy efficiency in the industrial and commercial sector and reduce environmental pollution. This has resulted in Ahmedabad Municipal Corporation (AMC) investing funds to retrofit water pumps, and streetlights. In addition to this initiative AMC invested and additional $700 000 in energy efficiency equipment in 1997.[111]
- *More efficient vehicles*: An India-US joint venture recently announced that India's first electric car would soon be available on the commercial market.[112]
- *More efficient appliances and equipment:* The increasing affluence of the Indian population is giving rise to an increasing demand for appliances and equipment. The Indian government is interested in ensuring that this demand is met with highly efficient appliances and equipment.

Non-energy related sources

- *Reducing CH_4 emissions on dairy and livestock system*: US EPA is currently conducting a pilot study to demonstrate feed technology for livestock.

7.6.2 Factors Influencing Technology Needs

The Indian government has signed and ratified the United Nations Framework Convention on Climate Change and has committed to preparing national communications on the different aspects related to climate change.

India is a signatory to the Kyoto Protocol and although it has no voluntary emissions reduction targets for the first Kyoto budget period, India is involved in an "Integrated Agriculture demand-side management" pilot AIJ project related to energy efficiency with Norway.

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[110] ibid.
[111] US Government (1998), see op. cit.
[112] ibid.

Air pollution, municipal sewerage, solid and hazardous waste issues are more pressing environmental concerns than climate change in India. Air pollution in India is severe, particularly in the country's most congested urban centres. Of the 10 cities in the world suffering from the highest levels of air pollution, three are in India: Bombay, Calcutta, and Delhi. Over 2,000 tonnes of pollutants are emitted daily in New Delhi and 70% of these emissions are produced by motor vehicles[113] (mainly two-stroke engine vehicles). In the context of climate change, the power sector is one of the largest sources of greenhouse gas emissions in India.

India is the world's second most populous nation. With a population of 960 million people in 1997[114], India constitutes more than 16% of the world's population. The annual growth rate of 1.71%[115] indicates that India's population increases every year by the population size of Australia or Sri Lanka. India's population doubled in the last 30 years and is expected to surpass China's population early in the 21st century.[116]

Between 1994-96 GDP grew at 7%, placing India among the world's best performing economies. According to World Bank data, India's GNP per capita in 1997 was US$390 and net GNP was US$375 billion.

In terms of per capita income, India is a poor country, however, India's middle class of approximately 250 million people enjoy an income level that sparks demand for commercial goods which consequently drives the demand for energy. The demand for electricity in India is growing by 8% per year. According to the Asian Development Bank, India's lack of adequate power supplies will be the single most important constraint to economic development in the coming years.[117] IEA data for 1996 indicates that India produces 3.2% of the world's total energy, not too far below Canada's 4.2%. India is also the world's third largest producer of coal and is ranked among the top ten net importers of petroleum products, and oil.

Coal is India's least-cost source of energy and meets two-thirds of the country's energy needs. In terms of installed capacity, India's energy supply is 71% thermal (of which 90% is coal-based), 26% hydro, and 3% nuclear. India's installed nuclear capacity has reached 2,225 MW. There are now 9 nuclear power plants in operation, and a further 4 are under construction or at the advanced planning stage.[118]

7.6.3 Factors Influencing Market Access

The newly liberalized economy is continuously working to increase external and internal competition and has substantially reduced the red tape that discouraged foreign investors.

[113] The Delphi Group (1997), "India's Environmental Sector: Business Opportunities for Canadians"
[114] www.worldbank.org (March 22nd 1999), "Countries and Regions : India"
[115] www.worldbank.org (March 22nd 1999), see op. cit.
[116] US-AEP (1997), "Country Assessments"
[117] www.dfait-maeci/gv (March 22nd 1999), see op. cit.
[118] www.dfait-maeci/gv (March 22nd 1999), "India: Power Sector Market Report"

In 1997, foreign direct investment totaled C$3.2 billion in 1997-98, nearly 25 times higher than it was before the economy was liberalized. Tariff rates have been reduced from a peak rate of 300% in 1991 to a ceiling of 40% (with a few exceptions) in the 1997/98 budget. Despite the significant tariff reduction, Indian tariffs are still some of the highest in the world, especially for goods that can be produced domestically.[119]

The current size of the market for environmental technologies is estimated at US$ 0.5 billion and is expected to grow at an annual rate of 20 % to 25% to touch about US$ 4.0 billion by the year 2000. The opportunities exist in prevention, control and remediation of air, water and land pollution. Market size for air pollution control equipment is estimated at US$ 85 million. Although domestic firms manufacture a variety of air quality control equipment, opportunities exist for technologies for fly ash utilisation, flue gas desulphurization, gas scrubbers, SPM reduction processes, microprocessor based energy management systems for electostatic precipitators, and coal washing technologies to reduce ash emissions.

Overall, the strongest demand for environmental goods and services is from the industrial rather than government sector. Large to medium sized industrial firms in all sectors that are seeking to improve or upgrade existing facilities or to equip new plants with required pollution controls are considered to be the best prospects for sales. Opportunities are especially attractive in the electric power industry. Technologies such as energy efficiency, renewable energy, and clean coal are GHG mitigation technology needs that can simultaneously improve India's air quality.

The local pollution control industry in India is capable of manufacturing a wide range of air pollution control equipment. A few domestic companies such as Bharat Heavy Electricals (a state corporation) and Flakt India produce precipitators, primarily for thermal powerstations. Since then, many new companies have entered this market. For Air Pollution Control equipment, foreign companies who are present either by representation or collaboration are: Flakt AB, Wheelbrator USA., Lurgi, Anderson 2000, Dust Suppresion International, Peabody Holmes, Research Cottrell, Zurn Industries, Ventilatorenfabrik Oelde, James Howden, Foxboro, Environment, Columbia Scientific, Fischer Klosterman.

Despite India's liberalised economy and the country's outreach for direct foreign investment, there are several barriers that are of concern to foreign suppliers of environmental technologies:

- India is internally focused, prefers using Indian technology, and has a large capability for science and technology research and development.

- Transparency remains the key issue. The circumstances under which government contracts are awarded can be dubious, often governed by such extraneous factors as illicit payments etc. This problem is tied to endemic corruption in the political system and bureaucracy, whether at the national or the state level.

[119] www.infoexport.gc.ca/section2 (March 22nd 1999), "India"

- Lack of ability of Indian firms and public sector entities to pay. 1997 per capita income in India is only about $390 US which severely limits public ability and willingness to incur the costs of environmental protection through taxes or user fees. National and state agencies have limited budgets. Large private corporations are in a better position to pay, but often look for low cost domestic equipment and service vendors before accepting high-cost imported technologies or equipment.

- Indian firms are often concerned about the ability and willingness of foreign companies to provide after-sales service and support. Many Indian firms express doubts about the long-term commitment of foreign firms to stay in the market. Therefore potential agents or partners want assurance that foreign firms are prepared to make substantial commitments.

- State-level operating and environmental clearances are problematic, with a number of projects getting derailed following contract awards. For example the renegotiations of a signed contract for 2 015 MW power project awarded to Enron by the Maharashtra state government and the decision by Coal India Limited to require foreign companies to substantially cut prices after winning competitive bids for coal washeries.

The US currently has the largest market share for environmental technologies in India at 10%. Germany follows with 8%, Japan 7%, and UK 6%.[120]

In 1997, Canadian exports totaled $459.4 million, while Canada's imports from India were $740.3 million. The figures for 1997 show an upward trend in Canada's exports to India with two-way trade approaching $1.2 billion. Over 500 Canadian companies are actively involved in India. Canadian technology suppliers that are currently active in the Indian environmental technology market either independently or through joint ventures including R.V. Anderson Associates Ltd., Peekay Holdings Ltd., ADI Systems Inc., Esco Engineering, and Babcock & Wilcox, and Eco-Tec Inc..[121]

India's main foreign investors are US, Europe, Japan, Canada and Australia[122]. India primarily trades with the US, Germany, Japan, UK, Hong Kong, Belgium, and Canada. Trade in environmental technology is mainly with US, Sweden, Germany, UK, Switzerland, Holland, Japan, Netherlands.[123]

7.7 Mexico

[120] US Department of Commerce (1996), " India: Environmental Technologies Export Market Plan"
[121] The Delphi Group (1997), see op. cit.
[122] US-AEP (1997), see op. cit.
[123] US Department of Commerce (1995), "The Environmental Technologies Export Handbook"

7.7.1 Technology Needs

Many of Mexico's technology needs are in the energy production and energy end-use sectors. Mexico is the third largest producer of energy in the western hemisphere, behind the United States and Venezuela. It has the eighth largest proven reserves of crude oil in the world and is the eighth largest producer of natural gas.

In 1990, Mexico's net CO_2 emissions were 402 million Mt and total CH_4 emissions were 2.9 million Mt. Emissions data for nitrous oxide were not available, The main source of CO_2 emissions is fossil fuel combustion in particular from the energy industry and transportation. The main sources of CH_4 emissions are livestock, fossil fuel extraction and finally waste.[124]

Mexico's installed generating capacity is 80% thermal and emits an estimated 57 million tons of carbon dioxide per year as well as emissions of other pollutants such as sulfur dioxide and nitrogen oxide.[125] CFE, Mexico's Federal Electricity Commission, is planning 23 additional power projects, with a total capacity of 9767 MW to satisfy additional demand to the year 2005.

To combat air pollution, Mexico is promoting switching to cleaner fuels through a new fuel price structure which favours natural gas and lower sulphur fuel. Efforts are also being made to reduce emissions from mobile sources by switching to highly oxygenated, unleaded gasolines and modernizing the vehicle fleet. Specific demands for GHG mitigation technologies includes those for:

Energy production

- *More efficient conversion of fossil fuels in electrical generation:* The US Agency for International Development (USAID) is providing bilateral support to accelerate technology transfer to CFE. The program aims to promote energy efficiency technologies and introduce low carbon-emitting energy systems.[126]
- *Substituting natural gas for coal and oil* : A number of Mexican companies have already switched to natural gas and the new thermal plants that will be built in Yucatan and Coahuila will be fired with natural gas.[127]
  In addition, an aggressive campaign is planned to update up to eight existing plants to shift from the use of heavy fuel oil to natural gas. A total of 4510 MW is scheduled to be converted, shifting the use of natural gas from the current 37% of the total to a planned 51%.
  Pemex, Mexico's state oil monopoly, plans to invest in exploration and production of natural gas. One of the largest planned projects is Cantarell, in Campeche Sound. The Cantarell project involves the development and operation of the world's largest nitrogen plant to enhance natural gas extraction.

[124] World Resources (1998), see. Op. cit.
[125] www.dfait-maeci/gc (March 22nd 1999), "Mexico"
[126] US Government (1998), see op. cit.
[127] US Department of Commerce (1997) "Mexico : Environmental Technologies Export Market Plan"

- *Biomass cofiring* : Mexico has a considerable supply of various biomass feedstocks. Mexico and the US have also agreed on an AIJ project which has not been implemented yet. This project will involve constructing a 15 megawatt plant to convert biomass waste to energy.[128]
- *Increased use of integrated energy systems, cogeneration* :
The National Energy Savings Commission (CONAE) has estimated that potential for cogeneration projects could be anywhere from 7000 to 14 000 MW.[129]
- *Upgrade/replace existing power plants*
- *Increase use of renewable resources:* The CFE is placing increasing emphasis on becoming less reliant on heavy fuel oil. Most new production will be combined cycle, but new capacity will also be added using *hydroelectricity* and *geothermal* generation.
Mexico and the US participate in an AIJ project which involves developing a hybrid power system, using solar, wind and diesel, to replace a 205kW generator which is currently running on diesel.
Additional small-scale production is being planned using wind and solar energy.

Energy end-use

<u>*Transportation*</u>

- *More efficient vehicles:* Mexico City has a established a goal of converting 45 vehicles to compressed natural gas by the year 2000.
- *Public transport and traffic management:* The US EPA is involved in demonstrating fuel-cell buses, which have zero emissions, in Mexico City. They are also training operators and potential buyers on fuel cell technology.[130]

<u>*Buildings*</u>

- *More efficient appliances and equipment*: Mexico and Norway participate in an AIJ project which also receives additional funding from UNDP's Global Environmental Facility. The project will replace approximately 200,000 ordinary, incandescent light bulbs with compact fluorescent light bulbs (CFLs) in the Mexican cities of Monterrey and Guadalajara. These CFLs require 25% of the energy of ordinary light bulbs to produce similar or better quality lighting, resulting in less electricity generation and fewer fossil fuel emissions. They last up to 10,000 hours, or thirteen times longer than ordinary bulbs.

Carbon dioxide management

- *Sequestration/storage: Agricultural sinks:* This Mexico/US AIJ project is located in the northeast Chiapas and involves assisting farmers to develop small agroforestry and forestry enterprises. Reduction in forest degradation, conversion to agriculture and improving the sustainability of local farming systems will increase carbon sequestration.
- *Forest sinks:* Another Mexico/US AIJ project involves rehabilitating degraded forest through agroforestry and plantation establishment, and preventing further

[128] US EPA (1998), see op. cit.
[129] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[130] US Government (1998), see op. cit.

degradation of standing forest by controlling pests, disease and fire to increase carbon sequestration.

- *Geological storage*: Another Mexico/US AIJ project involves the cultivation of a salt -tolerant euphorb plant. This plant will then be introduced in a coastal desert region to enable the sandy soil to accumulate and store carbon and thereby reduce GHG emissions.

Non-energy related sources

- *Landfill gas capture and use:* The US EPA is working with Mexican officials on a pilot project on landfill methane recovery methods.

7.7.2 Factors Influencing Technology Needs

Mexico has signed the Kyoto Protocol but does not yet have an established emissions reduction target. Mexico is taking concrete steps to improve its air quality with assistance from the World Bank. For the past five years, Mexico has been implementing a Transportation and Air Quality Improvement Loan. Many of the efforts it will take to reduce air emissions will also help to reduce GHG emissions which translates into good opportunities for Canadian GHG mitigation technology suppliers.

The four main areas of priority environmental concern in Mexico are water pollution, air quality, solid and hazardous waste. Mexico City's air quality is one of the poorest in the world. This is a result of the winter thermal phenomena where warm air traps cool air under it preventing pollutants from industries and vehicles from escaping. In addition, since Mexico City is above sea level, industries and vehicles are forced to use greater amounts of fuel to operate thereby increasing emissions of pollutants.[131] Although Mexico City is regarded as having the most severe air quality problems, other Mexican cities such as Guadalajara and Monterrey are encountering equivalent air pollution dilemmas.

In 1996, the government announced that it plans to double spending on environmental programs by 2000. Mexico City will spend US$13 billion between 1996 and 2000 to reduce air pollution. Most will be spent on improving public transportation networks, and improving fuel mixes. Government-owned companies PEMEX (petroleum), CFE (electricity) and FERRONALLES (railways) have announced environmental investment programs worth a total value of US$628 million.

A long-term framework for tackling the most important air pollution concerns is the Valley of Mexico Air Quality Improvement Program which was also developed in 1996. This initiative will institute stricter regulations and provide stronger economic incentives for compliance. Target areas in the private sector are fuel conversion in the industrial and service sectors and fleet modernization in the automotive and transportation sectors. In

[131] US Department of Commerce (1997), see op. cit.

the public sector, the target areas are improving transportation fuels and local power plants and improving public transportation. [132]

In 1998, Mexico's population was 95.8 million. Although the population is growing, the rate of growth is decreasing. The estimated average annual population change between 2005-10 is 1.2%. By 2000, 74% of Mexico's population will be living in urban areas. By 2020 this will increase to 79%.[133] Although the population growth rate is not very high, the Mexican population is growing and this growth will be accompanied by an increase in the demand for energy.

CFE estimates that an additional 13 189 MW of installed capacity will be required by the year 2006 to meet a projected 5.5% annual increase in demand in electricity. The peak demand increases will occur in the highly industrialized northeast (6.7% yearly), Yucatan Peninsula (7.2% yearly), and Baja California (7.6% yearly). Demand for natural gas is also expected to grow rapidly over the next ten years, from under 2.4 billion cu.ft/day, to approx. 4.2 billion cu.ft/day in 2005.

Mexico's economy recovered from it's 1994 economic crisis by 1997 and growth has been strong in the last two quarters. The consensus is that economic growth will steadily increase into the 21st century and inflation will continue to decline to about 10% by 2000. GDP is expected to grow at about 5% per annum between 1997 and 2000.[134] Mexico's per capita GNP was US$ 3,320 according to World Bank 1997 data.[135]

The target for inflation and GDP growth in 1998 were 12% and 5.20% respectively. Estimates at the end of 1998 suggest that inflation was 17.80% and that GDP had grown by 4.60%. In spite of this, GDP is expected to grow in real terms.[136] In addition, the peso has appreciated, in real terms, and has been stable over the last 2 years.[137]

The average price for electricity in Mexico is below long run marginal cost. In Mexico, the price of electricity for households is US$0.0556 kWh and for industry it is US$0.0500 kWh. As a benchmark, the corresponding prices in the US are US$0.0831 kWh and US$0.0407 kWh. Significant cross subsidies exist among residential consumers with medium to large consumers subsidizing smaller users.[138] The Federal Electricity Commission of Mexico (CFE) is committed to eliminating these subsidies and to providing other measures intended to level the playing field and attract the necessary investment into the sector. Removing the subsidies should cause the price of previously subsidised energy to rise. Energy producers will then either increase efficiency to bring the price down to more competitive levels or reduce production and allow lower priced imports into the market. Either option presents opportunities for Canadian exporters of GHG emissions mitigation technologies.

[132] ibid.
[133] World Resources (1998), see op. cit.
[134] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[135] World Resources (1998), see op. cit.
[136] www.mexicool.com (March 22nd 1999), "Business Center : Economic Data"
[137] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[138] ibid.

7.7.3 Factors Influencing Market Access

Mexico is aggressively pursuing privatization, deregulation and trade liberalization. Public participation in development of policies and programs is also increasing.[139] In addition the government is decentralizing and giving individual states more power. These positive changes in Mexico's economic and political climates have attracted foreign investment. Mexico was recently among the top ten foreign capital recipients in the world. In spite of these improvements, there are still some gray areas in the laws and regulations governing foreign investment.[140]

Mexico's policies on foreign investment and trade are currently governed by NAFTA and the Foreign Investment Law. Under NAFTA, Canada and the US receive preferential treatment and the Foreign Investment Law has lifted restrictions on foreign investments in many areas. There are also no controls on foreign exchange transactions.[141]

NAFTA essentially reinforces patent and copyright protection, eases restrictions on cross-border trucking and enables Canadian companies to bid on contracts from Mexico's oil and electricity production sectors which is comprised of government controlled companies and agencies such as PEMEX, CRE and CFE.[142] Mexico also belongs to WTO. Being part of WTO, ensures that Mexico follows international tariff standards and trade regulations.

Maximum tariff for imports is 20%. Customs duties for imported equipment from North America are reduced to between a maximum 14% tariff and total exemption under NAFTA.[143] Mexico has recently lifted import tariffs for pollution control equipment in an effort to make it easier for small Mexican firms to meet tough new water, air and waste management rules through imported environmental technologies. This move is expected to create a market among Mexican SMEs that could reach US$200 million by 1998. However, the types of equipment that qualify still have to be determined on a case-by-case basis. Equipment for desulphurization of emissions, electrostatic precipitators for air particle reduction, and higher-efficiency combustion technologies are among the targeted products. However, most environmental goods are exempted from customs duties.

The Mexican government also requires that all imports meet national product standards, testing, labeling and certification regulations before entering the Mexican market.[144] These requirements are similar to those stipulated by the Canadian Standards Association.

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[139] US Department of Commerce (1997), see op. cit.
[140] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[141] Dun & Bradstreet Int'l (1999), "Exporter's Encyclopedia"
[142] ibid.
[143] US Department of Commerce (1997), see op. cit.
[144] Dun & Bradstreet Int'l (1999), see op.cit.

The 1994 devaluation had a significant effect on the Mexican environmental market. The value of the environmental technology market in Mexico was an estimated US$3 billion. In 1995, this figure fell to less than US$1 billion. The Mexican economy's strong recovery in 1996/7 and Mexico's recent export boom is forcing Mexican manufacturers to import modern technology to meet international standards.[145] In addition, the government has taken concrete steps, described below, towards ensuring that the environmental market achieves significant growth to restore pre-1994 levels:

- Mexico is a leader in Latin America in terms of developing and enforcing environmental laws, regulations and standards.
- The governments has increased the effectiveness environmental institutions through decentralization.
- Mexico has a good reputation of enforcing its environmental regulations especially for export industries with high public health risks. Although enforcement is not strong in other areas, the main feeling is that it is becoming stronger.[146]
- The creation of the North American Development Bank, which provides low cost capital for environmental infrastructure projects in the US-Mexico border region and FINFRA, a publicly owned infrastructure development fund, are successful attempts to increase credit availability and the lower the price required to secure it. Since the market is driven by available project funding, not need, financing is a serious barrier to growth.[147] Another source of low cost financing is untied Japanese credits which are specifically geared towards environmental and trade projects.

In taking these steps, the government has been able to revive the environmental market's growth and economic credibility and to subsequently increase business confidence. By 1996, Mexico's total environmental market had grown by roughly 21%, and is now worth more than US$3 billion.

Mexico is one of Latin America's most attractive markets for Canadian exports of environmental technologies and services. The Mexican environmental market is dominated by imports. Import penetration in the electric power generation, distribution and transmission equipment sector is approximately 62%. Seventy percent of the import market is maintained by the United States, followed by Japan and Spain, with 9% and 6% respectively. Other important competitors include Germany, France, Italy and Brazil. Although Canada's import market share is only about 1.3%, Canadian exports to Mexico increased by 9% in 1996. Competition, however, will remain intense with American firms who not only benefit from NAFTA, but also from geographic proximity.

Canadian suppliers have established a presence in the Mexican market. There are currently over 100 Canadian mining companies in Mexico.[148] TransCanada Pipeline has

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[145] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[146] US Department of Commerce (1997), see op. cit.
[147] www.dfait-maeci/gc (March 22nd 1999), see op. cit.
[148] ibid.

been contracted to build a US$400 million project to transport gas for the Merida III power station in the Yucatan peninsula. Canada's Westcoast Energy is part of a consortium that was awarded the US$1 billion contract to build and operate the world's largest nitrogen plant to enhance natural gas extraction at Cantarell, as a 20% equity partner.

Canadian environmental exporters can also benefit from more than US$850 million in line of credit financing facilities available for exports to Latin American countries that Canada's Export Development Corporation (EDC) has established with banks and other institutions. For example, EDC and Pemex have an agreement in place for a C$500 million line of credit.

Funding from the Canadian International Development Agency's (CIDA) Industrial Cooperation Program is available for qualified projects and export companies, depending on current budget availability.

7.8 Brazil

7.8.1 Technology Needs

In response to the country's growing energy need, the Brazilian government introduced the Renewable Energy Rural Electrification Project in 1992 as part of its national environmental policy. This project aims to provide electrical service to rural households and businesses. This type of energy may be useful in Brazil's northeast where only 4% of rural properties are connected to the grid and a severe energy shortage is predicted by the year 2000.[149]

Specific demands for GHG emission mitigation technology include:

Energy production

- *Upgrade/replace existing power plants*: With the privatisation of Brazil's state-owned utilities, it has become obvious that inefficiencies exist in power generation, transmission and distribution. The World Bank is loaning Brazil US$150 million for an energy efficiency project of which 70% is directed toward utility programs. The state of Sao Paulo is currently carrying out a US$98 million World Bank funded gas distribution project aimed at expanding and improving gas distribution to industry and residences. The Association of Infrastructure and Basic Industries (ABDIB) recently estimated that over the next three years, an investment of approximately US$85 billion would be allocated to over 550 separate projects for generation, transmission, and distribution.
- *Biomass cofiring*: A Biomass Pilot Power project funded by the Global Environment Facility will include commercial scale demonstration technology for electricity generation based on the gasification of wood chips or sugar cane

[149] www.dfait-maeci/gc (March 19th 1999), see op. cit.

bagasse to replace fuel oil. Brazil is also interested in using coal with fuelwood and charcoal from its afforestation programs.

- *Integrated gasification combined cycle*: US Agency for International Development (USAID) collaborated with a Brazilian utility company and pig-iron producer to perform a study on using waste pig-iron blast furnace gas to power internal combustion engine generators for electricity production. There are 141 pig-iron blast furnaces in the state of Minas Gerais that could provide blast furnace gas with an estimated power generation capacity of 180MW. This would obviate the immediate need for construction of a similar capacity fossil-fired power plant providing an annual emissions savings of 840 000 tonnes/year of CO_2.
- *Renewable energy and advanced photovoltaics*: Due to diminishing opportunities for Brazil to expand energy supply from hydro power, The World Bank is supporting a rural development project in Brazil's north and northeast with an aim to meet their energy needs with renewable energy systems. Brazil would ultimately like to increase market penetration of photovoltaics, wind systems, PV wind-water pumping systems, home PV systems, village scale hybrid PV replacement for diesel and has started doing so with the US DOE in partnership with the Department of Minerals and Energy.

Energy end-use

- *More efficient appliances and equipment*: In order to meet future energy demands and decrease GHG emissions, it is essential for Brazil explore opportunities to conserve energy. A World Bank sponsored project is helping to improve the efficiency of electricity supply and use through the use of demonstration projects involving new energy efficient technologies for Electrobas. USAID is working with Brazil's National Energy Conservation Energy to support demand-side management activities in Manaus where more than half the electrical load is attributed to lighting and air-conditioning. Brazil is also interested in implementing higher energy efficiency standards, and appliance testing & labeling.
- *Improved Industrial processes*: In order to conserve energy within Brazil's industrial sector, Brazil is participating in project to improve energy management in Brazilian industry and GHG emissions reduction. This is a two year project sponsored by The Canadian Environment Industry Association. Six energy management demonstration projects will take place in each of the following sectors: food processing, auto parts and metal mechanics, textiles and leather, plastics production, furniture manufacturing, and foundries. Collectively, these industrial sectors represent 50 % of the manufacturing establishments in Brazil.

Non-energy related sources

- *Landfill gas capture and use*: municipal landfills are a major environmental concern for Brazilians. USAID in collaboration with various Brazilian agencies are in developing viable projects to reduce methane emissions from each of the fourteen selected landfills by approximately 1 million cubic metres over the next 20 years, while generating about 100 MW.

7.8.2 Factors Influencing Technology Needs

Although Brazil is a signatory to the Kyoto Protocol, it has not yet accepted any voluntary targets to reduce GHG emissions to date. Brazil has not participated in any AIJ projects either. This demonstrates Brazil's commitment to economic and industrial growth and development as well as its preference to use domestic technologies to address the country's environmental concerns. However, Brazil was one of the countries originally supporting the Clean Development Mechanism (CDM) concept. The modalities for the CDM are still being designed. Once the CDM is active, Brazil will likely be receptive to project concepts that address its priority technology needs. For example, Brazil is interested in technology that can help to ameliorate local environmental problems as well as reduce GHG emissions.

Overall, Brazil's major environmental concerns lie in waste water treatment, stationary source air pollution, municipal solid waste, hazardous waste treatment, storage, and disposal, and overall pollution prevention. Compared to water quality and water pollution issues, climate change is not considered to be a significant national problem. However, with the country's phenomenal pace of population and economic growth, GHG emissions from Brazil's energy and industrial sectors will increase dramatically, and provide opportunities for Canadian suppliers that can simultaneously address local and climate change issues.

In 1997 Brazil had a population of 163.5 million with an annual population growth rate of 1.4% between 1991-1997. The population growth rate coupled with the large segment of the population that currently comprises the lower to middle-class, suggest that the demand for energy and consumer goods will increase and subsequently result in a further increase in Brazil's GHG emissions.

Brazil is currently the world's eighth largest economy and possesses the industrial base and sophistication normally attributed to G-7 countries. According to World Bank data, Brazil's GNP per capita was US$4 720 billion.

In recent years, Brazil has implemented significant economic liberalization measures. Brazil has become increasingly open to a wide range of imports, as reflected by the growth in Canadian exports to Brazil. In July 1994, the federal government introduced the Plano Real, in order to ensure economic stability for the country. This resulted in a dramatic drop in the monthly inflation rate, from about 45% before July 1994 to less than 2% in 1996. These reforms coupled with the government's large privatization programs for the petrochemicals, transportation, and utilities, will increase market competition, industrial output and drive the emissions of greenhouse gases.

7.8.3 Factors Influencing Market Access

Brazil is a country of great economic potential. The Collor government introduced Constitutional amendments, which were passed by the Cardoso government Congress in August 1995. The passing of these amendments allows for more foreign participation in the domestic economy. This includes investments in the petroleum sector, transportation, public utilities, telecommunications and certain segments of the mining sector.

Canada and Brazil share a Double Taxation Agreement (DTA). At the moment, there is no Foreign Investment Protection Agreement (FIPA), but Canada is aggressively pursuing a resolution of this issue. Brazil's overall accelerated pace of tariff reductions has had a positive impact on Canadian exports to that country. The average tariff now stands at 14.3%, with the highest tariff being no more than 35%. Furthermore, Canadian environmental exporters can benefit from more than US$850 million in line of credit financing facilities available for exports to Latin American countries that Canada's Export Development Corporation (EDC) has established with banks and other institutions.

The following is a list of barriers that may constrain the access of Canadian suppliers of technology to the Brazilian market:

- The Brazilian government has reserved large sectors of its economy to state monopolies which are closed to foreign investment.

- Brazilian regulations also favour Brazilian national firms in government procurement contracts.

- Brazil's federal, state and municipal governments, as well as related agencies and companies follow a "buy national" policy which gives preferential treatment to national companies

- Investment in the form of technology transfers is subject to specific controls based on government objectives. The INPI (National Industrial Property Institute) considers all contracts from the viewpoint of i) the value of the technology to Brazil, ii) the existence of a similar national version or iii) the possibility of developing one within a reasonable period.

- Royalties and interest are normally subject to a 25 per cent withholding tax. The Canada-Brazil double taxation agreement provides for a preferential 15 per cent withholding tax in these cases. Brazil offers a preferential withholding tax rate of 15 per cent to investors of some 20 countries (mostly OECD and Latin American). Japan benefits from a rate of 12.5 per cent.

- Foreign firms wishing to participate in international bids are required by law to have local representation or an association with a local company.

According to the São Paulo Federation of Industries (FIESP), Brazil has about 200 environmental equipment manufacturers, engineering firms and providers of consulting services which collectively comprises approximately 85% of Brazil’s environmental market. Although, a huge portion of the environmental market is supplied by domestic firms, Brazil's domestic environmental industry uses licensing of foreign technologies, agreements, joint ventures with foreign firms and technology transfers to develop local expertise.

The size of the Brazilian market for pollution control equipment was approximately US$600 million in 1996 and is estimated to reach US$650 million dollars in 1997. Foreign participation in this market amounted to 25% of the total expenditures on pollution control equipment in Brazil during 1996, with the United States constituting 30% of the import market. Eighty-percent of the market is slotted for municipal and industrial water pollution projects, 15% for air pollution control and 5% for solid and hazardous waste management.

Brazil is Canada's largest trading partner and export market in South America. In 1996, Canadian exports totaled $1.38 billion, an increase of 5.7% over the previous year. The two-way trading relationship is currently valued at over $2.5 billion. Canadian suppliers have carved out a significant market presence in mobile cellular systems, telecommunications and informatics equipment and services, environmental equipment and services, aircraft engines, leisure watercraft, automotive industries, advanced manufacturing equipment, value added foods, and remote sensing and geographic information systems (GIS).

Brazil also trades with US, Argentina, Germany, Japan, France, Netherlands, and Italy and imports most of its environmental equipment from the United States, Germany and Japan. These countries will likely provide stiff competition to Canadian exporters of GHG mitigation technology.

7.9 Spain

7.9.1 Needs Assessment

Spain's priority technology needs are in the energy production sector, since the majority of Spain's GHG emissions originate from fossil fuel extraction and combustion. In addition, Spain has initiated various programs to accelerate the development of domestic renewable energy technologies. In particular, Spain has expressed an interest in the following technologies:

Energy production

- *Substituting natural gas for coal and oil:* The Spanish Government is promoting the use of natural gas to replace coal and oil in energy production. The government has committed itself to increasing the use of natural gas in energy production for industrial use. This expansion will eventually result in the restructuring of the electrical and industrial sectors. It is also expected to reduce costs and provide growth opportunities for related sectors.

- *Upgrade/replace existing power plants*: 480 hydroelectric power plants have been renovated in the past 11 years. Recently, waste-to-energy plants have also been renovated, namely the plants in Gerona and Maresme-Mataro. It has been estimated that Spanish industry will need to spend approximately US$10.6 billion in the next few years just to adapt industrial plants to EU regulations.[150]

- *Increased use of renewable resources*: The Spanish Government has supported renewable energy policies since 1978 through periodic renewable energy plans that establish specific targets by sector. For example the national renewable energy initiative "PER" is a 10-year renewable energy development program (1991-2001). Since its implementation, an additional 508,787 Toe/year (tonnes of oil equivalent) of energy from renewable sources have been produced. Biomass and hydropower are the most significant forms of renewable energy in Spain. The development of other alternative sources such as wind, photovoltaic solar, thermal sola, and solid waste is steadily increasing. In 1996, renewable energy sources contributed to over 4.2% of primary energy consumption in Spain.[151]

- *Cogeneration*: major purchasers of private sector cogeneration projects are companies in heavy polluting industrial sectors such as heavy metal production, construction, food processing, chemical, pharmaceutical and paper. Cogeneration is also attractive to the mining, quarry and timber wood industries.

- *Biomass*: between 1995 and 1996, biomass output (in toe) only experienced 0.53 % growth increase. Nonetheless, biomass is currently the most important energy source in Spain, grossing 3.2 million Toe in 1996. The Spanish biomass industry applies the most advanced technology to their gasification and cogeneration projects and to the production of biofuels for transport purposes. The integration of other renewable energy sources to the energy matrix is not sufficient without the contribution of biomass energy. As a result, biomass will continue to occupy a position of prime importance in Spain's available energy network. Annual investment in this sector amounts to US$14.2 million. Goals for this sector include the integration of advanced technology and equipment for commercial applications and the introduction and market consolidation of energy crops, biofuels, electricity generation stations, and district heating installations.[152]

- *Waste-to-energy:* between 1995 and 1996, waste to energy output in tonnes of oil equivalent increased by 70 %. Spain produces over 14.3 million tonnes of solid waste annually. The countries waste -to-energy network has an installed capacity of 93.7 MW. Average annual output is 525.4 GW and is continuing to grow to meet national

[150] US & Foreign Commercial Service and US Department of State. 1998. *Environmental Market*. July 27th
[151] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th
[152] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th

needs. Active plant construction and renovation are currently taking place, making this sector highly favourable for increased development. Recently, new plants have been built in Madrid, Melilla, and Palma. Plants are currently under construction in La Plana, Ceuta, and Zabalgarbi.

- *Small hydro (under 10MW)*: between 1995 and 1996, small hydro output in tonnes of oil equivalent increased by 51.43 %. From 1991 to 1996 installed capacity has increased by an average of 70MW/year.[153] Annual investment in this sector totals approximately US$78.6 million.[154]

- *Wind energy:* between 1995 and 1996, wind energy output in tonnes of oil equivalent increased by 44.5%. Spain is ranked among the four European Union (EU) states with the largest increases in installed capacity for wind energy.[155] Capacity increased from 0.4MW in 1986 to 95.9MW in 1996. The possibilities for further development are significant, with the total theoretical capacity for annual electricity generation from wind energy reaching 12x106 MWh. Regions with the most potential include Galicia, Andalucia, Aragon, Catalonia, the Basque Country, Navarra, Murcia, and Valencia. In 1996, investments in this sector totaled US$ 107.14 million and continue to increase. Spanish firms have contracted foreign technology experts for the production of medium and large scale air-generators. Other sales opportunities for foreign technology suppliers include blades, towers, generators, transformers, electrical supplies, and control and monitoring equipment.

- *Photovoltaic solar:* This market is divided into two types of photovoltaic solar energy. Energy separated from the power generation grid (including rural electricity, agriculture, telecommunications) and energy connected to the grid (electric generators, existing installations). Growth is most notable in the grid-connected sector. Regions with the highest installed capacity for solar photovoltaics are Andalucia, and Catilla-La Mancha at 2789.9 KWh and 1109.7 KWh respectively. Other regions, such as Valencia, and the Balearic and Canary Islands present excellent opportunities for solar photovoltaic energy development.[156]

- *Thermal solar:* between 1995 and 1996, thermal solar output in tonnes of oil equivalent increased by 43.3 %. This energy is primarily used for heating water in the domestic sector. Thermal solar energy has been applied to large-scale projects in hotels, apartment complexes, and schools. Possible future applications include agriculture and swimming pool heating. The market volume for thermal solar energy has stabilised at approximately 10 000m^2/year and the collector surface area is 330 000m^2. Considering the abundant sunlight hours in Spain and the size of the tourism and domestic sectors, both figures are far below Spain's potential. Therefore, there

[153] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th
[154] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th
[155] Eurostat 1994/1995
[156] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th

are lucrative market opportunities for further development of thermal solar energy in Spain.

7.9.2 Factors Influencing Technology Need

In addition to rising emissions of GHGs, Spain faces several environmental problems. Serious environmental degradation is not uncommon in several areas throughout the Spanish mainland. The main environmental problems that Spain currently faces include a lack of sufficient wastewater treatment and waste disposal facilities, water pollution -particularly in the Mediterranean Sea - from raw sewage and effluents from the offshore production of oil and gas, deforestation, and desertification. Spain is also struggling with air quality problems. Spain's major sources of air pollution continue to be municipal power plants, road vehicles, and other stationary sources of CO_2, CO, SO_2, NO_2 and lead emissions.

Spain's environmental policy is supported by several specific plans and projects on the national, regional, and local levels. There are several key issues included in the environmental policy that the government is currently seeking to address. Some of these elements will enhance the demand for climate-friendly technologies:

- The Energy Efficiency and Saving Plan (US$2.6 billion through the year 2000) to define a strategy for the efficient use of energy and renewable energy.
- The National Plan for Water Cleansing (US$1.4 billion through the year 2005) to install collection, desalination and purification equipment.
- The National Plan for Hazardous Waste Recycling (US$1.4 billion through the year 2000).
- The National Plan for Recover of Contaminated Land (US$1 billion through the year 2005) to recover polluted areas.

The implementation of these plans will generate demand for equipment, technology, and services from the private sector.

Spain is the third largest country in the European Union. It has a domestic market of nearly 40 million people with an estimated per capita income of more than US$14,000, in 1996, and additional demand from over 60 million tourists who visit the country every year. OECD figures reveal that private consumption in Spain is steadily increasing, despite a negative population growth rate. Vigorous demand and substantial expansion of production have driven the rapid growth of the Spanish economy in recent years. This growth is strengthening the government’s commitment to liberalizing the economy. This growing economy, coupled with a population that is placing an increasing value on consumer goods will require additional energy capacity in the future. Because of Spain’s need to reduce GHG emissions, an increasing portion of this energy demand will need to be met by non- or low-carbon energy sources.

7.9.3 Factors Influencing Market Access

Canadian companies attempting to access the Spanish market will face barriers similar to those in other EU countries. Since joining the EU in January 1986, all EU legislation is fully applicable in Spain and the country receives most of its structural and cohesion funds from the EU to finance infrastructure and development projects. Market opportunities may vary region to region because of the decentralisation of political power. For administrative purposes, Spain is divided into 17 Autonomous Communities, each containing one or more provinces. There are a total of 50 provinces. In addition to the central government, these 17 Communities have their own regional governments which issue environmental laws and regulations mandatory for their territories. The regional governments also incorporate laws issued by the central government as well as EU directives. Suppliers trying to access the market need to consider Spain as an umbrella of distinct, smaller markets.

Spain has been criticised in the past for not effectively enforcing its environmental legislation. As a result, the Ministry of the Environment, which was created in 1996, has made enforcement of environmental regulations one of its priorities and fines are strictly imposed on polluting industries. This is forcing Spanish industry to look into cleaner technologies and pollution control equipment that will create greater opportunities for Canadian environmental companies over the next few years.

The Fundacion Entorno, Empresa y Medio Ambiente, is a Spanish public agency in the environmental sector that assists, supports and encourages Spanish industry in its efforts to protect the environment. According to the agency's figures, Spanish industrial investment in the environment amounts to approximately US$ 667 million. However, in the OECD ’s 1997 Environmental Performance Review of Spain, it is estimated that in order to meet present EU levels of environment protection, nothing less than approximately US$ 4.7 billion needs to be invested by both the private and public sector by the year 2005.

Recent developments in the electricity sector will also enhance the market for climate-friendly technologies. The Spanish electricity sector is government regulated and electricity rates are fixed annually. In December 1996, the government approved a major reorganization of the electricity sector. This reorganization includes:

- allowing electricity consumers to choose their suppliers,
- the free entry of foreign operators into the market,
- full price liberalization by 2008,
- liberalization of the raw material market for generation, with the exception of nationally produced coal. Generators will have to continue to use local coal for 15% of their energy output,
- a cut in electricity tariffs that commenced with a 3% reduction in 1997, 2% in 1998 and 1% every subsequent year to 2001. This would effectively force the privileged Spanish electricity companies to increase efficiency.

Spain is quite open to foreign investment. This is characterized by the liberal laws and few restrictions that govern foreign investment. Spain has free trade zones in Barcelona, Cadiz and Vigo. In the 1988-1997 period, Spain was ranked fourth among OECD countries in terms of receiving foreign direct investment, only surpassed by the USA, the UK and France. Spain was also ranked first in terms of profitability of investment in the business sector.

Since Spain acceded to the EU, member states' exports, unlike North American exports, have benefited from lower tariffs. Spain uses the Harmonized System of tariff nomenclature for applying duties and Canadian goods are taxed under the EU's normal dutiable rate. Spain's import procedures are governed by international trade regulations. Spain has adhered to the GATT code since 1963, and it subscribes to the 1969 Multilateral Trade Negotiation (MTN) codes on technical barriers to trade, subsidies and customs valuation.

Spanish customs value shipments at CIF (cost, insurance, plus freight) prices. In addition, a 16% Value Added Tax (VAT) is levied on all renewable energy equipment whether produced domestically or imported. European suppliers enjoy an added advantage since Spanish import duties and VAT are levied on the CIF value of the item imported.

Canadian exports to Spain have expanded dramatically since 1986, the year Spain joined the European Community. In 1997, exports accounted for CAD$ 576 million (estimated), while Canadian direct investment in Spain totaled CAD$ 400 million in 1996. Canadian commercial activities in Spain are centered around the export of raw materials such as mining products, pulp and paper, mineral fuels, wood, agricultural and fish products.

The market size for environmental technologies for industry, in the chemical, energy, steel and non-ferrous metallurgy sectors is estimated at US$14 billion through to 2005. The total market for renewable energy equipment is estimated at US$400 million. Including services and related activities, this market size would be close to US$1 billion.

In terms of renewable energy, Spain's domestic market has large capabilities and is well equipped with technological and industrial infrastructure. In the last few years, technology parks have proliferated in the main industrial areas and near universities and R&D centres and R&D expenditure has risen significantly. The third national R&D Plan (1996-1999) forecasts that R&D expenditure in 1999 will amount to between 0.9% and 1.3% of GDP.

Although most of the renewable energy equipment in Spain is developed and manufactured locally, under technology transfer agreements, opportunities for foreign participation exist as imports comprise approximately one third of the total market. Overall, the best sales prospects for equipment in the Spanish renewable energy sector are for hydraulic turbines, turbine generators with over 300Kw capacity, rotor blades for turbine generators, converters and batteries, photovoltaic/wind generator systems for isolated areas, geothermal generators, solar cells.[157]

In 1995, Spain's main trading partners were EU countries, with 72.3% of total exports and 65.4% of total imports. Japan accounts for 1.4% of exports and 3.3% of imports. Latin American countries (excluding Venezuela and Ecuador) represent 5.2% of Spanish exports and 3.7% of imports, and the US accounts for 4.1% of exports and 6.4% of imports. Spain exports its environmental technologies to Latin America. Imported technology primarily comes from Denmark, Germany, the US, France, and Italy.[158]

Therefore the major competitors of Canadian exporters of climate-friendly technologies to Spain are likely to be are Western European and Japanese companies. European exporters provide generous financing and engage in extensive cooperative advertising. Their governments also support exporters' efforts by assisting with trade promotion events.

Canada has developed a successful bilateral trade agreement with Spain and Spain is now ranked as Canada's tenth largest export market in Europe. Canadian products are competitive when compared to other exporters to the EU because of lower production costs and the devaluation of the Canadian dollar vis-a-vis European currencies since 1994.

Although Canadian products are well respected for their high level of technology and overall quality, Canadian firms often fall short of their competitors in terms of flexibility/financing, adaptation of product design to local market needs, assistance with marketing, and after-sales service.

Most exporters sell their products in Spain through distributors. Canadian companies interested in selling their technology and sophisticated equipment in the Spanish market should, therefore, look for cooperative or joint venture/licensing agreements with an engineering or contracting partner. The Commercial Division of the Canadian Embassy in Madrid can assist Canadian businesses in their search for qualified representation in Spain. In addition, foreign companies established in Spain may be able to obtain subsidies for renewable energy projects from regional governments and from Ministry of Industry, part of the central government.

Bilateral investment between Canada and Spain is on the rise, with the environmental sector offering significant opportunities for Canadian suppliers of products and services. Canadian companies in the environmental industry, like Trojan Technologies and Kam Biotechnology, were awarded substantial contracts in 1996. Over 20 major Canadian companies have a presence in Spain, and Spain is one of the top ten destinations for

[157] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th

[158] US & Foreign Commercial Service and US Department of State. 1998. *Renewable Energy.* January 11th

Canadian investment abroad.—Canadian companies established in Spain include; Cominco, North West Energy, Royal Bank, Seagrams, Hiram Walker, Monenco, ABC Group, Cercast, Molson, Lawson Mardon and Quebecor.

7.10. Ukraine

7.10.1 Needs Assessment

The following is a detailed list of climate friendly-technology needs for Ukraine:

Energy production

- *Increased energy and carbon efficient processing of fossil fuels:* efficient oil and gas extraction technologies are desperately needed to help further develop the domestic resources.[159]

- *Energy efficiency for crude oil refining*: The Ukrainian government is interested in improving the energy efficiency of the oil refineries.

- *Coal bed methane:* Ukraine has requested assistance in assessing the viability of capturing methane from coal beds. The US Environmental Protection Agency (EPA) worked with the Ukrainian Government to develop a coal bed methane centre and to commercialise coal bed methane in Donbass.[160]

- *High efficiency coal based power generation:* The Ukrainian Government has plans to explore new coal sources within the country to alleviate its energy crisis and ensure that there will be enough energy to support future growth. Ukraine wants to use clean coal technologies and energy efficiency to reduce the environmental impacts of coal consumption.[161]

- *Increased use of nuclear:* Ukraine is actively seeking to expand the contribution of nuclear energy to the country's overall energy matrix. Ukraine currently has a total of five nuclear facilities with a total generation capacity of approximately 13.6 KW.[162]

- *Upgrade/replace existing power plants:* In June 1993, the Ukraine Government, with the assistance of the World Bank and multi- and bilateral agencies, started the preparation of a number of projects to rehabilitate Ukraine's hydropower plants, thermal power plants, and gas transmission and distribution metering facilities.

[159] DFAIT. 1998. *A Guide to Doing Business in Ukraine*. May.
[160] US Government. 1998. *United States Government Support for Climate Technology Cooperation. Project and Activities*. November.
[161] 1995. *Joint Implementation in Countries in Transition: An Analysis of the Potential and Barriers*. March (www.pnl.gov/aisu/jiforweb.htm) April 25, 1999.
[162] United States Energy Information Administration.1998. *Ukraine*. September.

Significant opportunities exist in this area given the scale of upgrading that needs to be completed.

- *Biomass:* Ukraine's wood and peat resources appear to have great potential for this form of energy. There is a need for detailed studies to assess the true potential of biomass.

- *Hydroelectric power:* Hydro resources are significant but are almost fully developed. In April 1995, the World Bank approved a US$114 million loan to help rehabilitate hydropower plants. The objectives of the World Bank sponsored Hydropower Rehabilitation and System Control Project are to a) improve the efficiency, reliability, safety, and environmental performance of hydropower plants, b) increase hydropower generation capacity, c) improve the quality of electricity supply by upgrading load and frequency control. The project includes the following components: a) implementation of the complete rehabilitation program for the Dnieper I and II hydropower plants, and the Kiev pump storage plant (PSP), complete rehabilitation of the Kiev, Kanev, Kremenchug, and Dniprodzerzhinsk hydropower plants.[163]

Energy end-use

<u>Industry</u>

- *Improved industrial processes:* As with all countries with economy in transition, there is a huge need in Ukraine to improve the energy efficiency of industrial processes. The US Department Of Energy (DOE) is supporting Ukrainian firms in their effort to improve energy efficiency and gain competitiveness in light of Ukraine's economic reforms. Six large factories approved a comprehensive package of recommendations related to energy efficient measures, including the installation of 30-45 MW of cogeneration capacity in one facility, and a highly efficient furnace in another. These two facilities will save a combined equivalent of 35-65 MW in capacity, the equivalent of up to US$19 million per year when implemented.[164]

- *More efficient industrial equipment:* Several opportunities have been identified within Ukraine's public services and utilities sectors to improve energy efficiency in heating systems, housing development, urban transport, and water supply and sewerage systems. Heat and water losses are high in comparison to western systems, with losses in transmission and distribution systems estimated at about 20%. Ideally, these losses could be reduced to 6-8%.[165] The main measures targeted towards the heating sector includes the replacement of obsolete boilers high efficiency ones, the introduction of anti-corrosion protection in heating systems and insulated pipelines, the introduction of automated control systems at production plants, and the use of alternative fuel and energy sources.

[163] World Bank Country Profile: Ukraine (www.worldbank.org) April 25, 1999.
[164] World Bank Country Profile: Ukraine (www.worldbank.org) April 25, 1999.
[165] World Bank Country Profile: Ukraine (www.worldbank.org) April 25, 1999.

In early 1994, the Ukrainian Parliament passed a Law on Energy Conservation. The law provides economic incentives for investments in energy conservation by industry. Its success is contingent on the establishment of a national and local extra-budgetary fund based on funds accumulated from special taxes on coal and penalties for inefficient energy use by industrial enterprises. In 1996, the government approved the regulations for the operation of the national extra-budgetary Energy Efficiency fund. However, to-date, revenues of Fund have been relatively insignificant.

In 1997, the governments of Ukraine and the US agreed to make the modernisation and replacement of gas turbine compressor stations a top priority. The US DOE is now working closely with the Ukrainian State Committee on Oil and Gas and UkrNaftohaz (Ukraine's gas transit company) to study the feasibility of this project.[166]

<u>Buildings</u>

- *More efficient appliances and equipment*: the Ukrainian Agency for Rational Energy Use and Ecology (ARENA-ECO) is currently helping the World Bank evaluate a $US 40 million loan to install energy efficiency technologies in public buildings in Kiev.[167]

<u>Municipalities</u>

- *Efficient street lighting system:* inefficient street lighting is a common problem in cities throughout Eastern Europe and the countries of the Former Soviet Union. Inefficient street lighting systems consume large amounts of electricity and are expensive to maintain. The Town of Rovno was one of several cities in Ukraine with inefficient street lighting. The Rovno pilot project involved the replacement of 150 to 200-watt incandescent lamps, and 250 to 400-watt mercury lamps, with sodium lamps. Replacing the incandescent and mercury lamps with sodium ones is expected to reduce final electricity consumption in the city's lighting network by an average of 53%. The pay back period for the investment has been calculated at 4.5 years. Following the retrofit, the energy intensity of the average fixture in the system will drop from 225 watts per unit to 106 watts per unit. In addition, the use if sodium lamps will reduce the mercury content of the lamps by 95%.[168] Opportunities of a similar scale exist in other towns.

- *District energy:* total heat demand for Ukraine is projected to increase from 166,000 Gcal/h in 1995, to about 203,000 Gcal/h by 2010. Accordingly, the National Energy Program of Ukraine for 1997 to 2010, calls for the continued development of centralised District Heating (DH) systems and Combined-Heat-and-Power (CHP) plants. The Program seeks to reconstruct and rehabilitate existing DH equipment,

[166] US Government. 1998. *United States Government Support for Climate Technology Cooperation. Project and Activities*. November.
[167] Pacific Northwest Laboratory. November 19, 1998. (www.sciencedaily.com/releases/1998/11/981119172248.htm) April 25, 1999
[168] Pacific Northwest Laboratories. 1997. *Cities in a No Regrets Climate Strategy: Lessons from Transition Economies*. October.

promote the use of waste gases in heat production, install new capacities, and construct high efficiency heat-only-boilers (HOBs) with capacities up to 180 Gcal/h.[169] A World Bank study assessed the Kiev DH conditions and priority needs. The Kiev DH system has an installed capacity of about 15,000Gcal/h, and networks totaling 2,300 km. It is the third largest in the countries of the Former Soviet Union (FSU), after the Moscow and St. Petersburg systems. In Kiev, the DH system provides most of the heat and hot water for urban dwellers as well as steam for industry. The system consists of several DH operators. Kievenergo, supplies heat to the main system and owns and operates the main heat sources which consist of two CHP plants, and 9 large boiler houses. The main transmission network is 768 km in length.[170]

Non-energy related sources

- *Reducing CH_4 emissions in dairy and livestock systems:* As the "bread basket" of the Former Soviet Union (FSU), Ukraine accounted for one fifth of the FSU's total meat and dairy output. Due to the need to control methane emissions from the dairy and livestock sector, the US EPA conducted a feasibility assessment to examine improving the diets and productivity of large ruminant animals in order to reduce methane emissions per unit of meat or milk produced.[171] The study found that significant prospects for reducing emissions exist in the agricultural sector.

7.10.2 Factors Influencing Technology Need

While Ukraine's priority is to alleviate the economic depression the country is currently challenged with, there are a number of environmental concerns that affect the country. Ukraine suffers from air and water pollution, deforestation, and radiation contamination in the northeast that resulted from the 1986 Chernobyl nuclear power plant accident.

Ukraine is Europe's fourth most populous country and largest in land area. Since independence in December 1991, Ukraine has posted negative population and real GDP growth rates, including four-years of double-digit negative GDP growth, between1993 to 1996. However, GDP is expected to experience a growth rate of 2% in 1999 as a result of increased exports, rather than domestic demand. Despite the prospects of positive growth, and the implementation of economic reforms, Ukraine's transition to a market economy continues to move at a slow pace. This slow pace of reform has jeopardized financial assistance from the International Monetary Fund (IMF), the World Bank, and other foreign investors.

[169] World Bank Country Profile: Ukraine (www.worldbank.org) April 25, 1999.
[170] World Bank Country Profile: Ukraine (www.worldbank.org) April 25, 1999.
[171] United States Government. 1998. *United States Government Support for Climate Technology Cooperation. Project and Activities.* November.

Another factor that further complicates Ukraine's path towards economic recovery is country's unofficial economy. A World Bank report estimated that 51.7% of Ukraine's GDP in 1996 was not reported to the government, and that the unofficial economy currently accounts for 40 to 60% of GDP. The government's inability to implement structural reforms and over-regulation of the economy are considered to be major reasons for growth in the unregistered economy.[172]

Nevertheless, over the past three years, there have been notable accomplishments. The annual inflation rate has been reduced from 8,000% in 1993 to 16% in 1997, the trade regime has been liberalised, domestic prices are now decontrolled, consumer subsidies have been reduced, and energy prices have increased to world levels. Ukraine has also announced its intention of becoming a member of the World Trade Organization (WTO).[173]

Within the former Soviet Union and Eastern Europe, Ukraine is one of the largest producers and consumers of electricity. In 1996, Ukraine produced 200 billion kwh of energy of which only 187 billion kwh were consumed. Most of Ukraine's electricity is generated from 14 large fossil fuel plants, five nuclear power plants, and 10 hydroelectric plants. However, production from thermal plants has declined due to depreciation, plant maintenance problems, and fuel shortages.[174]

Ukraine's gradual economic growth is expected to place an increased demand on Ukraine's already dwindling energy resources and consequently continue to further escalate the country's GHG emissions from the energy sector.

Although Ukraine's commercial and residential sectors receive priority over industry for the distribution of energy, heating and electricity for residential and commercial uses are being rationed in some areas due to insufficient and inefficient energy production.[175]

7.10.3 Factors Influencing Market Access

Estimations on the potential size of Ukraine's market for environmental goods and services are not available. However, a related sector with tremendous opportunity is the energy sector. The Ukrainian Government has given priority to the revitalisation of the energy industry at an estimated cost of US$ 7 billion. Energy-conserving technologies are needed in all industry sectors especially if Ukraine's restrictions on energy consumption and non-payment are to be enforced, and if heavy industry is to compete on the world market. Companies are looking for more technically advanced equipment, to replace the out-dated and incompatible Soviet equipment.[176]

[172] United States Energy Information Administration. 1998. *Ukraine*. September.
[173] DFAIT. 1998. *A Guide to doing business in Ukraine*. May.
[174] United States Energy Information Administration. 1998. *Ukraine*. September.
[175] United States Energy Information Administration. 1998. *Ukraine*. September.
[176] DFAIT. 1998. *A Guide to Doing Business in Ukraine*. May

Since Ukraine's independence in 1991, Canada has sought to develop trade links between the two countries. Basic Agreements have been signed including Double Taxation, Foreign Investment Protection, and Economic Cooperation. The Intergovernmental Economic Commission (IEC) along with the participation of their private sector counterpart, the Canada Ukraine Business Initiative, are working to identify and resolve challenges hindering business development in order to support Canadian investments in Ukraine.[177]

To make Ukraine attractive to foreign investors and to increase its competitiveness on the world market, Ukraine has deregulated a number of sectors, licencing requirements have been reduced, new simplified registration procedures have been introduced, the privatisation of medium-and-large enterprises is taking place and proceeding at a satisfactory pace, and energy sector reforms are being conducted. Additionally, in January 1998, a new accounting system that is compatible with international standards was introduced.

In terms of sources that offer financing to support Canadian business in Ukraine, Canada's Export Development Cooperation (EDC) and chartered banks have initiated export credit facilities and services in Ukraine. Project financing, other than that available from partnering with local organisations, can be sought through international financial institutions (IFIs). The European Bank for Reconstruction and Development (EBRD), and the World Bank's International Bank for Reconstruction and Development (IBRD) are both active in Ukraine and have local offices.[178]

Ukraine's major imports consist of oil, gas, transportation equipment, machinery and parts, textiles, and chemicals. Ukraine's major trading partners are Belarus, China, Germany, Russia, Turkmenistan, and the US.[179]

Overall, Ukraine is an important market for Canadian exporters. In 1997, Canada's exports to Ukraine totalled $CDN 22 million, and imports were $CDN 27 million. To improve market access, Canada is seeking lower tariff levels on products of export interest such as oil and gas equipment, high technology products and additional industrial items, construction materials, and agri-food products and equipment.

7.11 The Czech Republic

7.11.1 Needs Assessment

The following is a detailed list of climate friendly-technology needs for the Czech Republic:

Energy production

[177] DFAIT. 1998. *A Guide to Doing Business in Ukraine*. May.
[178] Ibid.
[179] United States Energy Information Administration. 1998. *Ukraine*. September.

- *High efficiency coal based power generation:* Pilot projects to improve the efficiency of coal based power generation are underway. For example, a coal upgrading program for Usti nad Labem assisted in significantly reducing the amount of pollution from three large district heating systems, and small residential coal fired stoves. The overall goal of the program was to assist the City of Usti nad Labem in developing cost-effective energy alternatives.

- *Substituting natural gas for coal and oil:* Significant needs and opportunities exist in this area. Some efforts have already begun. For example, in 1997, the Town of Kaplice's main district heating plant underwent a conversion from coal powered to natural gas powered energy generation. This fuel switching made it possible to connect private homes, public buildings, and industrial enterprises to the main district heating plant. A project in Decin is also regarded as a good model for meeting the Czech Republic' technology needs.

  Decin is one of the most polluted towns in Northern Bohemia. Primary concern is over the uncontrolled emissions of SO_2, NO_x, and particulates from the extensive use of locally mined brown coal (lignite) in heat production. To address these concerns, a fuel switching pilot project was designed for Decin and is now being implemented. This project was approved under the US Initiative on Joint Implementation between a US private sector entity and the Czech Republic.[180] Through the assistance of the US Centre for Clean Air Policy (CCAP), additional funds were raised to finance the replacement of a brown coal heating plant for natural gas one in one of the City's five district heating plants. This project will not only allow Decin to improve its air quality but will also allow it to contribute to international efforts to reduce GHG emissions. The activities undertaken by the project will increase supply-side efficiency via a fuel switch in a district heating plant, improve energy efficiency in district heating networks, install energy supply units, and cogenerate instead of heat only production. This project will yield the following results:

  - a reduction of 133,827 tonnes CO_2 over 25 years due to fuel switching,
  - a reduction of 475,125 tonnes CO_2 over 25 years due to cogeneration,
  - elimination of SO_2 emissions from the district heating plant, and
  - total elimination of ash[181].

- *Cogeneration:* The need for cogeneration technology is vast and has begun to be addressed. The State Environmental Fund (SEF) uses fines from polluters to fund environmental projects. The Town of Vratimov located in northern Moravia is a recipient of SEF support to develop a project to use waste heat from a local steel mill to supply its district heating system. Approximately 80% of its heat demand is met by heat from the steel mill at Nova Hut. This project replaced 15 coal boilers and one old gas boiler with a new district heating system. The total installed capacity of the

[180] JI Project development in the Czech Republic. (www.vol.cz/nondek/jicz/websi2.htm) April 27, 1999.
[181] Joint Implementation Network: The Netherlands. (www.Northsea.nl/jiq/fossil.htm) April 27, 1999.

new district heating system is 16MW, which can meet the maximum projected demand for heat with a substantial amount in reserve. Prior to the project's completion, unused heat escaped into the atmosphere. Implementing the project has already saved approximately 100,000 GJ of primary energy annually in the form of fuel. The use of waste heat in the Vratimov project saved 1,800 tonnes of black coal, 1,200 tonnes of coke, 1,200 tons of brown coal, and 100,000 tonnes of natural gas. Combined, this unused fuel results in the elimination of 9,700 Mt of CO_2 emissions per year.[182] After completion of the project, additional heat and energy savings were generated from the installation of heat meters and regulation devices. Households benefited directly from these measures because they had an economic incentive to conserve energy and therefore reduce their heating and hot water bills.

The World Bank is implementing a project to expand, modernise, and convert the Czech Republic's Energy Centre Kladno (ECK) from a district heating and industrial steam plant to an electricity generating plant. Converting the plant will require the following components: new coal-fired fluidised bed boilers, turbine generators, and a natural gas fired combustion turbine with a heat recovery unit for steam production. The new fluidised bed boilers and combustion turbines will meet both Czech and World Bank stack emissions guidelines. Upon completion of the project, the ECK will be a cogeneration plant that produces electricity and steam. A conventional Czech power plant typically uses only 35% of the fuel's heat content, the rest being lost as waste heat.[183] This project is expected to achieve thermal efficiency of over 50%.

Another waste heat utilisation project involves several implementing agencies including the Czech Ministry of Environment, Global Environment Facility (GEF), and the World Bank. The primary purpose of this project is to decrease GHG emissions by increasing energy efficiency and the reliability of the heat and power supply to the Vetropak Moravian Glass (VMG) factory and the City of Kyjov district heating system. Located in the City of Kyjov, VMG is the largest glass bottle manufacturer in the Czech Republic. Currently, the glass production facility produces substantial volumes of waste heat. As a result, a combined-cycle alternative will be implemented to use waste heat to produce process heat and electricity for the facility. The balance will be provided to the City of Kyjov as a primary heat source for its district heating system. This project will include the demonstration of gas-fired combined cycle cogeneration since this technology is not frequently used, and a demonstration of the benefits accrued by combining the processes of industrial heat production with district heat production for a city. Completion of this project will also displace power production at a local lignite plant with an associated decrease in emissions. It will also eliminate NO_x emissions from a total of 15 district heating stations located near the residential areas in the City of Kyjov.[184]

[182] Joint Implementation Network: The Netherlands. (www.Northsea.nl/jiq/fossil.htm) April 27, 1999.
[183] World Bank Projects in the Czech Republic (www.worldbank.org). April 27,1999.
[184] Workd Bank Projects in the Czech Republic (www.worldbank.org). April 27, 1999.

- *Upgrade/replace existing power plants:* A priority for Czech policy makers is to reduce reliance on aged and environmentally damaging coal generation plants. CEZ, the formerly state-owned electric company has reorganised its operations and has already closed several old and heavily polluting coal plants. By December 1994 12 units at six major sites were permanently shut down. At the end of the program in 1998, a total of 19 high polluting and technically obsolete coal-fired generating units, with a total capacity of 2.3 GW were closed. CEZ is also seeking to increase electricity generation efficiency by modernising power plant technology, much of which dates from the 1960s and 70s. Therefore, CEZ is substantially investing in retrofitting existing coal units with flue-gas de-sulphurisation and fluidised-bed combustion equipment. These measures reflect CEZ's commitment to switch from coal towards cleaner burning fuels, particularly natural gas.[185] CEZ's program to desulphurise its power plants is now entering its final phase. By the year 2000, emissions of SO_2, NO_x, and CO_2 from the utility's coal power plants should be 91%, 50%, and 10% lower than 1993 emission levels respectively. Additionally, CEZ will put the rest of the power plants that will remain sulphurised, on a reduced operation mode while additional desulphurising units are constructed.

  Another initiative that demonstrates the Czech Republic's aggressive plan to upgrade existing power plants is a project that involves the Bulovka Teaching Hospital in Prague and the Jilemnice District Hospital located in Northeast Bohemia. Both hospitals required significant upgrades in their central heating systems to reduce energy costs. The upgrades will result in savings that allowed the hospitals to reduce their overall operating costs without compromising their levels of service. Prior to the project, the Bulovka hospital complex was heated with steam generated from its own central steam plant. To ensure energy efficiency:

  - the hospital's external central steam system was switched to district heating,
  - a new energy management system, that allows for more precise control of indoor temperatures and hot water, was implemented,
  - a new air handler recovery system was installed,
  - the overall system was upgraded to include a new energy efficient gas boiler,
  - Control and monitoring equipment was also installed, and
  - much of the 50-year-old piping was replaced.

As a result, the original steam plant was closed, and the hospital now receives heating and hot water from newly installed heat exchangers. It is estimated that the upgraded system will produce an annual saving of about US$700,000 with a four year payback period. In effect, this upgrading substantially reduces the costs associated with energy generation and GHG emissions.[186]

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[185] United States Energy Information Administration. 1995. *Czech Republic*. September.
[186] World Energy Efficiency Association. 1995. *ESCO Case Study: Bulovka Teaching Hospital, Prague, Czech Republic*. December. (www.weea.org/best/bulovka) April 27, 1999.

- *Biomass electric*: A project to construct a wood-fuelled heating system for a kindergarten and adjacent houses within the Town of Lomnice nad Luznici is being sponsored by *Seven*, an energy efficiency research institute in the Czech Republic.[187]

Energy end-use

<u>Buildings (residential and commercial)</u>

- *More efficient appliances and equipment:* The majority of the Czech Republic's population reside in housing units that are energy inefficient. Brown coal (lignite) and bituminous coal are the cheapest residential heating commodities and are thus used by the majority of the population for heating purposes. The Federal Energy Efficiency Program is a state program that offers direct financial support for up to 40% of the total investment costs for an energy-saving project. The program receives funding from the Ministry of Industry and Trade in collaboration with the Czech Energy Agency (CEA). Recipients of this support may be individual households, municipal bodies, entrepreneurs involved in heat and electricity generation, and owners of residential buildings. This project is part of the greater strategy to improve the Czech economy through state support for investments in energy efficiency. In 1996, CZK$6.8 million was allocated from the state budget for power savings programs. In comparison to 1995, applications for energy efficiency projects had increased by approximately 50% in 1996 demonstrating the opportunities that exist for suppliers of energy efficient and climate-friendly equipment. In 1997, grants were awarded to projects that will result in:

    - reduced energy consumption (including heat and hot water) in households, and school buildings,
    - reduced energy consumption in health care facilities,
    - implementation of energy efficient measures in public buildings,
    - implementation of renewable energy projects and cogeneration in municipal systems,
    - improvement of energy supply systems for housing estates, and
    - implementation of energy efficiency measures and renewable energy projects in the transportation and agriculture sectors.

  Overall, participation in the above program could result in increased efficiency in the municipal sector by reducing energy consumption by 30%. This would save approximately 23 billion kWh of energy annually.[188] Thus far, energy efficiency programs conducted from 1991 to 1995 have resulted in average annual savings of 1,000 terajoules.

  Energy efficiency projects in the housing sector have resulted in significant government subsidy savings. This program has also reduced heat consumption in public buildings by 2% in 1992, 1% in 1993, and 4% in 1994. Between 1991 to

[187] JI Online: www.ji.org/projects/heat.shtml (April 27, 1999)
[188] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.

1995, the program has resulted in a 1.6 million Mt reduction in CO_2 and 7,600 Mt reduction in NO_x emissions.[189] Additional energy savings for the same time period include:

- *Weatherisation:* the CEA project installed 63 units to serve 6,300 housing units that resulted in energy savings of 100,000 GJ/year. This resulted in 49% savings per apartment.[190]
  - *Metering and controls:* the CEA project installed 23 units to serve 38,000 housing units. This resulted in 22% savings per apartment.[191]
  - *Gas boiler plants:* the CEA project installed 8 units in a total of 200 housing units. This resulted in 34% savings per apartment.[192]

As of July 1996, 160 small water power plants, 11 thermal pumps, 56 cogeneration units, 7 wind power plants, 5 solar devices, 3 biogas units, and 1 wood-combusting boiler were in operation throughout the Czech Republic. The 243 units installed through the renewables program have a total capacity of 20,000 kW_e and 8,500 kW_t and are expected to produce 70 million kWh_e each year.[193]

CO_2 Management

<u>Sequestration/storage</u>

- *Forest sinks:* The CO_2 absorption capacity between 1990 and 1993 increased from 1% to 4%. An approved JI project between the Dutch Face Foundation and Czech Republic involves reforestation of areas damaged by air pollution (acidic precipitation resulting from the emissions of high sulphur coal combustion) in the areas of Krkonose and Sumava Mts.[194]

Non-energy related sources

- *Landfill gas capture and use:* A project which uses biogas from community landfill disposal sites for energy is being sponsored by *Seven*. Zeravice I and Zervace II are two independent waste disposal sites located near the Town of Prerov. Gas will be captured from each waste site and transported through a middle-pressure gas pipeline for use by residents in the Prerov-Predmosti housing development. Existing heat exchangers will receive the gas and burn it in cogeneration units. The electric energy produced will be sold to the distribution company, while the heat produced will be sold to the company that supplies heat to the housing development.[195]

[189] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic.* February.
[190] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic.* February.
[191] Ibid.
[192] Ibid.
[193] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic.* February.
[194] JI Project development in the Czech Republic. http. www.vol.cz/nondek/jicz/websi2.htm
[195] JI Online: www.ji.org/projects/biogas.shtml. April 27, 1999

Cross cutting

- *Fuel switching/cogeneration/energy efficiency/power plant replacement & upgrade:* The Czech parliament has decided to use a portion of the State Property Fund to reduce regional pollution and introduced the national Program on Healing the Atmosphere (PHA) in July 1994. The program was designed to improve the quality of the atmosphere in cities and municipalities. PHA allocated US$200 million for investment into the program between 1994 to 1997. High priority measures include replacing the combustion of brown coal, briquettes, and coal sediment with natural gas, electricity, or other more environmentally friendly sources of energy for apartments and industrial equipment that require up to 50MW of power. Approximately 90% of the activities supported by PHA focus on replacing brown coal used in small combustion units with natural gas. Although this program was not designed to support international climate-related goals, it does so indirectly. Program funding may by used for the following activities:

    - Projects that improve air quality by converting from coal to natural gas,
    - Projects that reduce air pollution from stationary sources with outputs of up to 50 MW,
    - Construction of gas distribution systems or connections to city or local gas distribution systems, and
    - Construction of renewable energy plants with outputs of up to 50 MW to replace coal-fired plants.

  PHA reduces CO and NO_x emissions by approximately 64,000 and 5,000 tonnes per annum respectively. Although this program does not monitor CO_2 emissions, it is estimated that CO_2 emissions will be reduced by approximately 6.4 million tonnes between 1997 to 2000.[196]

  Approximately 10% of all CO_2 emission reductions from fuel switching can be attributed to PHA. This reduction constitutes approximately 30% of all economically feasible emission reductions from fuel switching until 2000. The overall size of the market for fuel conversion indicates that PHA could be expanded by two to three times its current size.

7.11.2 Factors Influencing Technology Need

Integrating the Czech economy into the global market, specifically the EU, is a government priority. The Czech Republic formally applied for EU membership in 1996 and is expected to receive membership by the year 2005. It is estimated that the Czech Republic needs to invest $US 15 billion in its environmental sector to comply with European Union (EU) standards and that funding will mainly come from public and private sources as well as the EU. Specific goals include stability between energy supply

[196] Advanced International Studies Unit. Pacific Northwest National Laboratory. 1998. *Climate Change Mitigation: Case Studies from the Czech Republic*. February.

and demand, competition within the energy sector, and energy prices that include environmental externalities.

According to a recent EU evaluation, the Czech Republic's environmental priorities include air quality, water treatment, and waste management. The Czech Ministry of Environment estimates that $US 6 billion will be required to deal with air pollution alone. The EU also recommended that the Czech Republic minimise energy consumption and waste by introducing advanced technologies to mitigate the other environmental problems.[197]

In 1997, the Czech Republic had a population of 10.3 million people and a negative projected population growth rate of -2% for the period between 2005 to 2010. Despite the Republic's negative projected growth rate, consumption of goods and services is increasing. Increasing consumption translates into increased demand for energy supply. According to *Seven*, per capita energy consumption is twice that of Western Europe. For example, energy consumption per unit of GDP remains 2.5 times greater than the EU average.

In 1991, the Czech Republic passed Resolution 252/91 to reduce the demand for power in the Czech economy. To reduce energy consumption it is necessary for the Czech Republic to replace the majority of its energy inefficient equipment and appliances and to increase fuel quality.[198] The resolution resulted in the creation of a federal strategic program to support the dissemination of energy efficient equipment, materials, and technologies.

The Czech Republic is one of the most advanced transforming economies in Eastern Europe. Since separating from Slovakia in 1993, the Czech Republic has proceeded, with success, towards developing a prosperous market-oriented economy. In 1997 GNP per capita was US$5,200, and the country's economic growth rate is currently estimated at about 4%. The government that was elected in 1998 is continuing with the main elements of the macro-economic adjustments that were already underway. Specifically, these adjustments include prudent regulation of the capital markets, adoption of a working bankruptcy framework, and continued progress towards privitisation.[199] At present levels of economic growth, levels of GHG emissions in the Czech Republic by the year 2000 will be 10% below 1990 baseline levels.[200]

The medium and long-term energy polices of the Czech government will focus on harmonising standards in the Czech energy sector with those of the European Union. This will translate into a decreased dependence on solid fuels (coal, coke, and wood) which accounted for 60% of energy production in 1996, to 40% by 2005. Energy prices in the Republic will continue to rise towards world levels as a result of the reforms in the

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[197] U. S. Department of Commerce - National Trade Data Bank, February 26, 1999

[198] Seven, The Energy Efficiency Center. 1999. *Energy and Economic Bulletin for the Czech Republic.* January.

[199] World Bank. 1998. *The World Bank Group Countries: Czech Republic*. August.

[200] Advanced International Studies Unit: Pacific Northwest National Laboratory. 1997. *Climate Change Mitigation: Case Studies from the Czech Republic*. October.

energy sector. This increasing cost of energy has contributed to the government's concern for energy efficiency.

7.11.3 Factors Influencing Market Access

The Czech Republic was the first post-communist country to join the OECD in December 1995. Accordingly, the Czech Republic is committed to a free market and maintains a generally open economy with few barriers to trade and investment. The Czech currency, the crown, is fully convertible for most business purposes. From 1990 to March 1996 total foreign direct investment in the Czech Republic was US$5 954.7 million.

The Czech Republic committed to not discriminating against foreign investors when it joined the OECD. Although legally the government is not permitted to differentiate between foreign and domestic investors, or between foreign investors from different countries, foreign investors do have some concerns. The main concerns for Canadian companies are the comparative advantages enjoyed by EU investors because of geography, the Republic's high taxes, slowness in decision-making in the government, and excessive red tape.

The industrial market for energy efficiency is estimated at US$3.15 billion.[201] Industrial goods represented 20.6% of total imports during the first five months of 1998. The Czech Republic's major import products are machinery and transport equipment, fuels and lubricants, manufactured goods, raw materials, chemicals, and agricultural products.[202]

There are 11 free trade zones established in several cities throughout the Czech Republic. Materials, components, and semi-finished products are exempted from customs duties or VAT if they are exported into a free trade zone. If the imported goods are used in the manufacturing or processing of a final product, which is then re-exported, they are also exempt from duties. The Czech Ministry of Industry and Trade issues import licenses to those seeking to import selected goods into the Czech Republic.

The Czech Republic is a member of the WTO and has adopted a tariff code with an average tariff rate of approximately 5%. Specific duty rates are published in the Czech tariff schedule based on the Harmonised System of classification. The basic rate for value-added tax is 22%. Most EU exports enjoy lower tariffs than other countries under the Czech Republic's EU association agreement. According to this agreement, tariffs on EU exports to the Czech Republic will be eliminated by the year 2000. In addition, the Czech Republic also belongs to CEFTA (Central European Free Trade Agreement), which also includes Slovakia, Poland, Bulagaria, Hungary, Romania, and Slovenia. Members of CEFTA are also subject to more favourable customs duty rates on their exports to Czech Republic.

[201] World Energy Efficiency Association. 1995. *ESCO Case Study: Bulovka Teaching Hospital, Prague, Czech Republic*. December. (www.weea.org/best/bulovka) April 27, 1999.
[202] United States Energy Information Administration. 1995. *Czech Republic*. September.

Over 60% of trade in the Czech Republic is with the European Union (EU) and its major trading partners are Slovakia, former Soviet Republics, Germany, Austria, Poland, Switzerland, UK, and Italy. The Czech Republic also trades with members of CEFTA. The strongest competition for Canadian exporters of climate-friendly technology will likely come from EU countries.

7.12 Argentina

7.12.1 More Detailed Needs Assessment

The following is a detailed list of climate-friendly technology needs for Argentina:

Energy Production

- *Integrated gasification combined cycle:* the CAPSA project is an approved US joint implementation initiative that involves the conversion of six gas turbines from simple cycle to combined cycle operation at the Capex power plant in the province of Nuegen. Converting to combined cycle will result in an increase of 185 MW in power generated by the plant through the use of waste energy, without increasing fuel consumption. The total GHG benefits of the additional power is estimated at roughly between 16.5 and 33 Mt of CO_2 over the project's 30-year lifetime.[203] Other projects include a joint venture between Argentina and Chile which includes a combined-cycle-gas-fired power plant and a 164 mile transmission line to be built to link Argentina's Salto Province with Northern Chile.[204]

- *Substituting natural gas for coal and oil:* After Venezuela, Argentina has the second largest proven reserves of natural gas in South America. Argentina's energy consumption is rapidly shifting to natural gas. Argentina's total gas demand has increased by over 80% over the past decade.

- *Increased use of nuclear:* Argentina has the most advanced nuclear energy program in Latin America. A CANDU 6 nuclear power plant, Embalse, of 648 MWe capacity is currently operating at near 100% capacity factor. Its overall capacity factor has been 83% since it went in-service in 1984. Currently, the Atucha I nuclear power station requires upgrading, and the Atucha II station requires an additional investment of US$700 million to complete construction and commissioning.[205]

- *Cogeneration:* in 1977, the INTA (National Institute of Agriculture and Technology) Castelar Rural Engineering Department began researching the utilisation of manure and crop waste to produce biogas (methane). Biogas studies are being conducted at the University of Rosario. One of their projects is supplying 60% of a school's

[203] US Initiative on Joint Implementation. March 17, 1999. *Four Central and South American Projects to Reduce over 100 million tons of Greenhouse Gas*.
[204] US Energy Information Administration. 1998. *Argentina*. November.
[205] DFAIT. *The Environmental Market in Argentina*.

electric power supply through the conversion of waste to biogas. Currently only a few private sector companies are using cogeneration technologies which have two advantages, overall fuel efficiency is maximised, and the waste problem is solved. The resulting emissions have low levels of CO, particulate matter, NO_x and other pollutants. With smaller types of cellulose wastes such as sawdust or small husks, the mix of solids with air is generally used in the torsional chamber. Industries that are using this technology include: Cellulosa Argentina (energy from corn stalk and cellulose waste), Nidera (energy from sunflower husks), and Milanos Rio de la Plata (utilises waste edible oil for biogas production). At present, companies whose main activity is installing cogeneration systems to convert waste to biogas do not exist in Argentina.[206]

- *Upgrade/replace existing power plants:* A consortium comprising of Siemens Power Generation and Black & Veatch, of the US, is planning to upgrade a unit in the Luyan de Cuyo steam power plant outside Mendoza, Argentina. Siemens will also provide a second 155 MW gas turbine for the Tucuman power plant in northwest Argentina.[207]

- *Renewables:* Argentina has small solar and wind energy programs and is investigating the expansion of their capabilities. Solar power currently only provides about 2 MW of electric power capacity and 1.8 GWh of generation per year, while wind power provides about 3.4 MW of capacity and 7 GWh of generation per year.

- *Hydroelectric power:* Argentina has about 8.1 GW of hydroelectric capacity. Total additions in 1997 amounted to 2,047 MW of new capacity from several completed projects including Yacyreta, Cada de Piedra, Filo Morado, Genelba, and Tucumán.[208] The Argentine government has proposed the construction and operation of several new hydroelectric power projects by private concessions including Garabí (1,880 MW), Corpus (2,880 MW), and Paraná Medio (3,000 MW). Additional on-going projects that will require climate-friendly technologies and equipment include the Yacyreta hydroelectric dam, the Hidrovia River transport project, the clean-up of the new hydro power/irrigation dams in Cordoba and San Juan, and power utilities.[209]

- *Solar photovoltaic:* Argentina is currently funding the "Project for Supplying Electricity to the Argentine Scattered Population" (PAEPRA) to supply electricity to areas where population densities are low. Approximately 1.85 million people in 22 provinces comprise segments of rural population without electric power and most of these end-users have no real possibility of connecting to a National or Provincial electric grid. The project aims to supply 1.4 million of the 1.85 million rural inhabitants with electricity, in addition to supplying energy to 600 public services (schools, small hospitals, police stations). Project coordinators estimate that 75% of

[206] US & Foreign Commercial Service and US Department of State. 1996. *Argentina Environmental Technologies.* Market Research Report
[207] DFAIT. *The Environmental Market in Argentina.*
[208] US Energy Information Administration. *Argentina*. November.
[209] US & Foreign Commercial Service and US Department of State. 1996. *Argentina Environmental Technologies*. Market Research Report.

the energy generated as a result of this project will originate from solar photovoltaic technology for communities in regions with the highest solar.

Another solar power initiative is the Small Village Water Supply Project (for villages with less than 500 inhabitants) that is being carried out by the National Institute for Water Sanitation (INOSE). The project entails providing electricity through solar photovoltaic panels for pumping water. [210] Solar energy is also being used in La Plata for illumination at night and in El Cebollar to provide power to an underground desalinisation plant. Solar power is also being generated for use in San Jose, Province of Mendoza, La Gruta, and Province of Catamarca.[211]

- *Wind energy:* Santa Cruz, Patagonia is home to the largest windmill park in southern Latin America. The windmill park is connected to the public system, and supplies 30% of the energy required by Santa Cruz's 12,500 residents. The government of Santa Cruz covered 30% of funding costs, and the remaining 70% came from the German Ministry of Technology and Investigations. The ten windmills installed have a total capacity of 1MW.[212] There are many communities in the southern provinces of Argentina that are connected to local electric grids which produce electric energy using diesel generators. For communities that are also in areas that have high wind speeds, project coordinators of PAEPRA are contemplating the installation of hybrid wind-diesel systems where each generator will generate between 5 to 150 kW of energy.

  Other wind energy projects include:
  - the Federal Program for Rural Schools Infrastructure, being carried out by the Ministry of Education. The objective is to provide electricity and water to,7 000 schools throughout the country.
    - In particular, the Province of Buenos Aires School Electrification Program entails the electrification of 500 rural schools using wind and solar technology[213]
  - San Juan Province's Department of Non-Conventional Energies is undertaking a project that will supply energy to four districts using 5 photovoltaic, and 4 hybrid wind-photovoltaic systems.[214]
  - The US Trade and Development Agency is currently funding a study for combined wind and thermal power generation for a cooperative in Comodoro Rivadavia, Chubut.[215]

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[210] US & Foreign Commercial Service and US Department of State. 1997. *Argentina Solar Energy Equipment Market.* Research Report.
[211] US & Foreign Commercial Service and US Department of State. 1996. *Argentina Environmental Technologies*. Market Research Report.
[212] Success Stories from Argentina: www.ncat.org/hemisphere/success/country-text/argentin/re/WindMill
[213] US & Foreign Commercial Service and US Department of State. 1997. Argentina Solar Energy Equipment Market Research Report.
[214] Ibid.
[215] Ibid.

Energy end-use

Transportation

- *More efficient vehicles:* Motor vehicle pollution is contributing to critically high concentrations of carbon monoxide and nitrogen oxides in Argentina's urban areas. Vehicle emissions are now regulated by national emissions and noise standards for both new and used vehicles. These standards encourage the adoption of vehicle emission control technologies such as catalytic converters. In January 1995, Argentina implemented Decree 875 to reduce vehicle emissions by 92% over a five-year period. This regulation is being adopted in stages through 1999 in accordance with an agreement reached between members of the Southern Cone Common Market (Mercosur) in 1993.[216]

  In 1985, a program of tax exemptions was introduced to promote the replacement of petroleum fuels with compressed natural gas (CNG). To date, the CNG program has led to the substitution of about 12% of diesel use on the Buenos Aires metropolitan area. Of the nearly 400,000 registered taxis, about 65% use CNG, with the rest still running on diesel. Of the 15,000 registered buses, only 300 of run on CNG. Taxi owners prefer CNG-fueled cars as the fuel costs are slightly below diesel prices, and new CNG taxis tend to be 30-35% cheaper than new diesel taxis. However, the potential for fuel-switching for buses is limited, partly because new CNG buses tend to be more expensive than diesel-fueled buses and partly as a result of the inconvenience associated with long refueling times.

Non-energy related sources

- *Landfill gas capture and use:* waste management is among Argentina's priority environmental concerns. The landfill gas management project is an approved US joint implementation initiative that involves the development of gas collection and combustion systems at landfills located in the Greater Buenos Aires area. The landfills are owned and operated by Coórdinacion Ecológia Area Metropolitana, Sociedad del Estado (CEAMSE) and serve the Greater Buenos Aires area. Because landfill gas is approximately 50% methane, combustion of landfill gas results in a significant reduction in methane emissions through oxidation of the methane to carbon dioxide. Because methane's global warming potential is 21 times that of carbon dioxide, on balance, this project results in a net reduction of GHG emissions. Five million mega tonnes of waste are deposited annually in the CEAMSE landfills. It is estimated that if all gas generated from this waste is collected and burned, the project would result in an emissions reduction of 4 million Mt of CO_2-equivalent per year. On the basis of a nominal 20-year project lifetime, this would result in 80 million Mt of CO_2-equivalent averted.[217]

7.12.2 Factors Influencing Technology Need

[216] Argentina Environmental Profile
[217] US Initiative on Joint Implementation. March 17, 1999. *Four Central and South American Projects to Reduce over 100 million tons of Greenhouse Gas*.

Argentina's main environmental problems are poor water quality, high surface water pollution, groundwater contamination, hazardous and solid waste, and air emissions from industry. In effect, few industries treat their effluents, many dispose of waste in hundreds of unregulated dumps scattered throughout the country, and air pollution control is virtually nonexistent.[218]

Once the details of Argentina's voluntary commitments to address its emissions of GHG are known, it will become clear where GHG emissions mitigation ranks vis-à-vis other policy goals. Although GHG mitigation is not currently a direct priority, Argentina's actions to improve air quality and reduce air pollutants will indirectly help to reduce GHG emissions.

Urban air pollution problems are concentrated in Argentina's largest cities and industrial areas including Buenos Aires, Cordoba, San Lorenzo, and Campana. In addition to the energy and industrial sectors, significant increases in the number of automobiles are also a major cause of rising levels of urban air pollution. The overall demand for air pollution control equipment is, therefore, mainly concentrated in the electric power, industrial, and transportation sectors.[219]

Argentina is the second largest country in South America with a population of 36.2 million people in 1997. The average annual population growth predicted for 2005-2010 is 1.1%. Argentina also has the highest GNP per capita and the highest standards of living in Latin America. Based on the stability fostered by the Convertibility Plan of 1991, Argentina has become one of the hemisphere's most promising emerging markets. The Convertibility Law of 1991 was Economy Minister Cavallo's plan to align the Argentinean peso with the US dollar.

The government seeks to promote economic growth under conditions of low inflation and external viability, increase savings and investment, deepen the process of structural reform, and improve efficiency on the economy. [220] Consistent economic policies since 1991 have brought Argentina a level of economic stability unprecedented in recent history. Economic growth during 1997 was 8.4%, with inflation minimal at 0.3%. Economic growth projections are estimated at 4.68% for 1999.

As a result of Argentina's strong economic performance, demand for electricity is continuing to increase. As part of its efforts to meet this rising demand, the Argentine government is committed to providing electricity to all rural areas by the year 2000. Estimates by Argentina's Energy Secretary indicate that Argentina's energy demand will increase by 4% to 6% per year from 1997 to 2000.[221] Subsequently, generating capacity to the year 2000 will double at a rate of 600 MW per year. In 1996, Argentina's installed

[218] US Department of Commerce. 1998. *Argentina Environmental Technologies Market Export Plan*. October.
[219] DFAIT. *The Environmental Market in Argentina*.
[220] US BEMS country commercial guides: Argentina
[221] US Energy Information Administration. 1998. *Argentina*. November.

electric generation capacity was approximately 19.61 GW. An additional 14GW of generation capacity will be installed by 2005 for both domestic and export purposes. In addition to Argentina's eight combined cycle thermal generating stations which have a total capacity of 1,800 MW, 10 additional stations with a 3,000 MW capacity will be completed by the year 2000.[222]

As a result of the country's abundant energy resources and its liberalised energy market, Argentina's energy prices are relatively low compared to other countries in the region. Low energy prices increase the demand for energy and also act as an incentive for overuse.

7.12.3 Factors Influencing Market Access

In comparison with other counties in the region, Argentina has one of the least developed environmental regimes. Although emphasis on environmental issues has traditionally been neglected in favour of industrial expansion, environmental considerations are beginning to receive greater attention by government and industry. Government representatives have recently expressed interest in attracting foreign investment to help develop a world class environmental technology industry.[223]

In 1995, Argentina accounted for approximately 14% of Latin America's US$7.8 billion environmental market, following Brazil (44%), and Mexico (22%). Approximately 25% of Argentina's environmental needs are met through imports. Provincial environmental laws have a greater influence on the market than federal laws and as a result, market opportunities vary across provinces and regions. Buenos Aires is Argentina's largest industrial region, has the most developed environmental regulatory framework and represents the greatest number of market opportunities.

In 1998, Argentina's overall market for environmental technologies and services was approximately US$885 million. The market segment for air pollution control equipment was estimated at US$45 million. This is relatively small considering the country's size and gross domestic product. However, once a more effective regulatory environmental framework is put into place, the market for environmental goods and services is expected to grow significantly.[224]

The market segments for other climate-friendly technologies are also expected to grow as a result of government and private initiatives to increase the supply of clean power. In the last few years, Argentina has incorporated solar photovoltaic systems into its overall energy matrix. Consequently the market for solar photovoltaic equipment and related technologies is growing. Furthermore, as a result of the government’s initiative to

[222] DFAIT. *The Environmental Market in Argentina*
[223] Personal Communication; Abyd Karmali (ICF Kaiser) with Dra. Maria Eugenia Di Paola (SeCzech Republicetaria de Planeamiento Urbano y Medio Ambiente, Government of Argentina), Americana Conference, March 28, 1999.
[224] US Department of Commerce. 1998. *Argentina Environmental Technologies Market Export Plan*. October.

replace petroleum fuels with compressed natural gas (CNG), substantial opportunities also exist in this market segment.[225]

Privatization has directly addressed the problem of rising debt by divesting inefficiently operated assets and companies. In addition, it is expected that the new owners of privatised assets will improve the assets by upgrading Argentina's infrastructure. Argentina's privitisation process resulted in power plant upgrades to increase efficiency as a result of capital injection from the new private owners. These upgrades also resulted in reduced GHG emissions.

In recent years Argentina has become a solid and stable economy, making it an attractive market for Canadian investors. The domestic economy has been deregulated, opened up to foreign trade, and a framework for foreign investment exists. The present environment for foreign investment in Argentina is one of the most attractive in the world. Foreign companies are not required to register with the government in order to operate in the country. Foreign companies receive the same treatment as local companies with access to all economic sectors, and equal access to incentive programs and contracts with the Argentine government.

To encourage foreign investment Argentina has employed unilateral market liberisation measures in combination with multinational trade agreements. Much of the country's complex structure of non-tariff barriers has been abolished and in 1994, the maximum tariff dropped from 50% to 20% on most consumer goods, with an average tariff of about 10%. Mercosur calls for a gradual elimination of tariffs on goods originating in and traded among the member states and the establishment of a common external tariff (CET).[226] The Argentine tariff Harmonized System was implemented in January 1992 and is aligned with the WTO Customs Classification Code. Argentina has also accepted the WTO Customs Valuation Code.

Many foreign firms continue substantial direct investment and have displayed interest in taking advantage of unique opportunities in Argentina arising from the Mercosur union with Brazil, Paraguay, and Uruguay. Along with its Mercosur partners, Argentina has taken an active role in talks involving 34 countries from North, Central, and South America on the creation of a Free Trade Area of the Americas (FTAA).[227] Furthermore, exports to Mercosur countries must comply with international requirements, not only with respect to waste but also with respect to the use of clean technologies. These requirements call for higher levels of environmental performance by local companies.[228]

[225] US Department of Commerce. 1998. *Argentina Environmental Technologies Market Export Plan*. October.

[226] DFAIT. 1999. *Argentina: Profile and Overview*. January.

[227] Embassy of the Republic of Argentina and Department of Foreign Affairs and International Trade Ottawa. 1997.*A Canadian Business Guide: Trade and Investment Opportunities in the Republic of Argentina.* July.

[228] US & Foreign Commercial Service and US Department of State. 1996. *Argentina Environmental Technologies.* Market Research Report.

Trade between Argentina and Canada has increased considerably in recent years. During the period between 1995 and 1996, two-way trade escalated from C$226 million to close to C$400 million. Bilateral trade for the first half of 1998 was C$278.6 million. Canadian exports to Argentina include machinery, agricultural products, minerals and metals, telecommunications equipment, mechanical and electrical appliances, newsprint, plastics, and chemicals. Companies entering into new business relationships in Argentina represent a broad range of industries and technologies from across Canada.

Canadian direct investment in Argentina as of 1997 is C$1.4 billion.[229] The Argentine government has also forecasted that Canada will rank as the third largest investor in the new wave of investment for the 1995-2000 period. The Team Canada 1998 visit to Argentina generated 75 new business deals worth C$143 million. To support these developments, Canada has signed a Double Taxation Agreement (DTA) with Argentina and discussions are underway for a renewed Foreign Investment Protection Agreement (FIPA).

Although Canadian technology, services, and products are highly regarded, in order to pursue growing market opportunities in Argentina, Canadian suppliers of environmental technologies may find it advantageous to form joint ventures or partnerships with local firms. In addition companies need a reputable local representative who is familiar with the market.[230]

Canadian firms entering this market will encounter stiff competition from both US and European firms. US firms have the largest share of Argentina's environmental market and are leading suppliers of water and liquid effluent treatment. Australian companies lead in mining and environmental technology exports, Swiss firms are noted for their air control and monitoring equipment, and German firms lead in soil remediation. Japanese, Spanish, British, and Italian companies are also present but on a smaller scale.[231]

Although Brazil is Argentina's most important trade partner and the recipient of 30% of its exports, in 1996 Argentina received 24.4% of its imports from Mercosur, 23.4% from NAFTA, and 29.1% for the European Union.

There are approximately 70 Canadian companies established in Argentina, and the Canada-Argentina Chamber of Commerce has been growing rapidly, with 44 confirmed members as of September 1998.[232] Canadian companies present in the Argentine environmental sector on a full time basis include Jacques Whitford, Golder Associates, and SNC Lavalin.

7.13 Thailand

[229] DFAIT. 1999. *Fact Sheet: Argentina*. March.
[230] Embassy of the Republic of Argentina and Department of Foreign Affairs and International Trade Ottawa. 1997.*A Canadian Business Guide: Trade and Investment Opportunities in the Republic of Argentina*. July.
[231] DFAIT. *The Environmental Market in Argentina.*
[232] DFAIT. 1999. *Argentina: Profile and Overview*. January.

7.13.1 Needs Assessment

The following is a list of specific GHG technology needs for Thailand :

Energy production

- *Switching to lower carbon fuels:* due to lignite's negative environmental impacts, its use in future power projects will be significantly reduced. By the year 2006, EGAT plans to decrease the portion of installed capacity in lignite-fired thermal plants to 13%. Several older fuel oil-supplied plants will be retired and their portion of installed capacity will decrease from 23.7% in 1993 to approximately 6%. To compensate, Thailand will increase its user of cleaner fuels and imported coal from 0 in 1993 to about 44% by 2006. Consequently, imported energy use will increase from 0 to 7%.[233]

  Natural gas and liquefied natural gas will continue to supply more than 40% of the fuel for power production.[234] In 1998, Thailand was ranked among the world's top 10 countries that produce electricity from natural gas.[235] Natural gas reserves are limited and are insufficient for future power generation. Therefore Thailand will be increasingly depend on external sources of energy in the next century.

Increased use of renewable resources

Thailand's search for alternative and renewable energy resources is a relatively new initiative. Opportunities exist for technology and projects that make use of biomass, biogas, solar, wind, and battery energy. With support from the Energy Efficiency Fund, projects are being supported primarily for demonstration purposes. Technologies such as biomass to energy, landfill gas to energy, wastewater gas to energy, and animal waste gas to energy are currently being developed.

- *Biomass electric*: EGAT is interested in purchasing projects from small power producers (SPPs) that use non-conventional fuels such as biomass, paddy husk, or firewood grown specifically for fuel. Rice husk to energy projects shave not been developed on a large scale in Thailand because of dispersed rice processing operations. Natural gas, oil, or coal can be used to supplement the biomass fuels. The most attractive industries for developing biomass projects are sugar, rice, saw mills, palm oil, and pulp and paper.

Energy end-use

Industry

[233] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*
[234] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*
[235] International Energy Agency. 1998. *Key World Energy Statistics*.

- *More efficient industrial equipment*: EGAT is promoting the concept of thermal energy storage (TES), and is demonstrating the technology at its headquarters. In the private sector, institutions and industry are assessing the possibility of retrofitting their buildings with TES systems. TES is a technology that aims to decrease the peak demand of electricity and reduce the number of power plants that will have to be built. The Asian Institute of Technology's Chilled Water System is a demonstration project that utilises TES. TES systems accumulate cooling energy by using power generated during the off-peak hours (9:30 PM to 8:00 AM), when there is no demand surcharge to make ice or chilled water. The system then discharges the stored cooling energy the following day for air-conditioning or process cooling. This will be the first chilled water storage system in Thailand. If this demonstration is successful, there will be significant opportunities with industrial and institutional end-users.

  EGAT is also planning on implementing a program of high-efficiency motors that are 2% to 10% more efficient than standard motors. The potential savings are highly significant since over a third of Thailand's electricity is used in factory motors. The potential savings are highly significant since over a third of Thailand's electricity is used in factory motors. Preliminary estimates of the efficient motors program indicate a saving of 70 MW and 375 GWh over four years. The International Institute for Energy Conservation estimates the market for energy efficient motors at US$39 million in 1998. [236]

<u>Transportation</u>

- *More efficient vehicles*: Bangkok and Thailand's other major cities suffer from severe ground level air pollution due to the large and rapidly growing number of vehicles and heavy traffic conditions. Bangkok is noted for its traffic jams that further contribute to the growing air quality problem. In 1995, transport accounted for over 38.5% of Thailand's total energy consumption, while total gasoline consumption has been increasing annually at approximately 12%, and diesel consumption by nearly 15%.[237] The primary transport fuels used in Thailand are gasoline, diesel, and to a lesser extent liquefied petroleum gas (LPG).

  The major sources of air pollutants in the transportation sector are emissions from two-stroke motorcycles, three-wheel taxies, heavy-duty diesel trucks and buses, and light-duty diesel trucks. The Royal Thai Government (RTG) has adopted an action plan to address the air pollution caused by highway vehicle emissions. Key elements include expanded monitoring of pollution and noise levels, establishment of emissions standards for new vehicles, supplying unleaded gasoline and low-sulphur diesel fuel, stipulating reformulation of fuels to be cleaner burning, encouraging alternative fuels, and requiring smokeless oils for two-stroke vehicles. A number of

[236] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

[237] The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.

measures have already been undertaken including the establishment of monitoring sites at some of Bangkok's major intersections. In September 1993, a requirement was introduced for catalytic converters on new cars.

Compressed Natural Gas (CNG) was first used in Thailand in 1983. Thus far, the Bangkok Metropolitan Transit Authority has converted 36 diesel-powered buses to use CNG. However, due to poor design and evaluation, the bus conversions did not work as successfully as they could have. A refueling station was built near EGAT's South Bangkok's Power Station.[238]

Thailand is one of the largest manufacturers and consumers of pick-up trucks and motorcycles in the world. As a result, the largest potential for technology that supports alternative fuels lies in the segment of the motor vehicle industry. The most promising market opportunities for alternative fuels and related vehicle and infrastructure technologies in Thailand are in CNG and electric power for the near term. At present, ethanol and LPG doe not appear to be feasible for the near-term.[239]

Bangkok appears to be well suited for electric vehicles (EVs). Gradual replacement of internal combustion engine vehicles with EVs could have a significant impact on reducing oil use, air pollution, and GHG emissions, depending on the technologies used. In 1992, the Minsitry of Science Technology and Environment (MOSTE) approached the US Agency for International Development for air pollution control assistance in Bangkok. The Thai Board of Investment granted privileges to Phoalasith Tuk-Tuk Motor Company to manufacture electric three-wheelers using a US-made battery powered engine. For participating in this pilot project, the Thai company was given a 90% tariff cut on all imported components for the first five years electric-powered tuk-tuk production. Pholasith invested US$40 000 to acquire the technology, and more than US$4 million to build the factory. To facilitate battery recharging of tuk-tuks, the PTT said that it would be will to install battery rechargers at its 400 filling stations. Conventional tuk-tuks sell for approximately US$2 450, compared to electric ones that cost three times as much.[240]

Hybrid electric vehicles may have the greatest potential to reduce urban air pollution and CO_2 emissions in Thailand. A hybrid EV can generate its own electricity on-board the vehicle using a small and efficient internal combustion engine. Either gasoline or an alternative fuel such as LPG or CNG may fuel the engine. This electricity is then stored in batteries that provide power to the electric motor.[241]

Gasoline vapour recovery technology is another area of opportunity for Canadian suppliers of climate-friendly technologies. Thai government agencies and private

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[238] The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.
[239] The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.
[240] Ibid.
[241]The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.

sector representatives have drafted regulations for gasoline vapour recovery. Vapour recovery is an effective way to prevent dangerous gases from escaping into the atmosphere, while at the same time conserving fuel. Regulations will require that gasoline terminals, transport trucks, and gas stations to install gasoline vapour recovery devices. These devices will be phased in over a five-year period from 1998 to 2003. The estimated market potential for vapour recovery in Thailand is US$300 million over 10 years.[242]

Thailand is the second largest market for light-duty vehicles in the world. This represents a prime area of opportunity for Canadian technology suppliers.

Buildings (residential and commercial)

- *More efficient appliances and equipment*: The promotion of energy efficient appliances is one of EGAT's several DSM programs. EGAT's efforts have largely focused on encouraging appliance manufacturers to produce more energy efficient products, and urging the public to use them. The DSM office offers various incentives to manufacturers that produce more efficient domestic appliances. The first activity the Demand Side Management (DSM) program promoted was an energy efficient fluorescent tube program. This type of program was instituted because of its potentially significant impact on energy savings. In 1993, EGAT signed a voluntary agreement with five major lighting manufacturers in Thailand to produce 36 W and 18 W fluorescent tubes in place of the 40 W and 20 W fluorescent tubes. By mid-1995, all manufactures had made the transition. At the end of 1997, a saving of 104 MW of peak power demand was realised.

  EGAT's Refrigerator-labeling program stands among the Authorities many successful DSM initiatives. Early results from the refrigerator-labeling program show that the initiative can save an expected 27 peak MW over a five-year period. This program began in 1994 with the voluntary cooperation from the five major refrigerator manufacturers. This popular program sparked stiff competition among manufacturers to produce highly efficient refrigerators. Additionally, an energy efficient air-conditioner program that closely mimics the successful refrigerator program is also slated for implementation in the near future. The air-conditioner program is targeted to save 23 MW over a five-year period, with a US$20 million fund to help the public finance the purchase of energy efficient air-conditioners, through interest-free loans.

Non-energy related sources

- *Landfill methane capture and use*: Thailand is generating waste at a rate of 35 000 tonnes daily and solid waste generation is growing at a rate of 4-5% a year nationwide. As a result, the Energy and Environmental Engineering Centre (EEEC) of Kasetsart University and the 79 Group developed a pilot electricity generating plant to be supplied by landfill gas from Thailand's largest landfill (the

[242] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

Kampaengsaen landfill). Since landfill gas-to-electricity technology is not currently being applied in Thailand, the participants are using this as a demonstration project. The system works to utilise an unused source of energy, improve environmental conditions in Kampaengsaen, and reduce methane emissions originating from the landfill. It is hoped that this project will pave the way for the development of additional facilities at other landfills throughout Thailand. The project has attracted funding from the Thai Royal Family through the Chai Pattana Foundation, Thailand's National Energy Policy Office (NEPO), and the Kenan Institute Asia through the US-Thailand Development Partnership Program. After a successful demonstration phase, it is expected that the private sector will invest in a full-scale facility at the Kampaengsaen landfill. In its demonstration phase the facility is generating 650KW of energy. In its full-scale stage, the facility will be able to generate approximately 2-5 MW of energy.[243]

7.13.2 Factors Influencing Technology Need

The main environmental problems that Thailand currently faces include poor air quality due to vehicular emissions and traffic congestion in its major cities, water and wastewater treatment, and solid waste management. At present GHG mitigation is not an urgent government priority. However, in Thailand's on-going efforts to control air quality and pollution from energy intense sectors, a substantive amount of GHG emissions are being indirectly reduced.

Thailand's rapid industrial development (in some years, more than 20% growth per year), its high rate of urbanisation, and the explosive growth in the automobile fleet have resulted in extreme air quality problems in Thai cities. These problems stem from industrial processes and emissions from power plant stacks, automobile emissions, and general ambient air deterioration from construction and other industrial activities in Bangkok and Chiang Mai. The World Health Organization (WHO) warns that Bangkok's air pollution levels exceed WHO safety standards by up to 600% in some areas. Technologies that can both ameliorate these local urban pollution problems as well as reduce GHG emissions are in high demand.

Thailand’s population was 61.2 million in 1998.[244] The average annual population change for the period between 2005-2010 is expected to be 0.6%.[245] Although the population growth rate is relatively slow, the size for the middle class in Thailand is growing and is expected to grow significantly over the next several decades.[246] Thailand boasted the fastest growing economy in the world over the period 1986-1996, with nearly 10% average annual growth in GDP. The combination of rapid economic growth and slowing population growth raised per capita income to more than US$3,000 per person

[243] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*
[244] 1999. *Fact Sheet-Kingdom of Thailand*. April. (www.infoexport.gc.ca) May 12.
[245] The World Resources Institute. 1998. *1998-99 World Resources: A Guide to the Global Environment.* Oxford University Press. New York.
[246] The International Institute for Energy Conservation, Sustainable Transport Program. 1997. *Alternative Transport Fuel Investment Opportunities in Bangkok, Thailand*. September 1st.

before devaluation of the baht resulted in increased consumption of goods and services and subsequently increased energy consumption.

However a sudden financial crisis in 1997 caused GDP to slightly decrease by 0.4%. This crisis was accompanied by a devaluation in the Thai baht from about 25 baht to one US dollar to 50 baht to one US dollar. During the same time period, Thailand's population growth fell from over 2% to 1.3%. By 1998, GDP had fallen to $US 116.2 billion and the GDP growth rate was -8%, falling from -4% in 1997. In addition, inflation was 8.1% in 1998.[247]

Thailand's economic problems were mainly a result of overspending and over-borrowing in the private sector rather than profligate government spending.[248] Thailand's economic plunge has caused a sharp decline in the demand for electricity and petroleum products. EGAT has announced cuts in many of its own investment programs.[249] However, the new government of Prime Minister Chuan Leekpai has made some progress in restoring economic confidence.[250]

According to EGAT's latest forecasts, despite Thailand's poor economic state, electricity demand will grow at a rate of 6% to 7% per year during 1999-2001 as opposed to 10% in previous years.[251]

EGAT is currently in the process of privatising its operations and is greatly expanding the scope of private participation in the power sector. In 1991, Thailand became the first Asian nation to formerly incorporate a comprehensive Demand Side Management (DSM) Program. EGAT, in cooperation with the Metropolitan Electricity Authority (MEA) and the Provincial Electricity Authority (PEA), is responsible for implementing this US$ 189 million plan.

Initial estimates of the DSM program showed a cumulative energy savings of 1 427 GWh, a peak capacity reduction of 238 MW, and GHG emissions reductions of 1.16 million tonnes of CO_2 per year by the end of 1997. According to The World Bank, Thailand's DSM project is the best in Asia, and ranks in the top 8 of the 110 worldwide programs according the Global Environmental Fund.[252]

Over the next five years (1997-2001), the Thai energy sector will be restructured by privatising the country's electric utilities, with up to 50% of the shares being offered to domestic and foreign investors. To ensure a reliable and steady power supply, Thailand is proceeding cautiously in its efforts to privatise the electric utilities.

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[247] 1999. *Fact Sheet-Kingdom of Thailand*. April. (www.infoexport.gc.ca) May 12.

[248] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

[249] US Department of Commerce. 1999. *Thailand Energy Sector Update*. May 5th.

[250] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

[251] US Department of Commerce. 1999. *Energy Industry in Thailand*. February 26th.

[252] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

For the Eighth National Plan period (1997-2002), investment expenditures in Thailand's energy sector were projected at US$18.4 billion. Through 2011, plans were in place to increase generation capacity by 30,929 MW to a total of 43,918 MW. Of this, 8,100 MW was to come from independent power producers and about 3,000 MW from small power producers.[253]

Many of EGAT's energy development plans to secure the future energy demands of Thailand are being reassessed as a result of the economic recession the country is currently faced with. Although EGAT had signed power purchase agreements with seven IPP consortia for a total of 5.8 GW of electricity for a period of 25 years commencing in 1999, new independent power producer (IPP) bid solicitations have been suspended. Only two independent power producers are building their plants and are expected to supply electric power to the national grid by late 1999 and the year 2000 respectively.[254]

7.13.3 Factors Influencing Market Access

The Energy Conservation Promotion Act is one of over 50 pieces of legislation that addresses environmental matters in Thailand. This act was passed to increase the energy efficiency of end-users and to positively benefit Thai industry and the environment. Under this act, the owners of controlled buildings and factories are required to nominate an energy manager, conduct energy audits, and implement energy saving measures based on energy audit findings. The act will thus serve as a market driver for energy saving technologies.

The Thai Government is also setting efficiency standards for appliances, equipment, and materials. Another important component of the act is the promotion of renewable energies. The Energy Conservation Fund was established to assist in implementing renewable energy projects. The National Energy Policy Office (NEPO) is responsible for overseeing this act and the Ministry of Science Technology and Environment's (MOSTE) Department of Energy Development and Promotion is the main implementing agency.[255]

The US Department of Commerce (DOC) estimated Thailand's pollution control equipment and environmental services market at US$1 billion in 1995. The Kenan Institute of Private Enterprise estimated that the total Thai Market was growing at 20-25% per year and would reach US$1.5 billion by the year 2000. However, due to the country's 1997 economic crisis, the market is not expected to grow between 1998 and 1999.

Thailand's energy efficiency market is being fueled by two major policy developments: the Demand Side Management Program (1991), and the Energy Conservation Promotion

[253] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*
[254] US Department of Commerce. 1999. *Thailand Energy Sector Update*. May 5th.
[255] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan.*

Act (1992). The total market for energy efficiency products was estimated at almost US$ 600 million in 1995, with imports accounting for US$ 310 million. Energy efficient products can be divided into three sectors, industrial, commercial, and residential with each accounting for 60%, 30%, and 10% of the total market respectively.

The overall air pollution control market is estimated, by the Asia Environmental Business Journal, at about US$ 90 million per year with growth at about 15-20% per year. Even faster growth is expected for gaseous emission control equipment.

Large-scale opportunities also exist for energy conservation products, equipment, and technology. The market size for 1998 was estimated at US$719 million by the International Institute for Energy Conservation.

Thailand has over 20,000 private sector factories that are classified as polluting industries. This presents tremendous opportunity in working with the private the sector. The Thai Board of Investment estimates that private factories spend approximately 4% of new invested capital on environmental control equipment and facilities. The key variable in determining the growth rate depends on Thailand's political will to enforce regulations that encourage the private sector to make investments needed to meet existing standards. Commitment to environmental preservation may decline if the economy continues to slow and companies insist they cannot afford the required improvements. However, due to the economic situation, the new government is likely to make economic growth and support for industry a higher priority than environmental improvement.

The most important drivers of the environmental technology market are, therefore:

- Effective enforcement of existing environmental regulations
- Government spending on environmental infrastructure
- Availability of funding support to private sector environmental projects
- Environmental standards for suppliers that are set by manufacturers
- Environmental standards for imports into foreign markets
- Perceived potential for "green marketing"
- Costs of industrial inputs such as water and energy
- Pace of adopting environmental management standards such as ISO 14000
- Privatisation of infrastructure projects

Thailand is a member of the Asia Pacific Economic Cooperation (APEC) and a founding member of the World Trade Organisation (WTO). Thailand is also a member of the Association of Southeast Asian Nations (ASEAN).

Import tariffs for energy efficient products are set at 30% to 35%. However import duties can be negotiated to as low as 5%. However, it is often challenging to prove that the products are energy efficient unless there is strong support from a Thai government agency.[256]

[256] US Department of Commerce. 1998. *Thailand Environmental Technologies Export Market Plan*.

Total bilateral trade between Canada and Thailand in 1997 was C$1.6 billion, of which C$1.2 were Thai exports to Canada, while C$466 million were Canadian exports. In 1998, Canadian exports to Thailand were down by 38% due to the depreciation of the baht. In June 1998, Canada agreed to extend a US$500 million line of credit to Thailand as part of an IMF assistance package to Thailand in response to its financial crisis.[257]

Total imports to Thailand in 1997 were US$ 55.1 billion, with the majority of imports from Japan, US, Singapore, Malaysia, and Germany. In the energy sector, foreign competition with Germany, UK, Sweden, and Japan is very strong. The US and Japan are the major suppliers of electric power generation equipment to Thailand. Japanese manufacturers control approximately one-third of the market share for energy efficient technologies. The US controls about 25%, Germany 15%, and Taiwan, Singapore, Hong Kong, Australia, and the UK hold smaller shares. The Europeans and Japanese have had manufacturing bases in Thailand for several years and are now increasing their product offering to include energy efficient products. The Thai market is therefore likely to offer Canadian suppliers with good opportunities but strong competition.

[257] DFAIT. 1998. *Canada-Thailand Relations.*

Appendix 8

Intersection Of Domestic And International Needs

Fossil Fuel

Domestic Need	Technological Solution	International Opportunity
Improve energy and carbon Efficiency More efficient pipelines Natural gas to liquid fuels Reduce fugitive gas emissions	Improved seismic information Improved drill bit design Heat recovery systems Electrification of well sites Downhole oil water separators Downhole pressure and temperature guages Increased efficiency of fuel gas use High efficiency burners in oil and natural gas production Increased looping High efficiency low emission natural gas turbines Exhaust gas treatment Drag reducing agent or viscosity reducers for pipelines Centrifical pump efficiency in pipelines Specialized pig valve Sonic flow meters in pipelines Ethanol fuel Improved aircraft fuels Methanol fuel and mtbe additives Improved leak detection	Most promise in Russia, Mexico, Ukraine, China, India, Indonesia CBM interest in China, India, Ukraine Reduction of fugitive gases – US Australia, Russia

Energy Production

Domestic Need	Technological Solution	International Opportunity
More efficient conversion of fossil fuels Substitute natural gas for coal Hydrogen Increased use of integrated systems Upgrade of existing plants Increased use of alternative fuels	Pressurized fluidized bed combustion coal plants; atmospheric circulating fluidized beds; coal refineries; improved pulverized coal-fired plants; coal water fuel (slurry); orimulsion; conversion of coal to gas, burners systems capable of handling rich gas; production of hydrogen from electricity; hydrogen reduction with non-CO2 electricity; extend life of Candu reactors; enhanced nuclear fuel waste-handling system; refine Candu product to extend life; cost-efficient and improved utilization of uranium sources through improved nuclear reactor technology; cogeneration; magnetohydrodynamics; repowering; efficient electrical transformers; more efficient energy storage; enzyme hydrolysis or fermentation; biomass fuels; solar thermal; solar photovoltaics; geothermal energy; wind energy, tidal energy; hydroelectric power	Improve efficiency of existing power plants - India, Brazil, Mexico High carbon to low carbon fuels – US, Australia Cogen-OECD, underspread – US Poland, Mexico Hydropower in China, India, Philippines, Thailand Nuclear - Czech Republic

Energy End-Use

Domestic Need	Technological Solution	International Opportunity
		Emission, air pollution and congestion - Mexico, China, India, Brazil

-Transportation

Domestic Need	Technological Solution	International Opportunity
More efficient automobiles and light-duty vehicles Next generation drive systems for automobiles and light-duty vehicles More efficient heavy duty trucks & buses Next generation drive systems for heavy duty trucks & buses More efficient aircraft Next generation drive systems for aircraft, improved infrastructure More efficient rail vehicles More energy efficient transportation processes Next generation drive systems for rails Next generation drive systems for marine	Aerodynamic improvements; advanced tires; advanced materials; advanced electronic controls; advanced automatic transmissions; light; safe and multi-form natural gas tanks; waste heat recovery technology, gasoline direct injection engine; advanced diesel engines; improvements to spark ignition engines; stirling engines; gas turbines engines; natural gas vehicles; electric vehicles; hybrid-electric vehicles; hydrogen storage vessels; lower cost natural gas refueling stations; insulated engines; electric buses; more efficient fleet management; reduced fuel consumption; composite materials for aircraft construction; reduced drag and weight; increased size; efficient jet engines; aircraft powerplants efficiency; advanced air traffic management systems; improved rolling resistance; simplifying loading and unloading processes; decreasing time and cost of mode to mode transfers; avoiding terminal congestion; improvements in diesel engines; gas turbines; diesel electric systems	Fuel efficiency, improve mass transit Broad applications internationally

-Forestry

Domestic Need	Technological Solution	International Opportunity
Improved energy efficiency in allied products and wood products	High intensity refining in pulp production; technologies to improve drying efficiency and heat recovery Systems approach to energy efficiency Medium consistency slurry transport On-machine sensors Hot pressing System approach to energy efficiency	

-Minerals and Metals

Domestic Need	Technological Solution	International Opportunity
Improved energy efficiency in primary iron and steel, aluminum, cement and concrete, lime	Process optimization, improved operating practices; natural gas injection to blast furnace; bof process gas recovery; smelting reduction processes; new direct reduced iron; iron production by electrolysis; cost efficient electrolysis using non CO2 electricity; hydrogen reductions by steam reforming of natural gas; thin slab casting; inert anodes; improved pre-baked anodes; improved feeder systems; conversion to natural gas; computer controls in smelters; computerized process optimization; optimization of raw material particle size feed delivery; installation of preheating systems in cement kilns; installation of precalciners; fuel burner replacement; extra stages at preheater cyclones; grate coolers with energy recovery; energy efficient natural gas; delivery of molten aluminum; design, geometry and insulation of heating, holding furnaces; utilization of waste heat and charge pre-heating; streamlining operations; utilization of recycled water; moisture curable cross-linking; optimization of heating, holding furnaces;; computerized process controls; optimization of limestone feed delivery; installation of preheating systems; refractor upgrade; switch to natural gas; high efficiency kilns	

-Other Manufacturing

Domestic Need	Technological Solution	International Opportunity
Prevent magnesium oxidation Material substitution in cement and concrete Improved energy efficiency of transportation equipment manufacturing Textiles; food and beverage General industry	Alternative magnesium cover gas; thixo-molding for die casters; supplementary cementing materials in concrete; closed-loop drying systems based on dehumidification; hydroforming; solar technology; computer controlled lighting and heating systems; insulation blankets for injection moulding machines; heat recovery system; high efficiency kilns; less intensive membrane separations as a replacement for thermal technology; two stage heat recovery process for conventional steam plants; improved sterlizers; conversion of CO2 to carbonates or bicarbonates; advanced control systems; smart industrial provess materials; integrated chiller system for managing peak load; efficient electric industrial motors; metal parts cleaning-bake and blast	Industrial process efficiency Industrial boilers Variable speed motors

-Residential Buildings

Domestic Need	Technological Solution	International Opportunity
Reduce energy intensity in construction Improve overall operational efficiency	Reducing the energy intensity of building materials; use of advanced framing techniques; advanced building insulation systems; heat pump technology; energy efficient window glazing systems; heat recovery ventilators; solar technology; passive cooling; building energy management systems	Demand side management lighting, air conditioning, appliances. New construction improvements- China, India, Mexico, Brazil

-Commercial Buildings

Domestic Need	Technological Solution	International Opportunity
Improve energy efficiency	Lighting, office equipment, HVAC, more efficient boilers	Demand side management District energy systems - Poland, Russia

Carbon Dioxide Management

Domestic Need	Technological Solution	International Opportunity
Improve carbon modeling Improve carbon sequestration	Simulation modeling of carbon sinks, a carbon budget model of the Canadian forest sector, geological storage technologies, techniques for reducing deforestation , increasing afforestation and reforestation	

Non-Energy Related Sources

Domestic Need	Technological Solution	International Opportunity
Reduce GHGs from municipal solid waste Improved soil analysis Reduced emissions from animal sources	Landfill gas recovery; waste diversion technologies, technologies reducing methane emissions from sewage treatment plants, waste management modeling software, technologies to reduce processing and packaging waste in agri-food; waste treatment technologies in agri-food; technologies to reduce by-product production in agri-food; rapid analytical methods to determine presence of undesirable substances in agri-food by-products; tools for quantifying, predicting and verifying soil seed changes; more efficient reactors; optimize use of chlorophyll to convert CO2 to O2; urea production; rangeland management to increase carbon and nitrogen sequestration; crop land management for carbon sequestration and nox reduction; livestock feed additives; fertilizers and practices minimizing nox production; animal waste management technology	Landfill gas capture and use Reduce methane emission from livestock and dairy systems

Appendix 9

Methodology for a Study on Domestic and International Measures for GHG Technology Innovation

The project team's approach to the tasks has been to use in-house reports and studies, recent literature on the national innovation system, and consultations with the measures working group as well as other Canadian and international experts to develop the inventory and analysis of measures.

There are several methodological challenges inherent in identifying and evaluating measures. As articulated in measuring the impact of publicly funded r&d by belinko and hollington, (1994), there are a number of practical difficulties in identifying, measuring, and analysing the benefits of measures designed to promote technological innovation. For example, there is often a long time lag between implementation of the measures and realisation of benefits. In addition, such measures are often multi-targeted, making objective evaluation of their performance extremely difficult. In addition, the diversity of measures, which range from standard setting to basic scientific research make meaningful comparisons often difficult. As a result of such challenges, the project team has often relied on its best professional judgement and experience from involvement over the past decade in various studies on technological innovation.

There has been a recent resurgence of interest from several academic disciplines in the concept of technological change, in what are increasingly knowledge-based economies. This stems from the widespread recognition of its significant impact on economic growth and because of the understanding that technology can exacerbate or remedy our environmental problems. In short, innovation has become the single most important factor in enhancing the wealth and international competitiveness of nations. Attempts to foster innovation and technological development are no longer confined to subsidising basic research. Innovation *policy* needs to go further by assessing and improving the socio-economic environment in which innovation flourishes. However, despite much research effort in this field over the past several years, both our theoretical knowledge and the available empirical evidence are incomplete. What is clear is that there are many determinants and outcomes of innovation and technological development. All factors point to the complexity and systemic nature of innovation. Attempts to design measures for promoting technological innovation must therefore take a holistic and multi-disciplinary perspective.

Three broad theoretical approaches exist for understanding the process of technological development and the role of government measures. These are the technological determinism, economic determinism, and social constructivism perspectives. Technological determinism is based on the principle that technological developments have their own dynamics and constraints that determine the direction of change even when stimulated by external measures. Economic determinism considers the market and economic competition to be the main driving forces behind innovation. Essentially this approach treats technology as a black box. Unlike the first two approaches, social constructivism attempts to move away from such unidirectional models. It maintains that different stakeholders are able to exert an influence on technological development and that technological development must therefore be seen as the product of a dynamic interaction, rather than one driving force from inside or outside a firm. In this study, no one approach is used, but considerable sympathy has been given to the social constructivism point of view. It must be said however, that the approach does take a hybrid approach and attempts to analyse measures through a variety of lenses.

Appendix 10

Examples Of Existing Domestic Measures

1. CANMET Transportation Energy Technologies Program
2. CANMET Combustion Technologies Program
3. CANMET Energy Diversification Research Laboratory (CEDRL)
4. CANMET Advanced Technologies for Process Optimization
5. CANMET Community Energy Technologies
6. CNAMET Heat Management R&D Program
7. CANMET Building Energy Technology Advancement Program
8. CANMET Energy Technology Centre (CETC)
9. Alberta Hydrogen Research Program
10. Small Power Research & Development Program
11. Energy Technologies Development Assistance Program (EATDAP)
12. Energy Productivity Program
13. Photovoltaic (PV) for the North Demonstration Project
14. Western Technology Seed Investment Fund
15. Renewable Energy Technologies Program (RETP)
16. Technology Partnerships Canada (TCP)
17. Industrial Research and Development Institute (RDI)
18. Pilot Emission Reduction Trading Project (PERT)
19. Canadian Renewable and Conservation Expenses (CRCE)
20. Industry Energy Research and Development (IERD)
21. Development and Technical Assistance Program (DATECH)
22. Project Bessemer Inc.
23. Pulp and Paper Research Institute of Canada (Paprican)
24. Forintek Canada Corporation’s ATHENA Project
25. Canadian Mining Industry Research Organization (CAMIRO)
26. Canadian Centre for Pollution Prevention (C2P2)
27. Global Environmental Facility Trust Fund
28. National Advisory committee on Air Technologies (NACAT)
29. Environmental Technology Verification (ETV) Program
30. Working Ventures Canadian Fund
31. Federal Buildings Initiative (FBI)
32. Technology Development and Demonstration Program (TDDP)
33. Pan-Western Environmental Technologies Loan Program
34. Canada’s SchoolNet
35. International Environmental Management Initiative (IEMI)
36. Development and Demonstration of Resource and Energy Conservation Technologies
37. Technology Road Maps
38. Environmental Technology Transfers
39. Asia Pacific Economic Participation (APEC)
40. Bilateral projects under the Montreal Protocol
41. Canadian Environmental Industry Trade Missions

42. Industrial Research Assistance Program (IRAP)
43. Small Business Loans Act
44. Business Development Bank of Canada
45. Community Futures Development Corporation (CFDCs)
46. Canada Community Investment Plan
47. Accelerated Capital Cost Allowance (ACCA)
48. Business Development Program
49. Financing Program for Innovative Businesses in Quebec
50. Canadian Environmental Solutions CD ROM
51. Industry Canada’s Strategies
52. Environment Industry Virtual Office (VO)
53. Canadian Business Environmental Performance Office (BEPO)
54. R&D Tax Incentives
55. The R&D Challenge Fund
56. Federal Industrial Boiler Program (FIBP)
57. Industrial Energy Innovators Initiative
58. Energy from the Forest (ENFOR)
59. Industrial Energy Efficiency Initiative (IEEI)
60. Auto$mart
61. Nuclear Energy Technology Development and Demonstration
62. Energuide
63. Canada’s Voluntary Challenge and Registry (VCR) Program
64. Government of Canada’s Joint Implementation Initiative (CJII)
65. GHG Emissions Reduction Trading Program (GERT)
66. National Biomass Ethanol Program
67. Alternative Transportation Fuels Research & Development
68. Advanced House Program
69. Program of Energy Research and Development (PERD)
70. Canada-Alberta Environmentally Sustainable Agriculture Agreement
71. Agricultural Energy Use Database
72. Resource Conservation Guides
73. Renewable and Alternative Energy Information Transfer
74. Hydrogen Study
75. Igloolik Wind Demonstration Project
76. ICLEI Energy Services, International council for Local Environmental Initiatives
77. Canada’s Clean Combustion Network
78. Technology Innovation Centre (TIC), Dartmouth
79. Greater Hamilton Technology Enterprise Centre (GHTEC)
80. Entrepreneurship Program at NRC
81. Hi Tech Entrepreneurship Association (HITE)
82. National Business Incubator Association (BIA) BatorLink Program
83. Entrepreneurship Centre, Ottawa
84. Energy Efficiency Regulations
85. Clean Vehicles and Fuels Program (B.C.)
86. Quebec’s Energy Productivity Program
87. Energy Performance Contracting (Nova Scotia)

88. Auto Propane Market (Newfoundland)
89. Federation of Canadian Municipalities International Trade Service
90. Motor Vehicle Emissions Reduction Regulation (B.C.)
91. APEC Harmonization of Equipment Standards
92. Forest Research Partnerships Program
93. Natural Gas Technologies Centre (NGTC)
94. Canadian Gas Research Institute (CGRI)
95. Industrial Research Chairs
96. Chairs in the Management of Technological Change
97. Canadian Microelectronics Corporation (CMC)
98. Community-University Research Alliances
99. Canada Foundation for Innovation
100. Regional Partnerships Program
101. Networks of Centre of Excellence Program (NCE)
102. BCIT Venture Program
103. BCIT Entrepreneurial Skills Training (BEST) Program
104. Ottawa Life Sciences Technology Park
105. University of Victoria Innovation and Development Centre - Incubation Facility
106. Alternative Transportation Fuels Market Development Initiative
107. Commercial Building Incentive Program (CBIP)
108. Motor Vehicle Fuel Efficiency Program
109. FleetSmart
110. Energy Innovators Plus
111. Energuide for Houses
112. Renewable Energy Deployment Initiative (REDI)
113. Home Energy Retrofit Initiative
114. R-2000
115. Canada Institute for Scientific and Technical Information (CISTI)
116. Canadian Innovation Centre
117. Canadian Intellectual Property Office (CIPO)
118. Great Lakes 2000 Cleanup Fund
119. New Environmental Technologies Evaluation Program (NETE)
120. Ontario Business-Research Institute Tax Credit (OBRITC)
121. Ontario Innovation Tax Credit
122. Scientific Research and Experimental Development (SR&ED) - Tax Incentive Program
123. ViaTech
124. Business Improvement Loan (BIL)
125. Canada’s Technology Triangle Accelerator Network (CTTAN)
126. Canadian venture Capital Association (CVCA)
127. EnviroCapital
128. Environmental R&D Capital Corporation (ER&C)
129. Canadian Standards Association (CSA)
130. Green Seal
131. Scientific Certifications Systems (SCS) (previously called Green Cross)
132. Build Green Program

133. Government of Canada Supplier Development Program
134. Government Incorporating Procurement Policies to Eliminate Refuse (GIPPER)
135. Green Procurement Institute
136. Energy Efficiency Act and the Energy Efficiency Regulations
137. National Energy Use Database (NEUD)
138. PRECARN Associates Inc.
139. Laboratoire des Technologies Electrochimiques et des Electrotechnologies (LTEE)
140. Information Technology Association of Canada (ITAC)
141. Canadian Environmental Technology Advancement Centres (CETAC)
142. Industrial Technology Assistance Program (ITAP)
143. Technology Inflow Program (TIP)
144. ORTECH Corporation
145. Ontario Waste Materials Exchange (OWME)
146. Services and Information on Ecotechnologies Corporation (SIE)
147. Saskatchewan Opportunities Corporation (SOCO)
148. Mine Environment Neutral Drainage (MEND) Program
149. The Environmental Choice Program (ECP)
150. Aboriginal Business Canada
151. International Trade Personnel Program
152. User Education and Training Initiative (UETI)
153. Natural Sciences and Engineering Council of Canada (NSERC)
154. DND/NSERC Research Partnership Program
155. Social Sciences and Humanities Research Council of Canada (SSHRC)
156. Canada in the World Grants
157. Model National Energy Codes for Buildings and Houses
158. Youth Employment Strategy
159. Canadian Council for Human Resources in the Environment Industry (CCHREI)
160. Aboriginal Environment Training program
161. Environmental Youth Corp. (EYC)
162. Canadian Forest Service (CFS) Research Centres
163. Medical Research Council (MRC)
164. Office of Energy Efficiency (OEE)
165. Millenium Scholarship Fund
166. Air & Waste Management Association

Appendix 11

Examples Of International Measures

1. Eco-Industrial Networking Software (US)
2. SO_2 Trading - The Acid Rain Program (US)
3. California's Regional Clean Air Incentives Market (RECLAIM) (US)
4. Arizona Technology Incubator (ATI) (US)
5. EcoDesign Program (Australia)
6. Centre for Environmental Assessment of Product and Material Systems (CPM) (Sweden)
7. Design for Environment Program (US)
8. National Energy Policy Act (US)
9. Electronic Conference on Alternatively Fueled Vehicles (US)
10. Carter National Energy Plan (US)
11. The Danish Wind Energy Program (Denmark)
12. Carbon Dioxide Tax (Sweden)
13. Accelerated Depreciation of Environmental Investments Measure (Netherlands)
14. The EUREKA Initiative (Europe)
15. 1993 White Paper on Science, Engineering and Technology (UK)
16. Centres de ressources technologiques (France)
17. CRADA: Co-operative Research and Development Agreements
18. Advanced Technology program (ATP) (US)
19. New Sunshine Program (Japan)
20. Voluntary Aluminum Industrial Partnership Program (US)
21. Clean Air Act Section 112 Standards(US)
22. Coalbed Methane Outreach Program (US)
23. Energy Star (US)
24. MACT (Maximum Achievable Control Technology) Rules (US)
25. Landfill Methane Outreach Program (US)
26. Natural Gas Star (US)
27. Ruminant Livestock Methane Program (US)
28. Utilities Program (US)
29. Transportation Partners (US)
30. Common Sense Initiative (US)
31. Common Sense Petroleum Refining Subcommittee (US)
32. Project XL for Facilities (Excellence in Leadership) (US)
33. Centre for Environmental Industry and Technology (US)
34. President Clinton's Executive Order on Government Procurement of Energy Efficient Computers (US)
35. Super-Efficient Refrigerator Program (Golden Carrot) (US)
36. National Industry Extension service (NIES) (Australia)
37. Technology Development Program (TDP) (Denmark)
38. The Technological Service Network (TSN) (Denmark)
39. Industrial Networks Program (NP) (Denmark)
40. The Danish Inventor's Centre (DIC) (Denmark)

41. European-Level Support for Technology Transfer: The Strategic Program for Innovation and Technology Transfer (SPRINT) - European Commission
42. Project for Manufacturing Technology (Germany)
43. The AGIT Local Network (Germany)
44. Regional Technology Centres (RTC) (Japan)
45. The Plaza Program (Japan)
46. The Innovation Centre for Inventions (ICI) (The Netherlands)
47. Business Development Using New Technology Scheme (Norway)
48. Aragon Regional Support Program (Spain)
49. Fatronik (Spain)
50. NUTEK AMT Action Programs (Sweden)
51. The Computer-Integrated Manufacturing (CIM) Program (Switzerland)
52. The Flexible Manufacturing Systems (FMS) Scheme (UK)
53. Small Firms Merit Award for Research Technology (SMART) (UK)
54. British Technology Group (BTG) (UK)
55. Independent Research and Technology Organizations (RTO) (UK)
56. Teaching Company Scheme (UK)