Climate Change and the Biosphere[1] Option: Moving to a Sustainable Future

1.1. Executive Summary / Abstract

The world's climate is changing and there is rising concern that the rate of change is both extraordinary and likely to have numerous adverse effects on our environment, economy and quality of life.

Human activities resulting in greenhouse gas[2] (GHG) emissions have been implicated as the primary factor 'forcing' climate change. This evidence led to a landmark international agreement in Kyoto (1997) committing the developed countries of the world to reductions in GHG emissions.

A 'Made-in-Canada' Approach

With only 0.5% of the world's population, Canada occupies 7% of the earth's land area, and accounts for ~4.5% of global biosphere CO_2 exchange.

Canada's 'biosphere option' for GHG management is both a national opportunity and a global responsibility.

In Canada, fossil fuel use over the past few centuries has released about 5200 Mt C into the atmosphere (Boden et al. 1999). An equivalent amount has probably been added as a result of deforestation and agricultural practice in this country[3].

If we can manage our biosphere better and return even a fraction of the lost biosphere C, we can make a significant contribution to reducing Canada's current annual GHG emission of 170 MT/yr. In the process, plants (including trees) will trap the sun's energy and build an energy-rich biomass that we can learn to utilize as an energy, chemical and material resource for the future. In doing so, we will relieve the escalating demand for fossil fuels.

The BIOCAP Network[4] will be a multidisciplinary group of university, government and industry researchers dedicated to exploring the scientific, technological and policy implications of this 'biosphere option'.

We will investigate opportunities for optimizing biomass production and GHG sequestration by:

- Understanding and quantifying biosphere, economic and social processes that affect GHG exchange *(Objective 1)*, and
- Identifying and verifying cost-effective management strategies for sustainable approaches to sequester C and manage GHGs in the Canadian biosphere *(Objective 2)*.

We will also develop opportunities to optimize biomass usefulness and reduce dependence on fossil fuels by:

- Selecting and engineering plants with enhanced biomass production and value *(Objective 3)*, and
- Developing bioprocess engineering tools that will use biomass to generate alternative fuel, chemical and material resources *(Objective 4)*.

Canada has always profited from being a resource-rich nation. The biosphere option represents an opportunity that cannot be overlooked. As it proves successful, Canadians will sustain their high quality of life not only through a healthier environment but through the growth of new industries and revitalized rural communities. We already have an infrastructure in place to begin exploiting increased biomass production and bioenergy use. There is every indication that other countries will capitalize on the biosphere option. Canada needs to understand the associated environmental, social, ethical and economic consequences, both for both developing sound domestic policy and for strengthening our national position at the international bargaining table.

[1] The Biosphere is the land, water and air of the world that can support life.

[2] Gases that absorb the sun's energy, including CO_2, N_2O and CH_4.

[3] Total human caused biosphere C losses in North America estimated at 27,000 Mt C (Defries & Field, 1999) with Canada accounting for about 20%.

[4] A proposed national university-based research network under the Networks of Centres of Excellence (NCE) Program.

1.2. Climate change – The science, risks and benefits

Observations of regional temperature anomalies and dramatic climate events frequently make the daily news. Global temperatures records of the last century show a warming trend with the greatest increase in mean temperature occurring since 1990 (Jones et al. 1999). A recent paleolimnological study reconstructed temperatures on a much larger time frame (Fig 1.1) and showed a warming of the northern hemisphere in the latter part of the twentieth century that was significantly greater than anything seen in the past 1000 years.

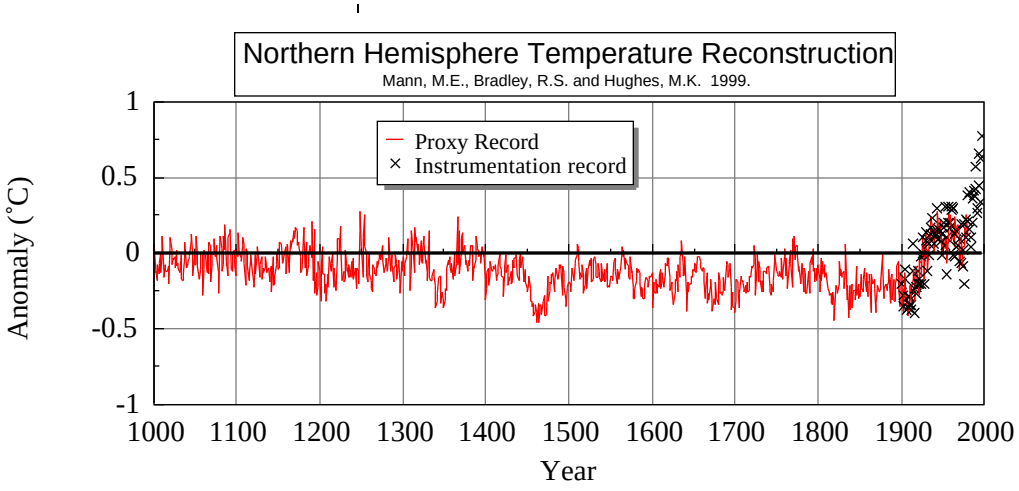

Fig. 1.1. *Paleolimnological proxy estimates (--) and instrumentation records (X) of northern hemisphere temperature anomalies over the past 1000 years. (Mann et al. 1999)*

Models of climate change suggest that impacts from global warming will be greatest at polar latitudes and over large land masses where there are no temperature mitigating effects from the oceans (***NOAA, 1999***). A world map of surface temperature anomalies for 1992-1998 (Fig 1.2) shows that the hottest spots have been in Canada and Russia. For example, Environment Canada records[5] for the spring of 1999 show an especially large temperature increase (5°C) from the norm in central Canada (based on an average from 1961-1990). All indications are that Canada will be more affected by climate change than most other countries and that it stands to lose or gain accordingly.

Increased temperatures will produce changes in ecosystems and ecosystem boundaries that will have enormous impact on the agricultural and forestry industries. A northward expansion is expected for grassland and temperate zones which could increase the amount of land suitable for agriculture in areas of central Ontario and the Peace River region of Alberta (Government of Canada 1997). On the other hand, increased frequency and severity of droughts expected in regions like the southern prairies may severely limit agricultural production.

Forestry operations likewise will be affected by ecosystem shifts; some regions will be more susceptible to fire, others will show marked changes in species suitability and changes will occur at a rate exceeding a natural adaptation process. Given the level of risks and opportunities associated with climate change in Canada, a proactive approach is needed to help slow the rate of climate change, take advantage of any beneficial effects, and minimize the detrimental impacts.

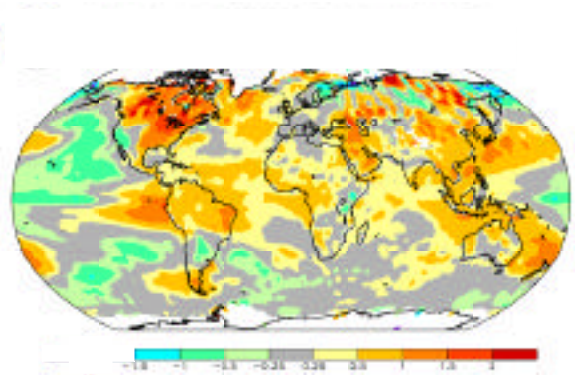

Fig. 1.2 *Surface temperature anomalies for 1992-1998 (from NOAA, 1999)*

[5] http://www1.tor.ec.gc.ca/ccrm/bulletin/

1.3. Greenhouse Gases, the Kyoto Protocol and Beyond

Although increases in solar activity have been duly acknowledged as affecting climate, GHGs have been implicated as major contributors to climate change. GHGs absorb radiative energy and elevate the earth's surface temperature. Models have linked the effects to global warming, climate change and severe weather events.

Over the past millennium, land use change (43%) and fossil fuel consumption (57%) have resulted in GHG emissions of about 420 GT C (DeFries and Field 1999), but the most rapid changes have occurred in recent decades. Today, global emissions of >6 GT C/yr are mostly (75%) attributed to fossil fuel use (IPCC 1995), and emissions associated with land use are mostly in the tropics.

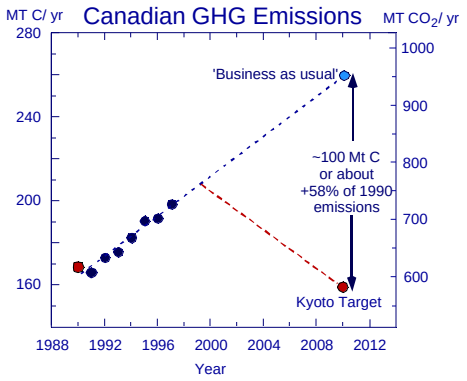

***Fig. 1.3**. Canadian Anthropogenic GHG emissions calculated including or excluding 'land use change and forestry'. Values presented as CO_2 equivalents (UN document FCCC/CP/1998/INF.9)*

Canada's contribution to global GHG emissions is about 2.1%, but on a per capita basis, its citizens are among the largest CO_2 emitters in the world (over 6 TC/yr/capita). The major activities associated with CO_2 emissions are energy production (*esp.* thermal electricity), and transportation. High energy use industries such as iron and steel, smelting and refining, cement and chemical manufacturers also figure strongly. Interestingly, the pulp and paper industry, another high energy user already obtains about 56% of its energy requirements from biomass and biofuels (Government of Canada 1997); renewable energy sources such as biogas are viewed as neutral elements in global CO_2 budgets as no net increase of atmospheric CO_2 is associated with their use.

The International Convention on Climate Change and the more recent Kyoto Protocol have attempted to address the issue of human caused emissions through the establishment of emission reduction targets for the world's developed countries. Canada agreed to an emission target of 6% below its 1990 level during the commitment period (2008-2012).

Neverthless, since 1990 CO_2 emissions in Canada have increased due to economic growth, greater fossil fuel exports, and land use change (Fig. 1.3). Consequently, to meet the Kyoto commitment, the nation is now looking at a reduction of about 39% or about 100 MT C/yr from a 'business as usual' projection.

Although the Kyoto Protocol is an important step in regulating GHG emissions, it should not be viewed as an end in itself. There are still many unresolved issues and more than a few international disagreements regarding its implementation.

The Protocol, however, does serve as an important signpost of measures to come. If we are to stabilize atmospheric CO_2 at twice pre-industrial levels (550 ppm), GHG emissions from all countries of the world will have to be reduced to 50% of 1990 levels by 2070. For Canada, that is a reduction of 115 MT C/yr below current GHG emission rates. Even if this were achieved, global climate change equivalent to a 1 or 2 degree increase in temperature is predicted. Such climate change may have serious environmental, social and economic consequences.

Canada needs a long term, strategic plan for developing renewable, sustainable energy, chemical and material resources for the future.

Weighing the costs of current actions against uncertain future costs and benefits is a very complicated task. However, if Canada does not take action immediately, it not only threatens its environmental health, it gambles with Canada's economy and quality of life.

It is apparent that Canada needs a long term, strategic plan, not only for dealing with the consequences of climate change, but also for developing renewable energy, chemical and material resources for a sustainable future.

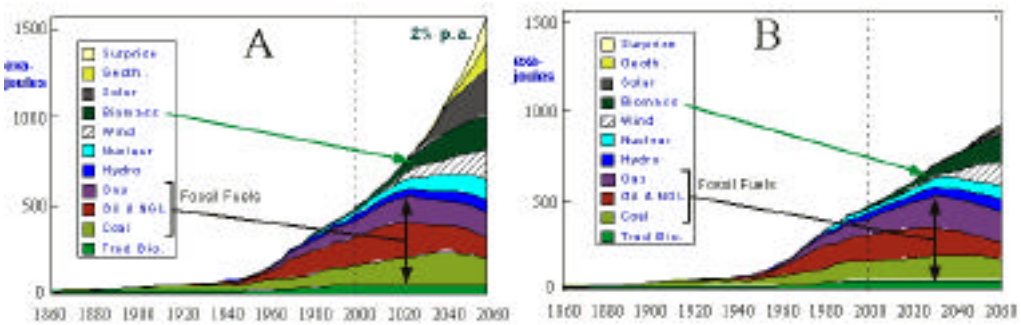

Fig. 1.4 *Past, current and future predicted estimates of the world's energy resources over the period 1860 to 2060. Future estimates assume a growth rate of 2% /yr (A) or at the incremental growth rate of the early 1990's (B). (from Shell Group Planning, Oct 1994).*

The BIOCAP Network is clearly looking beyond Kyoto, focused on those strategies that Canada can use to reduce its GHG emissions and develop a renewable energy resource for a sustainable future. A key part of our research efforts will be to develop the technologies and policy instruments that could be used to get to this future point from where we are today.

In looking to the future, it is clear that the world's energy supply in 50 years is unlikely to be dominated by one source, but will vary with the resources that are available to each nation or region. Shell Group Planning (Fig. 1.4) recently predicted that global petroleum use will peak in the next 25 years and that biomass energy will make a significant contribution to the shortfall. Canada's large biosphere and extensive, underutilized agricultural lands provide it with a strategic opportunity to develop biomass as a major low cost, energy, chemical and material resource for the future.

In the following section, we explore the potential of the terrestrial biosphere to meet the challenges of reducing our GHG emissions, while putting Canada on the road to a future where our energy, chemical and material resources will be both sustainable and renewable. This, indeed, will be a boon to Canadian's quality of life.

1.4. Canada's Biosphere Carbon Budget

Canada's Historical C Budget. The Canadian biosphere has been a major source of human-caused GHG emissions over the past few centuries. DeFries and Field (1999) reported that forestry and agricultural practice in N America from 1500 to the present contributed about 27,000 MT C to the atmosphere. Even if only 20% of this was from Canada, our net biosphere GHG emissions would be approximately equivalent to the total Canadian GHG emissions from fossil fuels (5,200 MT C, Boden et al. 1999) during the same period. [In contrast, total fossil fuel emissions in the USA (74,000 MT C, Boden et al. 1999) have been about 3.5 times that from the biosphere.]

These calculations illustrate the huge potential of the Canadian biosphere to store C, and the global responsibility that we have to use both it, and our fossil fuel reserves, more responsibly.

Given that past biosphere C emissions have resulted from human land use, the potential exists that we can learn to manage resources differently, in a way that will reverse the biosphere C flow of recent centuries.

Today's C Cycle in Canada. A further illustration of the potential of the Canadian biosphere to add or remove C from the atmosphere can be seen in a diagram of Canada's national C budget (Fig. 1.5). The biosphere C cycle in Canada is about 16 times the nation's anthropogenic (human caused, mostly fossil fuels) GHG emissions of 200 MT C per yr.

The biosphere also has a huge store, about 90,500 MT C or 450 times our annual GHG emissions, that has been built up since the last ice age. If the calculations of DeFries and Field (1999) are cor-

rect, this pool may have been over 95,000 MT C prior to the arrival of Europeans in N America.

Managing Biosphere C for a Sustainable Future. By improved biosphere C management, it should be possible to build a larger biomass, thereby creating a major C sink and reducing Canada's net GHG emissions. For example, if we could return 10% of the biosphere C that was lost as a result of land use change over the past few centuries (i.e. ~540 MT), the biosphere C gain would be equivalent to about 10 years of Canada's current Kyoto deficit (~50 MT C/yr). In the end, the total biosphere C reserves in Canada would be increased by less than 1%.

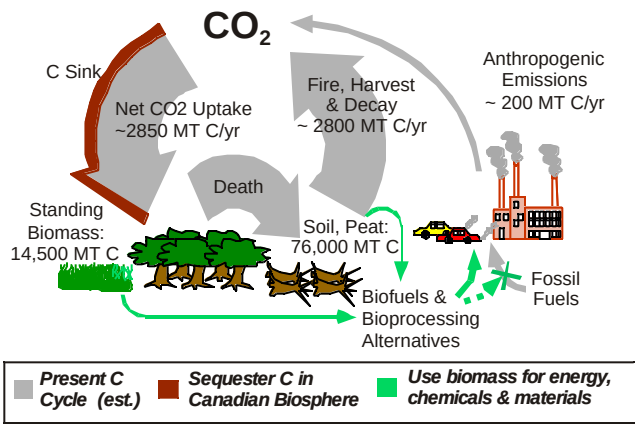

Fig. 1.5. *The Canadian terrestrial C cycle showing anthopogenic GHG emissions (primarily from fossil fuels) and the biological C cycle. Options for C sequestration and biomass utilization are also shown.*

Clearly, the Canadian biosphere has a huge capacity for C sequestration, especially relative to our fossil fuel emissions.

In photosynthesis, plants (including trees, herbaceous plants and algae) use the sun's energy to take CO_2 out of the atmosphere and manufacture the organic molecules (e.g. sugars, cellulose, protein, lignin) that make up the plant body. Much of the sun's energy is stored in the C bonds of this 'biomass', as evidenced by the heat which is produced when wood is combusted back to CO_2. It should be noted that fossil fuels are, in fact, very old trees that time - ca. 300 M yrs - heat and pressure have 'reduced' to coal, oil and natural gas.

Optimal biosphere C management, therefore, not only results in a net uptake of GHGs, but the biomass that is produced is a concentrated source of energy – a source that could be used to provide much of the energy, chemical and material needs of society that are now provided by fossil fuels.

1.5. The Biosphere Option: Moving to a Sustainable Future

The Biosphere option for GHG management involves:

- Optimizing CO_2 uptake from the atmosphere through plant photosynthesis and storage of the C in plant or soil biomass. This can provide a verifiable offset for GHG emissions from fossil fuels while enhancing agriculture, forestry and natural ecosystems.
- Optimizing the use of the biomass as a renewable energy, chemical and material resource, thereby relieving demand for fossil fuels.
- Ensuring that the rate of biosphere C sequestration either exceeds the rate of biomass utilization to offset fossil fuel emissions, or equals the rate of utilization, thereby renewing the resource.

Never before have Canadians had a mandate to manage C. Plants, however, have been in the business of C (and energy) management for over 300 million years. They can help us with this new challenge.

In this strategy, biosphere C sequestration plays an extremely important 'transitional role' in moving towards sustainability of our energy systems. It provides the nation with a low cost, 'green' option to reduce its net GHG emissions while building a cost-effective energy source for the future. It also gives Canadian industry and society the time and resources they need to become more energy efficient, while providing them with a clear message about the direction that the nation is moving in.

How much C could be sequestered and how much would it cost? Estimates of the actual cost of

large-scale biosphere C sequestration strategies are still preliminary, but initial estimates indicate that the costs are low compared to other options. For example, a 15 year afforestation program and a national soil C sequestration effort have been estimated to cost yield over 6 T C/yr and cost less than $16/TC (Sink Table Options Paper, 1999).

In a recent paper (Chen et al. 1999) models have been generated suggesting that a combination of rapid reforestation of disturbed sites, and low level fertilization of Canada's forests could provide the nation with a C sink of over 100 MT C/yr in the coming decades.

While few of these predictions have been tested experimentally, they clearly show the potential that exists within the biosphere to make more biomass.

Uncertainties with the Kyoto Protocol. Some would argue that research or implementation of the biosphere option is not worthwhile at present because the rules surrounding carbon sequestration remains unresolved in the Kyoto Protocol. Many possibilities associated with carbon sequestration have not been considered and there are controversies over the nature and definition of C credits. However, the BIOCAP Network would argue that to not act *now* would be shortsighted and unproductive.

Regardless of the success or failure of the Kyoto Protocol, there are important environmental and policy reasons for exploring opportunities and initiating programs related to the biosphere option. One thing is very likely: there will be other 'Kyoto-style' agreements in the future and Canada needs to be prepared with both understanding and experience in the scientific, technological and policy options associated with GHG management.

Also, among efforts to remedy the GHG challenge, the biosphere option definitely is 'green' in that it promotes enhanced forest growth, biodiversity and soil C reserves (Janzen et al 1998), with beneficial effects on forestry, recreation, agricultural production and rural development.

Giving Canadians a back door on the climate change issue. Concerns have also been expressed that biosphere C sequestration will relieve the pressure on Canadians and their industries to fundamentally change their behavior and drastically reduce energy use. We recognize this to be a complex issue which cannot be fully addressed here, but argue that we must move ahead with C sequestration for reasons which include:

- Reducing our GHG emissions is too important to leave to one strategy - we must use whatever resources we have.
- Fundamental changes in our energy systems will be expensive. We need healthy, globally-competitive industries to implement these changes
- If biomass is to become a more important source of energy and material resources in Canada, we must begin to build that resource now.
- There are other significant environmental benefits associated with biosphere C sequestration. We should work to enhance biosphere C even in the absence of a climate change imperative.

Biomass for Energy, Chemicals and Materials. When expressed as the energy per C released on combustion, biomass has 85% of the energy in coal, 69% of that in oil and 54% of that in natural gas (Delucchi 1999). Although fossil fuels are more highly reduced, and have more energy per C than biomass, biomass is renewable so its C emissions are not considered as GHGs as long as the biomass used is replaced by new biomass.

Biomass-derived products would include liquid fuels such as bioethanol, commodity chemicals, biopolymers, fine chemicals and solvents. In some cases it is possible to produce from biomass, the identical chemicals currently produced by the petrochemical industry. In other cases it may be possible, or more desirable, to produce suitable substitutes.

Biofuels such as ethanol can be used in combination with fossil fuels to smooth the transition to improved efficiency and alternative energy use. Virtually all of the economic infrastructure for biofuel use is already in place: ethanol is marketed as a 10% blend in gasoline and engines currently in production can operate on an 85% ethanol blend fuel. If bioethanol production costs can be reduced to 50% of current levels through improved 'cracking' and lignin metabolizing technologies, it will compete with petroleum directly in the marketplace and not require any tax incentives (Lugar & Woolsey 1999).

Currently, our forestry and agricultural systems provide food and fibre. To expand these markets to fuels and industrial feedstocks may involve selecting or engineering genotypes of either plants that produce value-added biomass, or microbes that metabolize cellulose and lignin (the primary components of most biomass) into useful products. This will draw heavily on the considerable expertise within Canada's biosciences and biotechnology sector. The BIOCAP Network will play a critical role in harnessing this expertise and focusing it on this area of critical importance to Canadians.

The Potential for Enhanced Biomass Production. Canada is home to only 0.5 % of the world's population, but is 7% of the global land mass, and produces about 5% of the world's fiber and 2.5% of the world's food. We have estimated that biomass left after harvest from current forestry and agricultural practice produces more CO_2 when it is burnt or decays (about 200-250 MT C/yr) than the entire CO_2 emissions from fossil fuels in Canada (ca. 170 MT C/yr). By better harnessing the energy in this waste biomass, we could meet a significant component of the ever-increasing demand for energy in Canada.

In addition, Canada has about 8 million hectors of underutilized or marginal farmland. This land could play a critical role in the biosphere option, as the site for initiatives in afforestation or biomass crop production.

Should agricultural land be used for fuels and feedstocks? As a result of world population growth, and increasing wealth in developing countries, demand for food is expected to double in the next 20 years. An argument could be made that Canada's excess agricultural land should be reserved for food production, not for biomass production. This is an important and complex issue which will be considered further within the BIOCAP program. However, strong arguments can be mounted suggesting that Canada's marginal lands will be far from the optimal or likely choice for feeding the world in the next century. Given the large biomass-producing capacity of our forests, concern about global food production is no reason to hold back from research and partial implementation of the biosphere option today.

USA Commits to Bioenergy & Biobased Products

"…[Biomass energy] will help us to meet the challenge of climate change, which I am convinced will be the most formidable environmental challenge the world faces over the next 20 to 30 years."

"… I am setting a goal of tripling America's use of bioenergy and biobased products by 2010. That would generate as much as $20 billion a year in new income for farmers and rural communities, while reducing greenhouse gas emissions by as much as 100 million tons a year – the equivalent of taking more than 70 million cars off the road."

"Anything we can do in this are in my judgement will have huge paybacks…We're talking about a tiny fraction of the budget for the combined recommendations we have made, that can change the whole future of this country and this world, in a way that the automobile and the perfection of the petroleum processing did at the beginning of this century."

President Wm. Clinton, August 12, 1999.
White House Press Release

1.6. The Research Challenges.

While the biosphere option surely appears to be a strategic opportunity for Canada, there are many unanswered questions, technological challenges and complex scientific and policy issues that need to be addressed. This is precisely the niche in which the BIOCAP Network has placed itself. Examples of these research challenges included in BIOCAP's key business objectives over the next seven years are:

How will Canada's biosphere respond to climate change itself? What capacity will it have to sequester C in the future? Recent experience (Fig. 1.2) and models suggest that some regions of Canada will experience more dramatic climate change than others, and we have much to learn about how these changes will affect GHG emissions as well as forest and agricultural productivity in each region. Comprehensive field studies of GHG emissions incorporating 'eddy covariance' (the 'gold standard') are required at sites across the country (see Theme 1).

What specific management strategies can we use to sequester C, how can rates be verified, and what policy instruments can be used for implementation? Changes in forestry or agricultural practice hold promise in dramatically altering biosphere C sequestration. Can we quantify these effects and, if so, can we develop verification technologies for large-scale implementation? What opportunities and barriers are there to implementation, and how much will it cost? In the proposed research of the BIOCAP Network (Themes 1,2,3 &5), three multidisciplinary 'Case Study Working Groups' will provide the forums to address these critical issues:

- **Forest C Management:** Including selective cutting, thinning, fertilization, pest control and fire management.
- **Afforestation and Fibre Crops:** Including use of traditional and fast growing trees and special annual fibre crops.
- **Soil GHG Management:** Including low till agriculture, crop rotation, and use of wetlands to enhance C sequestration while reducing N_2O and CH_4 emissions.

What should be Canada's position in future international negotiations surrounding climate change and the biosphere option? Canada's negotiators must be provided with an understanding of the science, technological possibilities, economic realities, national and international implications of various biosphere options for reducing GHG emissions (Theme 5).

What products currently made from fossil fuels could be produced from biomass and what are the cost and benefits in terms of $ and GHGs? A comprehensive 'business analysis' approach is needed, involving engineers, economists and bioscientists from university, government and industry. This is one of the issues that will be dealt with in the multidisciplinary 'Case Study Working Group' on **Sustainable Industrial Processes.** This working group will be derived primarily from researchers associated with Themes 3, 4 & 5.

How can we attract and retain Canada's best researchers to this field, and train them in the science, engineering and policy areas that are essential for this nation? Many Canadian researchers have expertise relevant to the needs of the biosphere option, and we need to get them to think differently about their research objectives (see BIOCAP's *New Initiatives Program*). In areas such as eddy covariance, biotechnology and science policy, we must attract new talent, communicate the enthusiasm and importance of the work and train them appropriately (Section D3)

What are the ecological, social and economic implications of the Biosphere Option from a Canadian perspective? International negotiations are currently underway to determine how national carbon accounting frameworks will be structured. We will need to comprehend what alternative accounting structures and potential penalties will mean for Canada's environment and economy. If we are to negotiate from a position of strength at the bargaining table, we must understand the ecological, social, ethical and economic implications of the biosphere option from a Canadian perspective. (Theme 5)

Do the benefits outweigh the risks associated with the use of genetic engineered microbes, agricultural crops or tree species? This complex, but extremely important question needs to be addressed using the tools of risk dialog and communication. (Theme 5)

What can be done to gain the support of Canadians for the Biosphere Option? The political will to change the basis of our energy economy will require more definitive insights regarding the role of GHG in climate change, the risks of climate change to Canada and the world, and the costs and benefits of implementing new measures. It will also require that these insights be packaged and communicated effectively. (Theme 5 and Sections D4, D5 and D6)

1.7. Why this Research is Important to Canada?

The biosphere option represents a pragmatic, 'do-something' approach to the challenge of GHG emissions and it is based on a well-developed skill set in this country: cultivating, managing, enhancing, and making use of renewable resources.

It could be said that the biosphere option essentially expands on and enhances the Canadian way of life. An exploration of this option is not simply a theoretical academic exercise; it is aimed at producing tangible and relevant results. The proposed research of the BIOCAP Network will be of value to Canada's policy makers at both the provincial and federal levels of government, to a wide spectrum of Canadian Industry, to the environment, and to the health and quality of life of Canadians. Examples of how our research initiatives will benefit each of these sectors are summarized below:

Industry: If the process of addressing the challenges of climate change and GHG emission control is not managed properly, it could have a devastating effect on the Canadian economy. The activities of the proposed BIOCAP Network will benefit Canadian industry in a number of critical ways:

- ***Policy Options.*** In developing a response to climate change, which involves interactions between scientific data, new technologies, and social-behavioural change, BIOCAP will focus attention squarely on the adaptive strategies that have the best chance of protecting the viability of Canadian society, economy, industry and environment.
- ***Communication.*** Through a number of structured communications formats (such as web sites, multi-media, briefings, workshops, public symposia, publications, etc. described in sections D5 and D6) BIOCAP will facilitate dialogue – primarily on risk factors and the science/policy interface – with industry, government, NGOs and the Canadian public.
- ***Carbon Sink Technologies.*** BIOCAP will identify, test and verify novel, cost-effective strategies for using the Canadian biosphere as a C sink.
- ***New Industrial Biotechnologies.*** BIOCAP will develop alternative, biologically-based technologies that have the potential to reduce GHG emissions currently associated with the use of fossil fuels.
- ***Adaptive Biotechnologies.*** BIOCAP will develop management approaches and biotechnologies to minimize the adverse effects, and maximize the beneficial effects of elevated CO_2 and climate change on Canadian agriculture and forestry.
- ***Improved Insights and Understanding.*** Research supported by BIOCAP will improve our understanding of how climate change ultimately will affect Canada, and the relative importance of GHG emissions in contributing to the climate change we are experiencing today.
- ***Training.*** Through investment in university research and partnerships with government and industry, BIOCAP will produce the highly qualified personnel who have the scientific, engineering and social science skills that are essential for developing new, environmentally-sustainable technologies for Canadian industry. (section D3)

Government: The Government of Canada is responsible for negotiating international environ-

mental agreements, and for making appropriate policy decisions on domestic and international environmental issues. It requires reliable information based on good science and it needs to know the scope and limits of technological capabilities. Provincial governments in particular, given their jurisdiction over crown land and natural resource management, also need reliable information for their policy formulations. Their efforts must complement federal and municipal initiatives; thus several of BIOCAP's Theme 5 projects acknowledge the complexities of these inter-jurisdictional relations.

The BIOCAP Network will carry out the necessary research, monitoring and verification of C sequestration as well as researching and developing technologies for biomass energy and materials usage. It will facilitate communication between governments and with other stakeholders through its Network of partnerships, and will communicate research findings in an accessible manner to decision-makers at all levels of government.

The Environment: The fundamental motivation for the BIOCAP Network proposal is to sustain a healthy environment. Lowering net CO_2 inputs to the atmosphere and developing a viable alternative energy and material resource will result in several other environmental co-benefits, such as cleaner air and smog-reduction. There are obvious other human-oriented benefits to be derived as well, such as reduction of respiratory illnesses and decreased damage to buildings and structures. There are also a number of beneficial side effects associated with increasing biomass production (mentioned earlier) including enhancement of biodiversity, aesthetic values and recreational opportunities, along with economic development for rural farm and forest communities, and improvement to soils over the long term.

The Canadian People: BIOCAP research is fundamentally important to Canadians in two respects. First, the Canadian public constitutes an essential 'stakeholder' in the BIOCAP Network. If C sequestration and biomass production are to eventually take place on a large scale, public debate, input, support and involvement will be crucial for implementation.

Secondly, just as with government bodies, the Canadian public needs reliable and credible sources of expert information to base their decisions upon. Concerns about such risk issues as climate change, bioengineering, and the attendant, potential environmental impacts must be heard; a university-based Network can provide a needed independent forum to encourage the essential public debate over the social, economic and ethical questions raised by applied scientific research.

The BIOCAP Network will seek to encourage and maintain an open, two-way dialogue with the Canadian public, opinion leaders and representative interest groups, and to work with them in carrying out the Network mission. Should the biosphere option prove viable and acceptable to the Canadian public, we can look forward to maintaining and in some cases improving our quality of life. All Canadians stand to benefit greatly from the social and economic opportunities inherent in the BIOCAP research mandate, as well as the mutually-shared benefits of a revitalized and sustainable environment.

1.8. Conclusion: Why Canada should support the BIOCAP Network.

This Socio-Economic section has attempted to answer two fundamental questions: first, why is the biosphere option important to Canada and second, why is a Network of Centres of Excellence essential if we are to move towards implementation of a biosphere response to GHG reductions?

The BIOCAP Network has positioned its program as a "made-in-Canada" solution to the challenges of managing GHG emissions and developing renewable energy, chemical and material resources for a sustainable future. Simply stated, our mandate is "to make more biomass and use it". We believe that this is a common-sense approach for Canada because of our uniquely rich natural-resource heritage.

As has been amply demonstrated, Canada is a forest nation. We are an agriculture nation. And we are increasingly a biotech nation. We are endowed

with 10% of the world's forests, we benefit from a huge agricultural base, and we have a highly educated workforce who enjoy (according the United Nations repeatedly each year) the world's highest quality of life. These resources provide us with both an extraordinary national opportunity and a tremendous global responsibility to use them wisely and sustainably.

We have argued throughout this document that the only responsible way to deal with the long-term challenges of climate change is through sustainable means, through a gradual transition to a new energy basis of our economy, and not through quick 'technological fixes' that may only provide short-term solutions. Although the idea of using biomass has been around for a long time, it never before has been regarded as a serious, cost-effective alternative energy source for our modern industrial society, mainly due to the seemingly inexhaustible supply of inexpensive fossil fuels.

The reality of climate change is slowly changing this perception, and the international mandate to manage C and place an economic value on it will only increase the economic opportunities for biomass production and usage.

As a resource rich nation with many large industries capitalizing on this fact, Canada has the relevant infrastructure in place to further capture the economic benefits of biomass creation and utilization. The biosphere option allows Canadians to build on our existing strengths, to use the capabilities of our energy companies, to revive our forestry and agriculture sectors, to revitalize rural communities and thereby alleviate pressure on our increasingly crowded and polluted urban areas. In addition, this option bolsters our high-technology sector by providing the bio-based feedstocks needed by environmental biotech industries, ultimately contributing to cleaner processes and production mechanisms for Canada.

Why is the BIOCAP Network approach so important? In the process of developing the Network Strategic Plan with our many partners, BIOCAP has discovered that one of its main "value-added" components is that it sits at the intersection of two fundamentally important and strategic science/policy issues for Canadian society: the integration of climate change and biotechnology. We have brought forward the message of the biosphere option to two completely different communities that up until recently have not been relating much with each other. We have discussed the potential of using biological approaches, including biotechnology, with decision-makers concerned with climate change, and we have highlighted the imperative (and opportunity) of climate change to the biotechnology sector. This could not be achieved without the interdisciplinary focus that is inherent in a Network approach.

BIOCAP has captured the attention of such a wide variety of sectors in Canadian society that it can truthfully claim the potential to be a vehicle to bring together very diverse interests to solve a common problem. Not only does Canada critically require research into the biosphere option, it needs it to be done by an independent, university-based network that is not hampered by either political or business agendas. Such a NCE can also serve to be a point of convergence for the manifold outputs of the National Climate Change Table Process as well as environmental elements of the Canadian Biotechnology Strategy.

BIOCAP's vision advocates that Canada explore the many advantages of our native natural heritage to contribute solutions to a pressing global challenge. BIOCAP's research program as well as its strategies for training HQP, for networking, knowledge transfer and technology exploitation, are all reflections of Canadian social values and economic priorities. The Network's many clients, sponsors and partners, and also its governance structure, reflect the importance of the science/policy interface in both research and dissemination. Most optimistically, BIOCAP's exploration of the biosphere option will contribute significantly to Canada's environmental health and international leadership position in the coming millennium.

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