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GLOBAL CHANGE AND OPPORTUNITIES:
BIOSPHERE SOLUTIONS TO CLIMATE CHANGE, ENERGY AND THE ECONOMY

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ABSTRACT: Climate change and providing a supply of clean energies have been considered two of the greatest challenges facing human society in the twenty-first century. The biosphere can contribute to the reduction of greenhouse gas (GHG) emissions by sequestering carbon into vibrant ecosystems, by reducing the production of methane and nitrous oxide (potent GHGs) emissions from agriculture, forestry and landfill sites and by providing biomass energy alternatives to fossil fuels. Canada has a 'green advantage' because of its large areas of forests and agricultural land and relatively small population. Between now and 2012, the biological systems of Canada that could contribute as much as 80 million tonnes of carbon dioxide equivalents per year, about 28 percent of the 285 million tonne reductions needed to meet the Kyoto Protocol target. The BIOCAP Canada Foundation, a national non-profit, research foundation, has a mandate to harness the research capacity in Canada, to focus on particular strategic areas that are going to help find sustainable, bio-based solutions to climate change and clean energy. BIOCAP has established 10 national research networks across Canada that have engaged about 400 researchers from university, government and industry. Research includes the areas of forestry, natural ecosystems, agriculture and bioenergy. Bioenergy and the movement to a bioeconomy should be integral parts of climate change and energy strategies for the countries of the Americas.

Keywords: climate change, energy, BIOCAP, bioenergy, carbon sequestration

1. Introduction

Climate change and the supply of clean energy are considered to be two of the greatest challenges facing human society in the twenty-first century. While these are problems for the entire world, they are critical challenges for Canada. Canadians have the dubious distinction of being the highest energy users in the world, on a per capita basis. The energy use per person is seven and a half times that for Brazil. Figure 1 shows greenhouse gas emissions per capita, indicating Canada is third highest in the world, and 9.2 times the value for Brazil. It is obvious that more sustainable energy systems must be found to reduce carbon dioxide emissions and other greenhouse gases that are thought to be forcing climate change. The biological systems of Canada offer solutions that can help address the challenges of greenhouse gas management. Some of the possible actions provide opportunities that could be applied throughout the Americas.

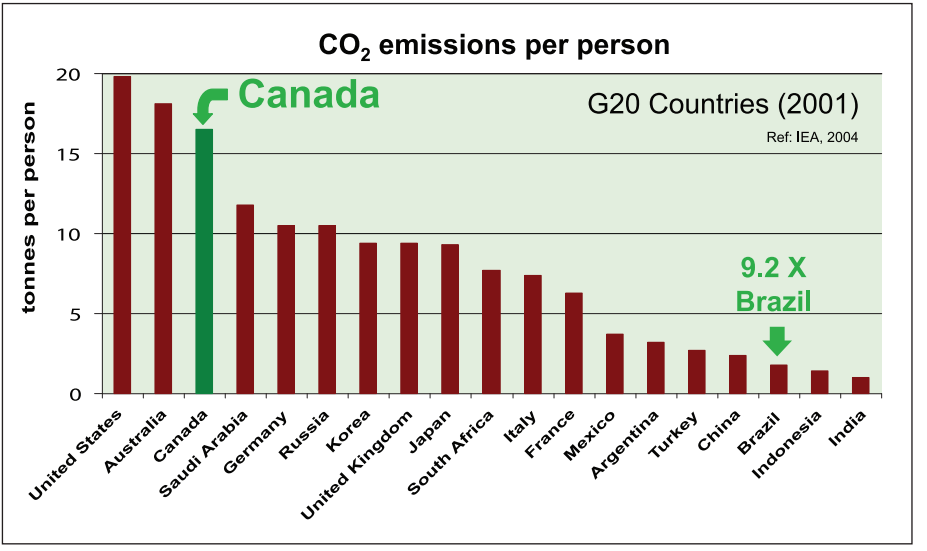

FIGURE 1

Comparison of greenhouse gas emissions per person, G20 countries.

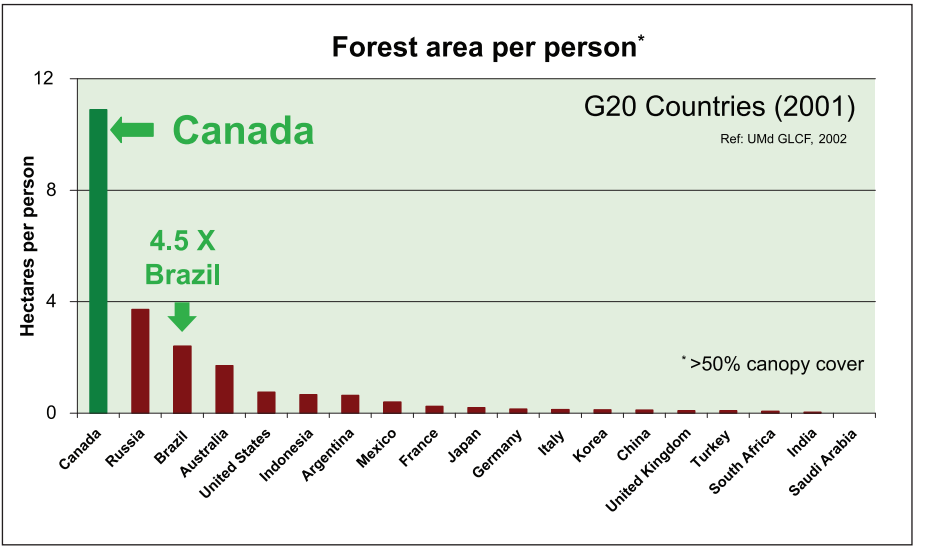

FIGURE 2

Comparison of forest area per person, G20 countries.

2. Biological Systems and Climate Change Solutions

When designing strategies for the supply of sustainable energy and the control of greenhouse gases, it is logical to consider the biosphere. The biological systems that dominate the biosphere have been in the 'business' of managing greenhouse gases and solar energy for more than 400 million years. If we can manage them better, they could be a strategic part of meeting the challenges of climate change and clean energy. Canada has one-half of 1 percent of the world's human population, but has stewardship over 7 percent of the world's land area and 10 percent of the world's forests. In terms of arable land area per person, Canada is second in the world to Australia and 4.5 times Brazil. Canada's forest land area is the largest in the world on a per capita basis and about four-and-a-half times that of Brazil (see Figure 2). This is a vast biological resource that represents a 'green advantage' for Canada - a national opportunity and a global responsibility to use this resource more efficiently.

The issue is more than just land area. Brazil has a much longer growing season and can produce more biomass. There are many other nations within the Americas that have very large biological resources and thus opportunities to determine how to use them to contribute to solving greenhouse gas and energy use problems.

What can be done to capture the green advantage? What can be done to address questions about greenhouse gas management and energy supply? The status of the world's carbon cycle is critical in determining whether biological systems are part of the problem or part of the solution to the challenges of climate change and clean energy. The carbon cycle is now being perturbed by our tapping into fossil resources. Fossil fuels have been outside of the carbon cycle for millions of years, but now they are being put back into the atmosphere and into the active carbon cycle. What can be done to manage our biosphere in order to reduce the impact of fossil fuel use on our climate and to provide a clean energy resource? Consider four categories of action:

- First, the removal of carbon from the atmosphere can be improved by sequestration technologies; enhancing the ability of forests and agriculture to remove carbon from the atmosphere; and converting solar energy into energy rich biomass.

- Second, emissions of methane and nitrous oxide, greenhouse gases that are associated with current agriculture production systems (fertilizer use, animal production, manure management) and with the management of municipal waste streams, could be reduced. These gases are many times more potent than carbon dioxide in their global warming potential.
- Third, biomass can be used to compliment and extend fossil fuel streams in providing the energy, chemicals and materials currently obtained from fossil fuels.
- Finally, management strategies and technologies can be developed that will help the biosphere adapt to a changing climate and a changing atmosphere. Only by doing this, will it be possible to maintain and preserve biodiversity as well as the food, fibre, carbon stocks and energy that our agricultural and forest ecosystems provide.

3. The BIOCAP Foundation

This suite of issues above is the focus of research within the BIOCAP Canada Foundation - a national non-profit, research foundation. BIOCAP is supported by the federal government of Canada (Environment Canada; Natural Resources Canada; Agriculture Canada) and the Canadian provinces of British Columbia; Alberta; Saskatchewan and Ontario. Nine major companies involved in oil and gas, power generation, fertilizer, forestry and steel making are also supporting the Foundation. In addition, some non-governmental environmental groups provide support and are actively involved in management.

The BIOCAP mandate is to harness the research capacity in Canada, by focusing on strategic research areas that will lead us to sustainable biologically-based solutions to climate change and clean energy. The strategy used over the past three years is to build a national 'network of research networks' that engage researchers in universities (for which Foundation funding is provided), government and industry. The main product is to develop the insights and technologies that can be used to inform policy and investment decisions by government and industry. When government and industry act on these insights and technologies, the changes emerge that are necessary to move Canada towards a more sustainable bio-based economy.

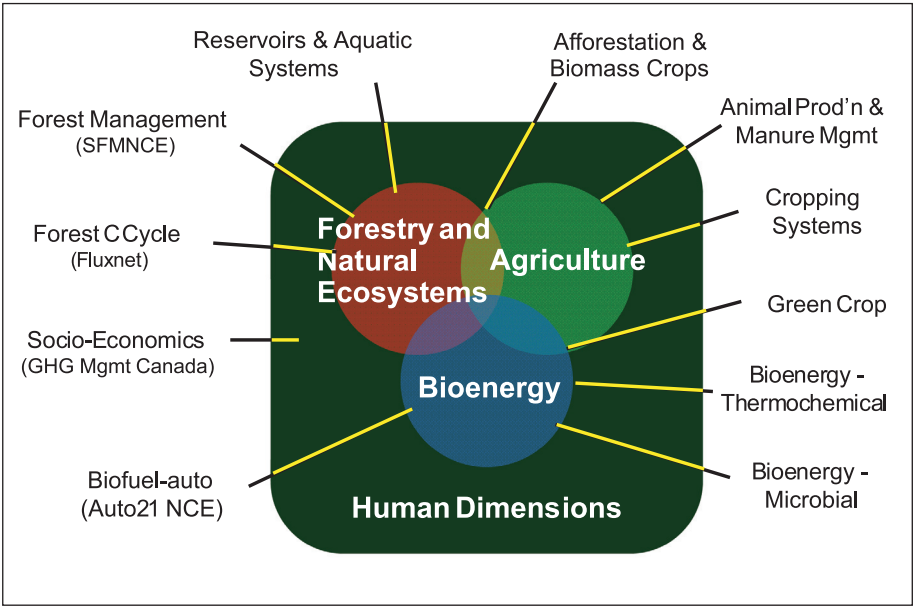

FIGURE 3

BIOCAP 'Network of Networks'

BIOCAP has established 10 national research networks across Canada (Figure 3), engaging about 400 researchers from university, government and industry. Research includes the areas of forestry, natural ecosystems, agriculture and bioenergy, as well as a 'cross-cutting' human dimensions focus. One key objective of all the research networks is to promote inter-disciplinary and trans-disciplinary research focused on achieving particular goals.

BIOCAP's research network on forest carbon and nitrogen cycling (Fluxnet-Canada, www.fluxnet-canada.ca) is studying the fluxes of carbon, water and energy in forest ecosystems from coast to coast to see how they are affected by climate change, natural disturbance and human activities. BIOCAP also supports a 'Centre of Excellence' network based in Alberta that explores how different forest management strategies affect carbon stocks and other forest values. Yet another network is studying the role that hydro-electric reservoirs and nutrient loading play in greenhouse gas sources and sinks from aquatic systems.

Two of BIOCAP's agriculture networks are studying how cropping systems and animal production / manure management systems affect methane and nitrous oxide emissions as well as soil carbon stocks. In addition, a new 'Green Crop Network' is developing agricultural crops that are selected or engineered to have less of an 'ecological footprint' by enhancing soil carbon, reducing nitrous oxide emissions or producing oil that could be used to make biodiesel fuel. Support for this network includes a CAN$6.5 million, five-year grant with Canada's Natural Sciences and Engineering Research Council (NSERC).

BIOCAP has also co-funded more than 15 projects related to conversion of biomass feed stocks into the energy, chemicals and materials that will support power generation, steel making, liquid fuels and biogas. With a longer term federal mandate, BIOCAP will work to bring these projects together into national networks.

Finally, a CAN$3.4 million, three year research network called *Greenhouse Gas Management Canada* has been assessing the cost and benefits as well as the barriers and bottlenecks associated with implementing policies and programs related to biosphere greenhouse gas management and bioenergy in Canada. Since international climate change issues are a federal responsibility and the resource industries are a provincial responsibility, there are many social, legal and structural issues unique to the Canadian Federation.

Over the 2002 to 2005 period, BIOCAP has invested about CAN$6.1 million to leveraged an additional CAN$21 million for about CAN$27 million of research activity. While this is a small start compared to what is needed, it is a valuable step in the movement towards a sustainable bio-based economy in Canada.

There are many questions that these networks will help to address, including:

- How can carbon stock changes be measured on the 230+ million hectares of forest productive land?
- How will the future atmosphere and climate affect forest wetlands and farmlands?
- What can be done to increase biosphere carbon stocks or to reduce the adverse impacts of climate change on biological systems?

- What are the optimal management strategies or policies for reducing emissions associated with land fill sites, crop or animal production systems?
- What are the optimal characteristics of a bioenergy system for providing heat, power or liquid fuels

A number of these projects have significant implications to other nations that also have major agricultural or forest production systems. Regarding biomass as complimenting fossil fuel energy, one issue is how much of a resource is available, and how is it mobilized? What is the best way to use biomass energy resources from a policy, economic or industry perspective, and then how does it compare with other energy options? How should changes in use patterns be implemented? How should incentives be provided?

Brazil has been a world leader in the use of bioenergy and bioethanol. Canada can learn from other nations that are much further along in answering these questions.

4. The Kyoto Protocol

Canada's biosphere could make a significant contribution to the Kyoto target during the 2008 to 2012 commitment period. Canada has a large 'gap' between its projected emissions and its Kyoto commitment.

Total emissions of greenhouse gas emissions in Canada by the 2008-2012 period will be about 800 million tons of carbon dioxide and the Kyoto target is about 530 Megatons of carbon dioxide equivalent per year. Therefore, the 'Kyoto gap' (Figure 4) is estimated to be about 270 Megatons of carbon dioxide equivalent per year plus an additional 15 Megatons of carbon dioxide equivalent per year linked to deforestation.

About 15 percent of Canada's greenhouse gas emissions are from landfill and agricultural methane, but the Canadian government has targeted them to provide about 25 to 28 percent of the solution. This target is possible if appropriate incentives are provided. Perhaps a 10 percent reduction in agricultural emissions and a 40 percent reduction in landfill emissions can be achieved in the first commitment period. Increases in agricultural soil carbon are expected to achieve as much as 20 million tons and an additional 35 million tons from forest carbon stock will also contribute significantly to Canada's Kyoto commitment in the first period.

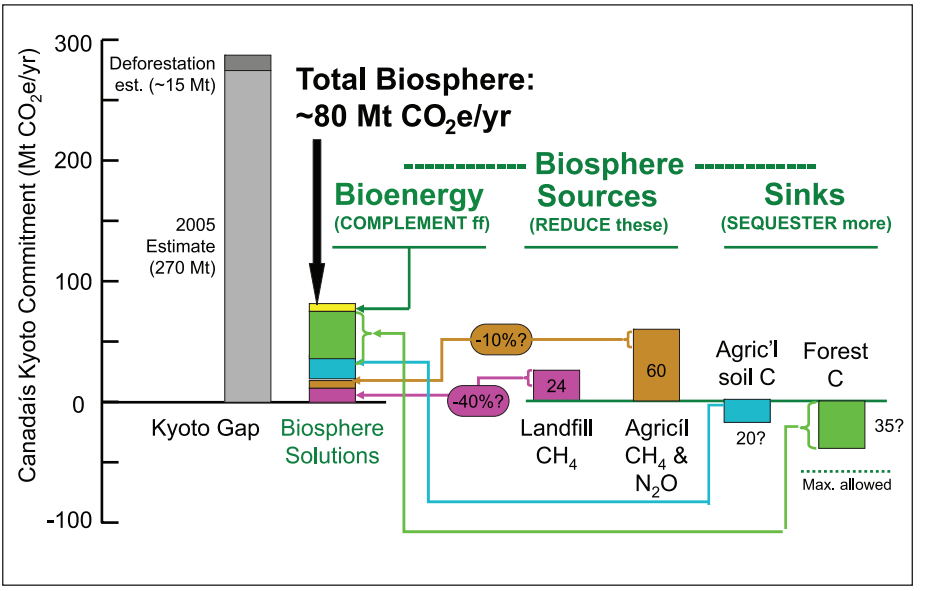

FIGURE 4

Biosphere solutions to climate change in Canada.

There is an additional bioenergy component, estimated at about 5 million tons. There is a total biosphere contribution from the biological systems of Canada that could contribute as much as 80 million tons of carbon dioxide equivalents per year, about 28 percent of the 285 million ton gap. While biological systems obviously play an important role, they cannot do it all. The same information is presented in a pie chart (Figure 5) showing the 80 million tons from the various biological sources. In order to achieve this, it is important to recognize that it will need considerable research investments.

To achieve the 'business as usual' carbon sinks in agriculture and forestry that the international community has allowed Canada to count, Canada must be able to predict what those sinks will be under current management practices, and then measure them over the commitment period. That is a major scientific challenge that BIOCAP researchers are helping to address. An important question remains: How can the carbon sinks be enhanced and reduce the greenhouse gas emissions associated with biological systems and also provide the technologies for the cost effective conversion of biomass into energy?

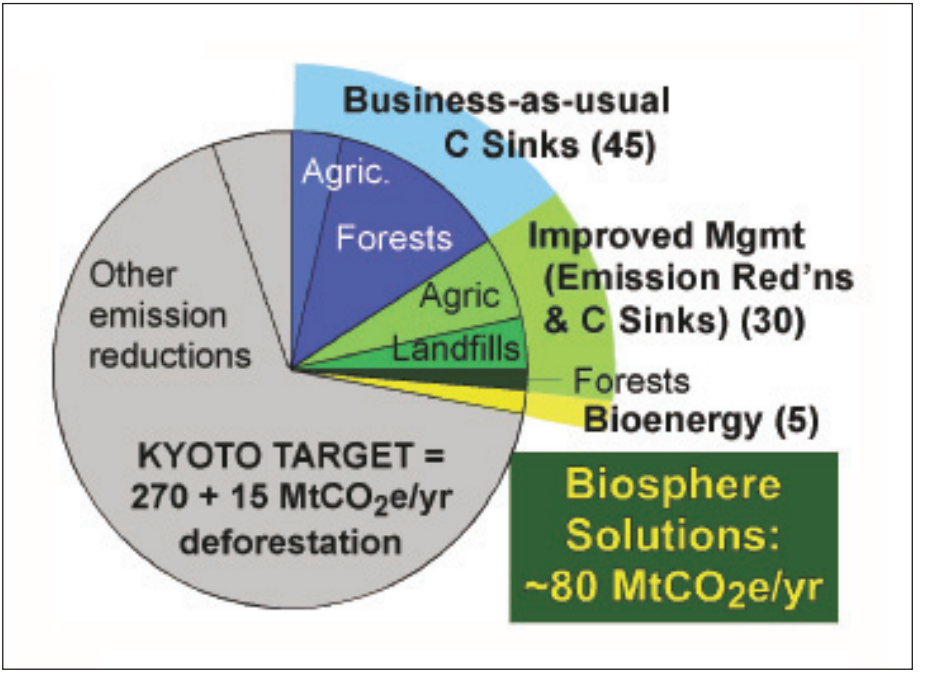

FIGURE 5

Total biosphere contribution from the biological systems of Canada to assist Canada's Kyoto Target.

Canada needs to develop new technologies for sequestering, reducing, complementing and adapting strategies for biosphere solutions. One of the important issues is to recognize that decisions on how Canada or how nations or people are going to respond, are probably not going to be based on climate and energy benefits alone. These climate or energy policies need to be integrated into other societal values, whether it is rural development, aboriginal affairs, clean air, or clean water.

5. Potential for Biosphere Solutions

The issues discussed in this paper so far are all related to the first commitment period of the Kyoto Protocol, and that represents a short time for research to be contributing to those sorts of insights. The Foundation has

also been exploring the role for biosphere offsets and biomass energy in the post 2012 period?

Since biomass has a lower energy content per unit carbon than fossil fuels, providing all of Canada's current fossil energy demand with biomass would require about 550 million dry tonnes of biomass feedstock (equivalent to about 1000 Megatons of carbon dioxide equivalent per year). To put this into perspective, this value is about twice the entire annual forest and agricultural harvest in Canada, including both the product yield and the residue left behind. Therefore, for Canada's agricultural and forest ecosystems to provide the nation's current fossil energy needs, plus current levels of food and fibre production, there would need to be approximately a tripling in annual forestry and agricultural production. While this may be theoretically possible, serious questions would need to be asked about the environmental sustainability of such an initiative.

What then is a realistic contribution for biomass to make as a sustainable source of energy? Figure 6 provides an estimate in a comparison with the Kyoto gap of 285 Megatons of carbon dioxide equivalent per year. Current municipal and industrial waste has enough bioenergy capacity to contribute energy in the range of 20 to 30 million tons of carbon dioxide equivalents a year.

In addition, Canadian forests experience many large disturbances such as fires and major insect infestations (for example, the mountain pine beetle in western Canada). These events leave a large amount of residual biomass that could be tapped as a sustainable energy source given appropriate management strategies and technologies. Planting of trees to produce biomass crops on unused agriculture lands and changing forest management practice to increase the productivity of forests are also potential sources of biomass for energy. Lower and upper estimates in the contribution that these biological systems could make to Canada's future energy supply are shown in Figure 6. In total, the preliminary and conservative estimates carried out here ranged from about 130 to 400 Megatons of carbon dioxide equivalent per year. The opportunities for Canada are probably reflected in many of the other countries within the Americas.

This amount of biomass could be used for a number of applications to displace fossil fuel demand including heat, electrical power generation, iron

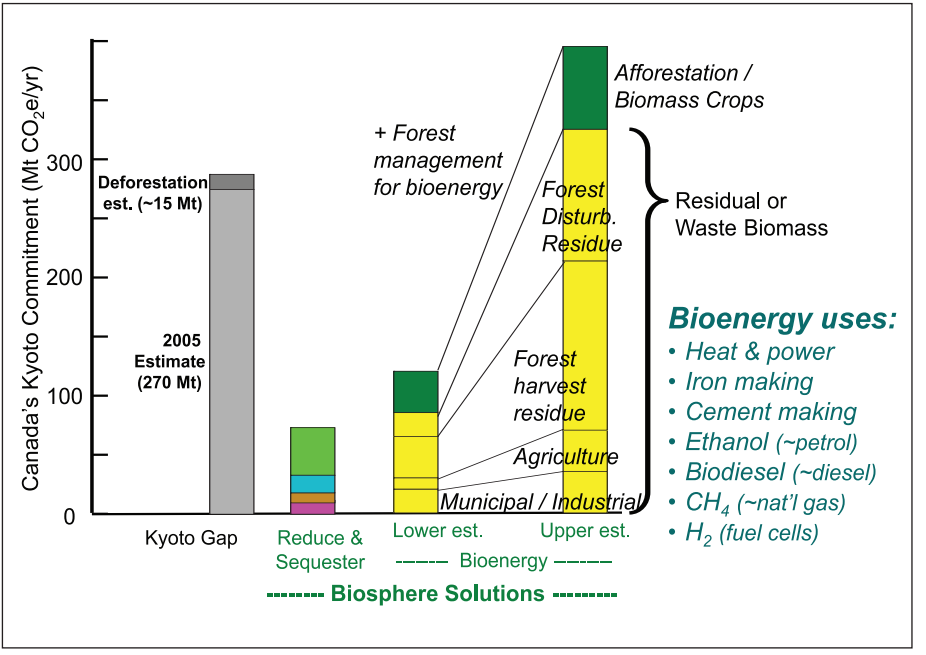

FIGURE 6

Estimates of the contribution that biological systems could make to Canada's future energy supply.

making, cement making, transportation fuels or gases like methane or hydrogen. A preliminary BIOCAP study (Layzell and Stephen 2006) shows that the actual greenhouse gas benefits associated with a tonne of biomass varies widely, depending on the form of the energy being created and the fossil fuel being displaced. For example, 10 million tonnes of biomass carbon per year (equivalent to about 20 Megatons of dry biomass) would have a major greenhouse gas benefit if used to displace coal for power generation, but less of a benefit in the production of bioethanol or biodiesel from a similar weight of biomass carbon (Figure 7). This calculation takes into account the life cycle cost of using biomass relative to existing energy sources. Clearly, policies for the use of bioenergy need to take into account the objectives for its use.

In the Americas, there are number of potential drivers supporting the movement to a sustainable bioeconomy, including:

- greenhouse gas mitigation as either a carbon stock increase, creating an offset for fossil fuel emissions or bioenergy to displace fossil energy use;
- healthier water, air and soil;
- energy security concerns associated with future fossil fuel supply and cost;
- rural development opportunities linked to new domestic markets for agricultural and forest production;
- innovation and the potential for new industries.

A challenge is the economics of change. A level playing field for all energy sources is needed; one that takes into account the total costs associated with energy sources like fossil fuels, and the subsidies already in place for other alternative energy sources (for example, nuclear).

6. Conclusions

All countries face challenges in reducing greenhouse gas emissions to meet the targets of the Kyoto Protocol. The biosphere can contribute to emission reductions by sequestering carbon, by reducing biologically-based emissions of non-carbon dioxide greenhouse gases, and by providing biomass alternatives to fossil fuels. In addition, it is essential to develop management strategies and technologies that will allow ecosystems to adapt to climate change in order to maintain sustainable industries and ecosystems alike. Like many other countries in the Americas, Canada has a major 'Green Advantage' with its large forest and agricultural resource. To capture this 'Green Advantage' and move towards a sustainable bioeconomy, the Americas need integrated, policy-relevant research focused on addressing the challenges of climate change and clean energy.

Reference

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