Forest Sequestration: Performance in Selected Countries in the Kyoto Period and the Potential Role of Sequestration in Post-Kyoto Agreements

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AN RFF REPORT

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Abstract

This report examines the rational and potential for the use of forests for carbon sequestration in the context of the Kyoto Protocol. It looks at the role that sustainable forest management might play and at progress made thus far in utilizing forests to sequester carbon under the existing Kyoto arrangement. It also focuses on the approaches, progress, and problems of the European Union, Japan, and Canada in using forestry to move toward their Kyoto targets. Additionally, this report begins to think systematically about the issues that might need to be addressed in the post-Kyoto world and what types of international arrangements might be most useful in responding to a continuing climate problem, with particular attention paid to the role of biological carbon sequestration under various arrangements. This approach includes a discussion of the mechanisms of the Kyoto Protocol for forest sequestration and possible extensions of forestry activities for carbon sequestration under this and subsequent international agreements. The report also examines the implications of some hypothetical scenarios of future Kyoto-type arrangements on the role of forest carbon sequestration in addressing climate change.

Contents

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Forest Sequestration: Performance in Selected Countries in the Kyoto Period and the Potential Role of Sequestration in Post-Kyoto Agreements

Masahiro Amano and Roger A. Sedjo[1]

Introduction[2]

The purpose of this report is to examine the rational for forests for carbon sequestration in the context of the Kyoto Protocol, to look at the role that sustainable forest management might play, and to look at progress made thus far in utilizing forests to sequester carbon under the existing Kyoto arrangement, with a focus on the approaches and progress of the European Union, Japan, and Canada. Additionally, this report begins to think systematically about the issues that might need to be addressed in the post-Kyoto world and what types of international arrangements might be most useful in responding to a continuing climate problem, especially the possible role of biological carbon sequestration under various arrangements. This approach includes an examination of the implications of some hypothetical scenarios of future Kyoto-type arrangements on the role of forest carbon sequestration in addressing climate change.

The Kyoto Protocol went into effect February of 2005 for ratifying countries. The carbon reduction targets for ratifying industrial countries are to be met during the five-year compliance period of 2008–2012. However, it is well recognized that the Kyoto Protocol is only the beginning of an effort to substantially reduce global anthropomorphic greenhouse gas (GHG) emissions over the next century. Additionally, the various limitations and defects in the current Kyoto Protocol are becoming obvious. Future multi-nation agreements need to have the capacity to involve the United States in a major way (Sugiyama et al. 2004), as well as involve the large countries of the developing world, including China, India, and Brazil. Some have suggested that the Kyoto Protocol is excessively rigid (e.g., Bodansky et al. 2004; Sedjo 2004), focusing largely on emissions reductions and implicitly driven by conservation, with much less focus on the development of technologies that will allow emissions reductions without forgoing

[1] Waseda University, Tokyo, and Resources for the Future, Washington, DC, respectively.

[2] See the Revised Terms of Reference, October 17, 2005.

development and economic growth. Others suggest that technical change will be a necessary element of successfully dealing with climate change and that technical innovation needs to be a major parallel approach to emissions management (e.g., Anderson and Newell 2004). In fact, while the U.S. government has not ratified the Kyoto Protocol, it has been active in funding research on new energy sources and emissions reduction. Hence, it can be argued that it has chosen a path much more oriented toward the development of emissions reducing and offsetting technologies than have most of the countries that have ratified the Kyoto Protocol.

Section I: The Role of Biological and Carbon Sequestration

Recognition of Forestry in the Kyoto Protocol

The UN Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol both recognize the efficacy of forests and sustainable management as a vehicle for addressing climate change. The UNFCCC states: "All Parties … shall … promote sustainable management … of sinks and reservoirs of all greenhouse gases … including biomass, forests" (Article 10). The Kyoto Protocol states: "Each Party included in Annex I … shall … implement and/or further elaborate policies and measures … such as … promotion of sustainable forest management practices" (Article 2).

Also, Article 3.3 of the Kyoto Protocol calls for the maintenance of forests by afforestation, reforestation, and controlling deforestation (ARD). Afforestation and reforestation credits are obtained, while deforestation is associated with debits. Article 3.4 provides credits for increases in the carbon sequestered by managed forests. Thus, there is clearly a role for forest sequestration under these agreements. Although a role for sustainable forest management (SFM) is not explicitly articulated in the Kyoto Protocol, a role for SFM is explicitly stated in the UNFCCC.

Technology and Cost

The interest in biological and forest sequestration derives from two aspects. First, the technology exists today to undertake programs to promote biological sequestration of carbon, it need not be developed. Second, numerous studies have suggested that biological sequestration of carbon is likely to be relatively inexpensive compared to alternative carbon-reducing approaches (Sedjo et al. 1995; Stavins and Richards 2005). Recent work has suggested that biological sequestration can substantially reduce the costs of addressing atmospheric GHGs. For example, a recent study by the Energy Modeling Forum of Stanford University found that using biological sequestration can reduce the costs of meeting certain 2100 climate objectives from 3.3 percent of GDP to 2.3 percent, literally trillions of dollars (Rose 2006). This reflects the fact that biological sequestration, and particularly forests, have the potential to sequestrate a substantial portion of the surplus carbon in the atmosphere. These estimates are consistent with the findings of the Intergovernmental Panel on Climate Change (IPCC) (2001) that biological sinks have the potential to capture up to 20 percent of the excess carbon released into the atmosphere over the first 50 years of the twentieth century. These estimates are supported by other work

(e.g., Sedjo et al. 2001). Appendix A presents the projections of Sedjo et al. (2001), which provide estimates of the potential of forests to sequester carbon under various assumptions regarding financial incentives in future carbon markets. These projections received subsequent further development by Sohngen et al. (2006).

The enthusiasm for biological sequestration varies considerably across countries. To some extent this appears to reflect the forest sequestration potentials of the various countries. For example, countries with modest forest and biological sequestration potential, such as most of Europe, have limited enthusiasm for forest sequestration. The limited potential in Europe has been suggested in studies such as Petroula (2002) and Amano and Sedjo (2003). By contrast, countries like the United Stats, Canada, and Australia, which appear to have substantial potential for forest and biological sequestration, have shown enthusiasm for forest sequestration. Other countries, such as Japan and the Netherlands in Europe, look for the forest and biological potential to be realized off-shore through instruments such as the Clean Development Mechanism (CDM). However, the use of such instruments has been, thus far, disappointing due to excessively stringent requirements. This is discussed to a greater degree below.

Despite varying degrees of enthusiasm, the potential and advantages of biological sequestration, and particularly forest sequestration, are substantial. Biological sequestration offers the potential for the sequestration of large volumes of carbon. In addition to potentially being able to sequester relatively large volumes of carbon at comparatively low prices, Bodansky et al. (2004) have pointed out that the use of biological sequestration has the advantages of allowing a more equitable sharing of overall effort; may offer lower-cost mitigation opportunities than other sectors; generates ancillary benefits, including protecting or improving soils, water resources, habitat, and biodiversity; generates rural income; and promotes more sustainable agriculture and forestry practices. They note that quantified approaches could be linked to emissions trading and that these approaches closely complement adaptation efforts. Such an approach might be attractive to certain developing countries where carbon sequestration and other goals may coincide in many aspects. More generally, forest sequestration can be highly complementary to other international activities, such as the Montreal and Helsinki processes, and the global forest certification activities that are now being implemented (Fischer et al. 2005). The simultaneously undertaking of a variety of forest activities by the international community points to the need for greater coordination.

In the post-Kyoto period, approaches to addressing carbon sinks will need to be revisited. Three ranges of alternatives can be envisioned: the Kyoto Protocol system can continue largely as is; the system can be simplified; and/or new modalities can be developed. Also, there is the question of how once registered Kyoto forests will be treated in the post-Kyoto period to be consistent with the first commitment period of the Kyoto Protocol. Although COP 9 indicated that once modified the forest would be modified indefinitely,[3] it is not clear how binding the provisions of the current Kyoto Protocol will be on activity and future agreements, which will almost surely be negotiated de novo. Obvious considerations for a second Kyoto Protocol could involve a restructuring of both Articles 3.3 and 3.4.

The Potential of Forest to Sequester Carbon under Various Price Assumptions

Evidence suggests that the role of forests in sequestering carbon can be very large. Appendix A presents figures that report the findings of a study supported by the U.S. Department of Energy that investigated the potential of forests to sequester carbon under various carbon payment assumptions (Sedjo et al. 2001). The approach estimates cumulative carbon quasi-supply curves under a number of different price scenarios. In figure A.4, the zero price scenario assumes the business-as-usual case where no price incentives are provided for forest carbon sequestration. The $5 scenario assumes carbon payments begin at $5 per ton of carbon and rise gradually to $61 by 2100. The $20 scenario assumes that payments begin at $20 per ton of carbon and rise gradually to $244 per ton by 2100. Note that the results suggest that carbon sequestration by forests could be substantial, with the $20 scenario being roughly consistent with the estimates provided in Chapter 4 of Third Assessment Report (2001). The model also demonstrates (Figures A.1, A.2, and A.3) that alternative market reactions depend not only on the carbon price level but also on the anticipated intertemporal price path. The final figure, Figure A.4, projects the total carbon that could be sequestered in the global forest system under a specific set of future carbon prices.

It should be noted that the increases in sequestered carbon depend not only on the land area in forest but also on the intensity of management and inputs. Thus, a given area of land can produce a variety of different wood (and carbon) output levels depending upon the inputs used

[3] For example, COP 9 agreed that CDM forests could constitute a sink for a maximum of 30 years with no baseline review (the tCER) and up to 60 years with a baseline review every 20 years (the ICER).

in production. Today, modern forestry, like agricultural cropping, commonly enhances productivity through better management and the application of increased inputs (e.g., see Hyde 1980; Sedjo and Lyon 1990).

The Role of Sustainable Forestry Management

Historically, humans have contributed to carbon dioxide emission in two ways: fossil fuel burning and deforestation (Figure 1). Initially, land use changes (deforestation) were the principle source of carbon emissions. However, after the beginning of the twentieth century, fossil fuel emissions rose rapidly, while emissions due to deforestation gradually declined. One approach to begin to address the issue of increasing carbon emissions is to maintain and increase the stock of sustainably managed forests. Throughout much of the world, largely the temperate regions, the gross annual forest volume growth exceeds annual volumes harvested. As Figure 2 shows, the net effect in much of these regions is for forests to sequester net amounts of carbon. Obviously, by managing forests in a sustainable fashion, net carbon emissions can be managed and reduced. Furthermore, planted forests, as well as natural forests, can contribute sequestration services. For example, Figure 3 shows the carbon sequestration capacity of plantation and natural forests in Japan by age. Although forests offer countries carbon sequestrating potential, forest areas and stock vary considerably by country, as shown in Figure 4.

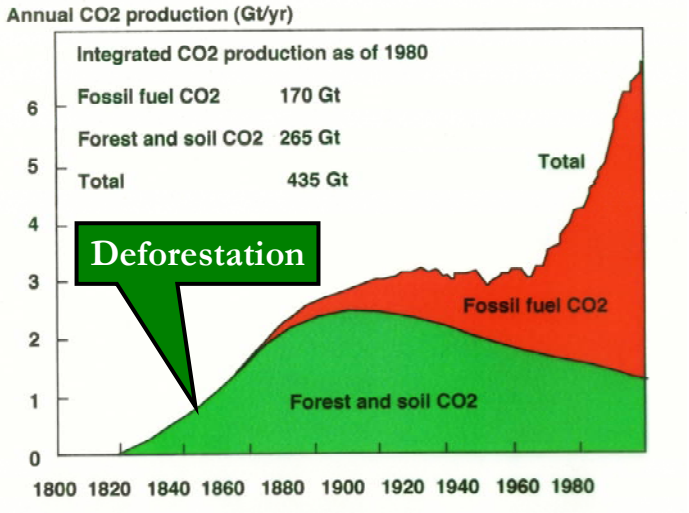
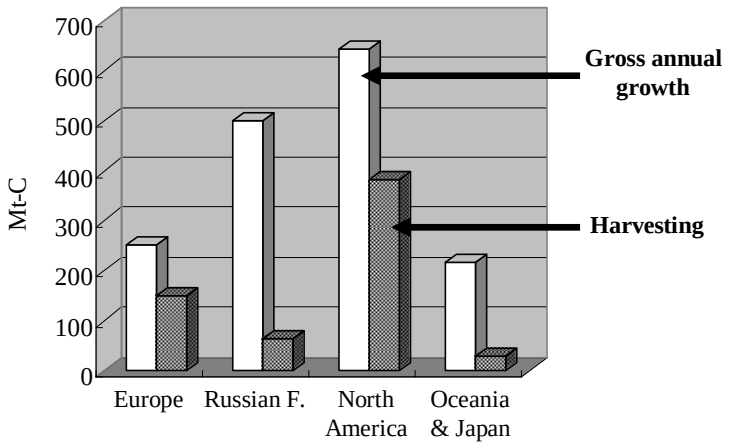


Figure 1. Historical Anthropogenic CO_2 Production



Source: Global Forest Resources Assessment (2000)

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Figure 2. Carbon Balance of Gross Annual Growth and Harvesting

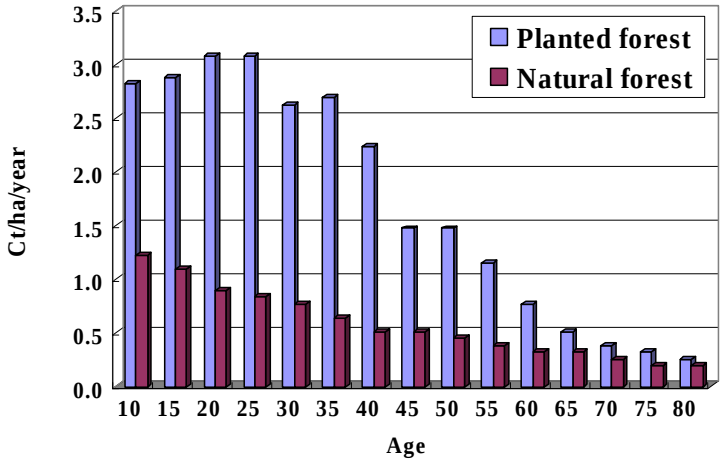
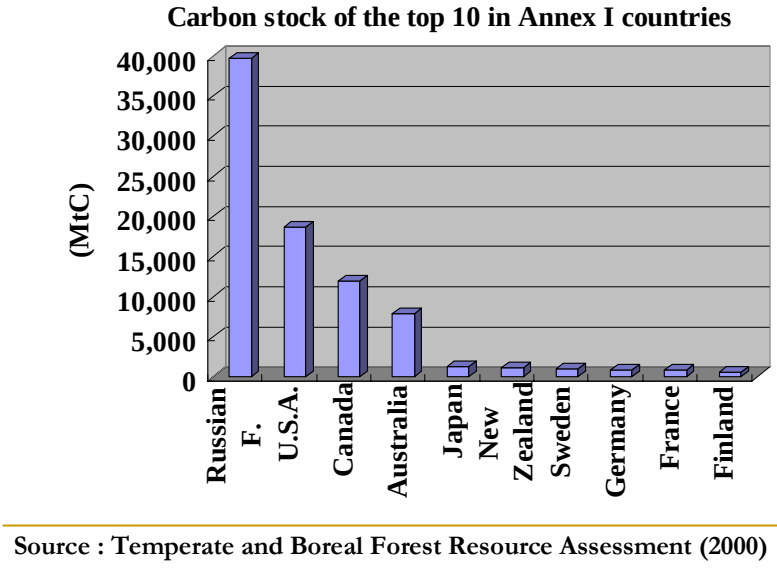


Figure 3. Carbon Sequestration Capacity of Plantation and Natural Forests in Japan



Source : Temperate and Boreal Forest Resource Assessment (2000)

Figure 4. Unbalanced Distribution of Carbon Stock in Forests

Section II: The Role of Forest Sinks for the European Union, Japan, and Canada

This section reports on and summarizes our earlier report (Amano and Sedjo 2003) that examined and compared the approach of the governments of Japan, Canada, and the European Union with respect to carbon sinks for meeting their respective Kyoto Protocol carbon reduction targets. The study examines existing as well as new government policies to stimulate the forest sector to achieve carbon sequestration by promoting ARD and forest management under Articles 3.3 and 3.4 of the Kyoto Protocol, as well as to establish a reporting system for the IPCC inventory report under Article 5.

While it is commonly believed that biological sinks are likely to constitute only a small portion of the carbon mitigation achieved to meet the various country targets, recent work by the IPCC (2001) and The National Institute for Public Health and the Environment (RIVM) (2003) suggests that the role of sinks in meeting the Kyoto targets could be much larger than recognized. The IPCC suggests that up to 20 percent of the excess carbon emissions to 2050 might be offset by biological sequestration, while the RIVM study suggests that up to 40 percent of the mitigation achieved worldwide could come from biological sinks.[4]

For each country or region, our study examines the extent to which the various governments are planning to utilize forest sequestration in attempting to meet their carbon reduction targets. The focus is on how afforestation/reforestation and forest management are being interpreted, promoted, and implemented under Articles 3.3 and 3.4 of the Kyoto Protocol across the three countries. Information used in this study was obtained from each of the three monitored regions as to the approaches and progress each was making with respect to the development of useful forest sequestration programs.

The Marrakesh Accords (2002) determined eligible activities under the CDM as "reforestation" and "afforestation" projects. The CDM provides for the implementation of carbon-reducing projects in non-Annex 1 countries that generate emission reduction units (ERUs) for the Annex 1 country. However, a CDM may be applied only to an afforestation or reforestation activity for carbon sequestration, not be carbon retained (not released) through the

[4] Part of this high percentage is due to anticipation that a substantial portion of the carbon mitigation credit will be due to credit for "hot air," which does not represent actual mitigation, although it does provide credit in meeting the Kyoto targets.

protection of an existing forest. Furthermore, there are limits as to how small the CDM forestry projects may be. Very small projects are not allowed since the monitoring costs would be quite high. Also, carbon gas removals from such projects are limited and may only be used to help meet emissions targets up to 1 percent of a party's baseline for each year of the commitment period.

Background

The approach of the governments of Japan, Canada, and the European Union with respect to using carbon sinks for meeting their respective Kyoto Protocol carbon reduction targets is currently under development and will be under development for the next several years. In articles 3.3, 3.4, 6 and 12, the agreement allows Annex I countries to take into account land-use change and forestry (sinks) activities to partly meet their carbon dioxide targets during the 2008–2012 commitment period. Article 3.3 refers to additional human activities involving forests and is compulsory, while 3.4, which refers to additional human activities involving forest and agricultural management, is optional.

When some of the rules for eligible activities were defined in Bonn and Marrakesh, they included some categories beyond 3.4 and 3.4. Article 6 and 12 refer to activities in foreign countries such as the CDM and joint implementation (JI) that may have sink components but are somewhat limited. Under article 6, JI projects can be undertaken by Annex 1 parties in other Annex 1 countries. Activities under both 3.3 and 3.4 are eligible under JI, but countries must include JI projects involving foreign management in the cap of forest management under 3.4.

At issue was the extent to which carbon sequestered by forest management activities could be counted against meeting the target carbon reductions of various countries. The agreed cap was 15 percent of current carbon sequestration totals attributable to forest management. However, for Japan, Canada, and Russia, the cap has been adjusted upward. A question that remains is whether and the extent to which the European countries, and particularly the European Union, are likely to use the sink option—something to be resolved by the individual countries during the compliance period.

European Union

Forest Sink Activities

The EU obligation under the Kyoto Protocol is an overall8 percent reduction in total emissions. This figure applies to 15 countries, although some adjustments could still be made as additional Eastern European countries join the European Union over the first compliance period of the Kyoto Protocol. Many EU countries already have imposed various types of carbon/energy taxes, although at different levels and with varying applications and exemptions, and the expectation is that much of the real emissions reduction will be generated through the energy sector.

Under Kyoto, the use of credits obtained via biological sequestration is constrained. Offsets to net emissions are subject to an 85 percent discount and an individual cap (listed in an appendix in the Marrakesh Accords, UNFCCC 2002) for each party. Also, reporting on the 3.4 article is optional. Countries have to decide if they are going to apply any or all the activities under 3.4 and they must declare which activities they are going to use at least two years prior to the beginning of the commitment period. This is also the deadline for changing the cap values for forest management (3.4). If they wish a reevaluation of these values, they have to submit new data up to 2006. The European Union is working as a unit to meet its emissions targets and the whole European Union could be in violation if some individual countries don't meet their targets.

In addition, the use of the land, land-use change, and forestry (LULUCF) activities remains controversial and countries have the right to choose not to use them. Sweden, for example, already has stated a policy of not using forest carbon sink credits (see below). Should a country chose not to use LULUCF to obtain carbon credits, then it will not be liable for emissions that occur on those lands. Some believe that Article 3.3 is likely to be significant in only a few countries, such as Ireland and some of southern Europe (Schlamadinger 2002).

The EU forest sink activities to mid-2002 are examined in a RIVM report (Petroula 2003), and this part of the study draws heavily upon in that report. The RIVM report develops data both through national communications, a system of regular communication among the countries established by the Kyoto Protocol, and from country specific data sources. According to Petroula (2002), the current preliminary evidence suggests that within the 15 existing EU countries, sinks are expected to contribute an average of about 2 percent of individual country reductions, with a range of one to 4 percent. However, sinks are not a high priority and the

anticipated delay in making final decisions could result in contributions that vary substantially from that level.

Additionally, Petroula argued that the various accounting systems and indicators make an accurate quantification of potential carbon sequestration difficult since new, improved guidelines on LULUCF-related activities were to be produced in 2003. However, the good practices guidelines developed from the 2003 process, which interpret the earlier rules established in Bonn and Marrakesh, still found accurate quantification difficult (Amano 2006).

EU Member Country Situations

The various members of the European Union are at various stages in providing updated estimates on sinks in their third national communication. For some countries, such as Finland, Sweden, the Netherlands and the United Kingdom, the updated estimates were developed from a combination of national communication data and country-specific data. Others, such as Austria, Denmark, and Germany, based their updated projections on country-specific data. Still other countries use additional sources of mostly national data. Many countries are still in the process of developing complete and current data and projections.

Most EU countries are expected to report carbon debits under Article 3.3 (ARD) and thus will not receive any credits. Furthermore, the data suggest that the majority of countries may reach or exceed their forest management cap. Biological sinks for the EU are estimated on a country-by-country basis by Petroula (2002).

Survey estimates of the countries' intentions toward the use of forest and agriculture management projects under Article 3.4 of the protocol suggest that most of the countries' intentions remain uncertain.

One question that remains is whether and the extent to which the European countries, and particularly the European Union, are likely to use the sink option. This will be resolved by the individual countries during the compliance period. A final option available to countries is the purchase of "hot air" credits; that is, excess credits available from Russian and other countries of the former Soviet Union that may be available due to their lower levels of economic growth from the projected baseline and the renovation of their carbon-emitting sectors. Table 1 gives the base-year (1990) emission levels and the reduction targets under the Kyoto Protocol. Table 2 gives the forest carbon caps provided under Article 3.4 for forest management.

Table 1. Base-Year Emissions (1990)

Party: Selected Countries	Emissions Mt CO_2/yr.	Percentage of Total	Reduction as % of base year
Austria	59,200	0.4	92
Belgium	113,405	0.6	92
Bulgaria	82,990	0.6	92
Canada	457,441	3.3	94
Czech Republic	169,514	1.2	92
Denmark	52,100	0.4	92
Estonia	37,797	0.3	92
Finland	53,900	0.4	92
France	366,536	2.7	92
Germany	1,012,443	7.4	92
Greece	82,100	0.6	92
Hungary	71,673	0.5	94
Iceland	2,172	0.0	110
Ireland	30,719	0.2	92
Italy	428,941	3.1	92
Japan	1,173,360	8.5	94
Latvia	22,976	0.2	92
Liechtenstein	208	0.0	92
Luxembourg	11,343	0.1	92
Monaco	71	0.0	92
Netherlands	167,600	1.2	92
New Zealand	25,530	0.2	100
Norway	35,533	0.3	101
Poland	414,930	3.0	94
Portugal	42,148	0.3	92
Romania	171,103	1.2	92
Russian Federation	2,388,720	17.4	100
Slovakia	58,278	0.4	92
Spain	260,654	1.9	92
Sweden	61,256	0.4	92
Switzerland	43,600	0.3	92
United Kingdom	584,078	4.3	92
United States of America	4,957,022	36.1	93

Source: UNFCCC, The Kyoto Protocol, http://www.unep.ch/iuc/.

Table 2. Forest Carbon Caps by Country under Kyoto[1]

Party	Mt C/yr.
Australia	0.00
Austria	0.63
Belarus	
Belgium	0.03
Bulgaria	0.37
Canada	12.00
Croatia	
Czech Republic	0.32
Denmark	0.05
Estonia	0.10
Finland	0.16
France	0.88
Germany	1.24
Greece	0.09
Hungary	0.29
Iceland	0.00
Ireland	0.05
Italy	0.18
Japan	13.00
Latvia	0.34
Liechtenstein	0.01
Lithuania	0.28
Luxembourg	0.01
Monaco	0.00
Netherlands	0.02
New Zealand	0.20
Norway	0.40
Poland	0.82
Portugal	0.22
Romania	1.10
Russian Federation	33.00 [2]
Slovakia	0.50
Slovenia	0.36
Spain	0.67
Sweden	0.58
Switzerland	0.50
Ukraine	1.11
United Kingdom	0.37

[1] The list of countries in this table differs from that found in decision 5/CP.6 as a result of consultations undertaken during the session.

[2] This figure initially was 17.63 but was increased to 33.00 Mt/C/yr by decision 12/CP.7 (forest management activities under Article 3, paragraph 4, of the Kyoto Protocol: The Russian Federation).

Source: UN FCCC/CP/2001/13/Add.1, English, p. 63.

Table 3 provides estimates of biological sinks, using current data, for the European Union on a country- by-country basis. The final column provides estimates of the percent of base-year emissions that potentially could be covered by sinks, given the 15 percent rule of Kyoto accounting. It ranges from 0.3 percent in Italy to 4.0 percent in Austria and Sweden.

Table 3. Estimates on the Removals of Sinks during the First Commitment Period (based on all available data)

	Base-year emissions	Max. estimates for sinks art. 3.3 & 3.4	Estimates for actual sinks art. 3.3 & 3.4 if art. 3.4 used	Max allow-ance for CDM sinks	Actual CDM sinks, if used	Possible total sinks either max. or actual, if art. 3.4 and CDM used	Estimates % base-year emissions
	MtC/yr	MtC/yr	MtC/yr	MtC/yr	MtC/yr	MtC/yr	MtC/yr
EU 15							
Austria	21.04	0.63	≤0.63	0.21	≤0.21	≤0.84	4.0
Belgium	37.24	0.03	<0.03	0.37	≤0.37	≤0.40	1.1
Denmark	19.08	0.14	!	0.19	≤0.19	0.33	1.7
Finland	20.51	0.16	≤0.16	0.21	≤0.21	≤0.37	1.8
France	148.96	0.88	0.88	1.49	0.45	1.33	0.9
Germany	330.28	1.24	≤1.24	3.30	≤3.30	≤4.54	1.4
Greece	29.28	0.09	!	0.29	≤0.29	0.38	1.3
Ireland	14.59	0.41	0.28	0.15	≤0.15	≤0.43	2.9
Italy	141.64	0.65	!	1.42	1.15	~1.8	0.3
Luxembourg	3.67	0.01	≤0.01	0.04	≤0.04	≤0.05	1.4
Netherlands	59.77	0.06	0.055	0.60	≤0.60	≤0.65	1.1
Portugal	17.12	0.22	!	0.17	≤0.17	0.39	2.3
Spain	84.13	2.53	2.08	0.84	≤0.84	≤2.92	3.5
Sweden	19.25	0.58	≤0.58	0.19	≤0.19	≤0.77	4.0
UK	208.84	1.22	≤1.22	2.09	≤2.09	~3.31	1.6

Source: Petroula, 2002

CDM = Clean Development Mechanism

The issue of to what extent the provisions of article 3.4 (forest and agricultural management) will be used has yet to be determined in many countries. Table 3 provides a preliminary judgment of the current intentions of the EU countries based on Petroula (2002).

Table 4 provides survey estimates of EU countries' intentions toward the use of CDM and JI projects. At the time of the survey, The Netherlands appeared most likely to use both CDM and JI. It would like to use the CDM to coordinate projects that promote AR-CDM carbon

sequestration and sustainable forestry in developing countries. Denmark was positively inclined toward JI but negatively inclined toward CDM. Italy was positively inclined toward CDM. The intentions of the remainder of the countries remain uncertain. Conversations with EU researchers and policymakers suggest that the union is unlikely to take full advantage of forest sinks. For example, Frank Messussen, Consular, Belgium Cabinet Minister of Federal Defense and Environment, mentioned a series of new fossil fuel carbon-generated taxes, incentives for insulation, higher gas prices, lower public transportation prices, and new wind powered electrical generation facilities. Forest carbon was almost disregarded in the European group, with expectations that any remaining obligations would be met from Russian "hot air."

Table 4. Countries Intentions toward the Use of CDM and JI Projects

	Use of CDM and JI	
	CDM	JI
EU 15		
Australia	?	?
Belgium	?	?
Denmark	?/-	?/+
Finland	?	?
France	?	?
Germany	?	?
Greece	?	?
Ireland	?	?
Italy	?/+	?
Luxembourg	?	?
Netherlands	?/+	?/+
Portugal	?	?
Spain	?	?
Sweden	?	?
United Kingdom	?	?

Source: Petroula, 2002
CDM = Clean Development Mechanism JI = Joint Implementation
+ = Yes -= No
? = not decided yet
?/+ = not decided yet, but possibly yes
?/- = not decided yet, but possibly no

Although Norway is not now part of the European Union, it has no plans for either biological sequestration or major biomass approaches. Most of Norway's electricity is generated by hydropower, but a cap is expected for carbon emitted by its North Sea gas-powered

generators. Norway is, however, looking for some form of hydrogen separation from oil that would allow carbon dioxide to be geologically sequestered (Greaker 2003).

Table 5 provides survey estimates of the EU countries' intentions toward use of forest and agriculture management projects under Article 3.4. France, Ireland, and Spain appear most likely to use forest management activities to assist in meeting their carbon targets. However, these countries are not inclined to undertake agricultural management for carbon objectives. The United Kingdom is the only county with a positive inclination toward agricultural management. Most countries' intentions remained uncertain at the time of the survey.

Table 5. Countries Intentions Toward the Use of Article 3.4 (Forest and Agricultural Management)

	Use of Article 3.4	
	Forest Management	Agricultural Activities
EU 15		
Australia	?	?
Belgium	?/+	?/-
Denmark	?	?
Finland	?	?
France	+	-
Germany	?	?
Greece	?	?
Ireland	+	-
Italy	?	?
Luxembourg	?	?
Netherlands	?	?
Portugal	?	?
Spain	+	-
Sweden	?	?
United Kingdom	?/+	?/+

Source: Petroula, 2002
+ = Yes -= No
? = not decided yet
?/+ = not decided yet, but possibly yes
?/- = not decided yet, but possibly no

Japan

The Kyoto Protocol requires Japan to reduce emissions 6 percent of its 1990 base, when emissions totaled 1,229 million tons of carbon dioxide. By 1999, however, such emissions had

risen about 7 percent above the base to 1,314 million tons. Furthermore, under current conditions, predictions call for emissions of 1,320 million tons in 2010. Thus, to meet the protocol's target, emissions must be reduced 165 million tons, or 13 percent, from the predicted 2010 level.

Basic Approach

The basic approach of the Japanese government is to hold energy use and emissions constant or have them decline from current levels by virtue of a program that calls for a reduction of 22 million tons of emissions through public efforts, largely voluntary, and various emissions reducing technological improvements. The program includes more than 100 domestic measures and policies. The introduction of wind, bioenergy, and other new energy sources, plus fuel conversion from coal to natural gas and a 30 percent increase in nuclear energy, will all provide increasing energy outputs without generating additional carbon dioxide emissions. Also, carbon dioxide emissions from non-energy uses are expected to decline slightly. The program seeks to expand the total share of new, non-carbon-emitting energy from 1 to 3 percent during the first commitment period (van Kooten 2004).

Finally, Japanese government's "New Climate Change Program," adopted in March 2002, seeks to develop policies and measures necessary for the achievement a 6 percent emissions reduction from the 1990 base (Table 5). The new climate change program should be viewed as a step-by-step program that will be revised periodically to meet the GHG emissions targets of the Kyoto Protocol.

The Role of Forests

Whereas forest sequestration is likely to account for a maximum of no more that 4 percent of the targeted carbon reductions in the European Union, the role of forest sinks in Japan is expected to be large, accounting for more than one-half of the targeted reductions from the base and up to one-quarter of the reductions from the business-as-usual 2010 level. Under the Kyoto targets, Japan is allowed credits of up to 13 million tons of carbon per year from forest sequestration, which can be used against its emissions.

Table 6: Japan's Quantitative Targets for Greenhouse Gases and Sectors

CO_2 emissions from energy use	± 0%
CO_2 emissions from non-energy use, methane emissions, and nitrous oxide emissions	-0.5%
Emissions of HFCs, PFCs and SF_6	+2.0%
Reductions by innovative technologies and change of lifestyle	-2.0%
The use of sinks	-3.9%

HFCs = Hydrofluorocarbons

PFCs = Perfluorocarbons

SF_6 = Sulfur Hexafluoride

Source: "The New Climate Change Policy Programme," March 19, 2002 (tentative translation).

Table 6 gives Japan's quantitative targets for GHG changes by sector for achieving the initial 6 percent reduction below the 1990 baseline level. Meeting that objective would require that Japanese forests sequestrate about 13 million tons of carbon annually—an amount equal to the maximum forest sink credit allowed for Japan under the protocol or more that half of the national annual target of 25 million tons of carbon reduction by 2010. Japan has a relatively young forest. Well over half of the forest area covered by trees regenerated since the end of World War II. As these forests continue to mature, they will increase substantially the amount of sequestered carbon. However, to meet the 13 million ton target, additional amounts of carbon must be captured.

Under a business-as-usual approach, domestic production of timber from Japanese forests is expected to be about 25 million cubic meters in 2010. However, it may need to be reduced to 17–18 million cubic meters so that the forests can sequester the requisite additional carbon. Accomplishing this objective while meeting the economy's needs for industrial wood may mean importing wood to fill the gap. Note that although this would allow Japan to meet its Kyoto target, it would simply push timber harvesting offshore. More than either the European Union or Canada (see below), Japan appears to be poised to use carbon sinks to meet it's Kyoto targets.

Canada's Climate Change Plan

Within the context of the Kyoto Protocol, Canada has committed to an emissions reduction of 6 percent or 240 megatons (MT) of carbon dioxide below the base year of 1990.[5] Canada released its Climate Change Plan in November 2002, outlining how it plans to achieve its Kyoto target, including creation of an emissions trading system. Canada's 2005 climate change plan reaffirmed the government's intent to implement a trading program for the GHG emissions of large final emitters (Government of Canada 2005)—a domestic emissions trading system (DETS) in which emissions reduction credits could be traded.

Canada anticipates sequestering 10 MT of carbon dioxide in agriculture and 20 MT in forestry from business-as-usual activities over the 2008–2012 period. Agricultural sequestration could be increased to perhaps 16 MT with appropriate incentives. However, emissions associated with the pine beetle infestation could make increasing the forest sequestration exceedingly difficult (Haites 2005).

The Climate Change Plan for Canada sets out a three-step approach for achieving Canada's objective of reducing annual GHG emissions by about 240 MT of carbon dioxide[6] (65.2 MT of carbon) and carbon dioxide equivalents. First, there are investments to date that will address one-third of the total reduction, or 80 MT of carbon dioxide (or 21.8 MT of carbon). Second, the plan articulates a strategy for a further reduction of 100 MT of carbon dioxide annually (or 27.2 MT carbon). Finally, the approach outlines a number of actions that should enable Canada to effectively address the remaining 60 MT of carbon dioxide (or 16.4 MT carbon).

Offset credits, which could be created by the sequestration of carbon in forest, agricultural systems, or reduced gas releases from landfills, could play a role in supplementing the emissions credits.

The DETS would be based on limiting carbon emissions from much of the economy's energy and industrial sectors. The outline of the system has yet to be finalized, but it would be similar to the following system, which includes early numbers under consideration. Emission permit allocations would be tied to recent or current sector and firm output levels. The

[5] The new Canadian Government announced on April 25, 2006, that it will not be able to meet the targets of the Kyoto Protocol. http://www.cnn.com/2006/WORLD/americas/04/25/canada.kyoto.reut/ (accessed May 8, 2006).

[6] Canada reports carbon dioxide instead of carbon, as is commonly reported. Note that it takes 44 tons of sequestered carbon dioxide to sequester 12 tons of carbon.

reduction in emissions is expected to be negotiated on a subsector-by- subsector basis, although it will average 15 percent for the affected sectors. However, the emissions reductions will not be an absolute figure but will be related to output. For example, if output increased by 15 percent, the absolute level of emissions allowed could remain unchanged, even as the target of a 15 percent reduction in emissions to output was met. Thus, the emissions targets are expressed in terms of "emission intensity targets" rather than in absolute levels of emissions reductions. This approached has raised questions about the international tradability of Canadian emissions credits in that they are different from other credits, such as European credits, since they do not represent an absolute amount of emissions reduction but a reduction in emissions intensity. This also implies that in a period of rapid industrial expansion, Canada may meet it 15 percent reduction in carbon emissions intensity but not meet its anticipated overall Kyoto target industrial sector emissions reductions.

Canada has been examining a proposed offset system for GHGs designed to encourage cost-effective, incremental reductions or removals (carbon storage) of GHGs in activities not covered by federal GHG regulations. Projects are expected to include forest and agricultural soil sinks. These could provide additional domestic credits by allowing carbon offset credits for certain types of certified domestic forestry and agricultural activities, as well as provide credits for capping GHG-emitting landfill emissions.

The recent election has brought in a new government that is not particularly friendly to the Kyoto process. Thus, it remains to be seen how actively the new government pursues the Kyoto objectives and targets.

Forest Industry Potential

Within this overall context, the Canadian forest industry could have a potentially important role. The phases of the forest industry are as follows:

- forest establishment;
- forest management, including harvesting and forest regeneration;
- transport;
- mill operations;

- further transport; and
- consumers.

Emission reductions could occur in several different ways. Establishment, forest management practices, transport, and mill operations allow for various forms of conservation that can capture or reduce carbon and/or increase efficiency to get more output from less energy, thereby reducing emissions per unit of output. Replacement is another option; biofuels could substitute for fossil fuels, as well as be a carbon sink before their harvest. Non-sink approaches include variants of the hydrogen economy, solar, and wind energy. Removing carbon—biological sequestration—is a third option. Forest growth, forest soils, longer rotations between harvests, full forest stocking, and immediate regeneration all promote greater sequestration. The focus of the following section is on removal options under consideration in Canada.

It is estimated that the Canadian forest sector will sequester roughly 35 MT of carbon dioxide annually in the first Kyoto commitment period from the managed forest (i.e., the net effect of forest growth, harvesting, and natural disturbances in the managed forest), as well as about 1 MT from business-as-usual afforestation/reforestation, while releasing about 16 MT from deforestation. Under the Kyoto Protocol, Canada is allowed 44 MT of carbon dioxide sequestration from forest management (under Article 3.4), as well as an unlimited amount from agriculture activities. However, it must select to use the biological sequestration option by 2006. Also, if there are net carbon emissions resulting from ARD, Canada can use removals from forest management to offset this debit up to a limit of 9 million tons.

Issues that arise with forest carbon sinks include measurement and monitoring, but these appear to be manageable (e.g., see Sedjo and Toman 2001). Much of the current focus is on the issue of permanence.

Canada perceives a basic carbon "gap" of about 240 MT between its Kyoto target and its likely business-as-usual carbon emissions.[7] Specifically for forestry, Canada is allowed to claim up to 44 MT of carbon dioxide (12 MT carbon) from forestry against its Kyoto Protocol emissions reduction target of 240 MT, or 18.3 percent from forestry. Of this, roughly 20 MT, or 11.8 percent, will result from existing forest management practices (from Article 3.4). A net of

[7] Canada's 2003 emissions were almost 25 percent above its Kyoto target; that is, the reduction below the 1990 baseline plus the increases since 1990.

5.4 MT of additional sequestered carbon dioxide will be captured after accounting for the estimated net debit from business-as-usual ARD (from Article 3.3). Additional actions "underway" are estimated to generate another 8 MT of carbon dioxide (2.2 of carbon). However, only a portion of the 8 MTs are forest sink removals—most of it is agriculture and landfills. That portion that is forest sinks comes from potential new afforestation efforts. The total is 28 MT (Canadian Climate Plan 2002), which is about 11.7 percent of the total targeted reduction. Since the allowable total forest sequestration for Canada is 44MT, this leaves a possible remaining potential (or shortfall) of 20 MT, or 10 percent of the total target that is eligible, still to be met by forestry.

To expand its use of forestry to meet the allowable forest sequestration target, Canada will almost certainly provide for the development of a number, potentially a large number, of carbon forest projects. And there is some question of how much of this 24 MT could be generated in time to be realized during for 2008–2012 compliance period. Offset credits would be given to investors to the extent that the amount of sequestered carbon exceeded that expected in the business-as-usual or baseline case.

Recent Updates for Canada[8]

By definition, business-as-usual sinks are the result of the continuation of existing practices. However, it is estimated that Canada's biological sinks can play a much greater role in fighting climate change. Biological carbon sequestration beyond business-as-usual levels could be achieved through the Climate Change Action Fund, a fund established by the Canadian government in 2005 to purchase GHG reduction and removal credits generated in Canada and abroad, and through government initiatives aimed at protecting ecological lands. It is estimated that the potential for beyond business-as-usual agriculture and forest sinks is on the order of 15–20 MT of carbon dioxide. How best to measure and induce incremental carbon sinks will be determined in partnership with the provinces, territories, aboriginal peoples, farmers, forestry companies, and other stakeholders.

In agriculture, business-as-usual practices are predicted to generate a carbon sink of 10 MT in the Kyoto commitment period of 2008–2012. An incremental sink of 16 MT or more beyond business-as-usual levels may be possible through practices such as reduced tillage, less summer fallow, and increased use of forage, which could be promoted through the climate

[8] From: http://www.climatechange.gc.ca, accessed December 5, 2005.

fund. Incremental emissions reductions from agriculture could result from activities such as revised beef feeding strategies and hog manure management.

With respect to forestry, the projection in the *2002 Climate Change Plan for Canada* was that existing forest practices would result in a carbon sink of 20 MT. Federal and provincial governments currently are working toward a revised estimate; that estimate could fall to zero as a result of the pine beetle infestation and forest fires in British Columbia. However, an incremental sink of 4 MT beyond the 20 MT originally expected may be possible through practices such as ARD, which could be achieved through the new climate fund.

Summary

This paper examines and compares the approaches of the governments of Japan, Canada, and the European Union with respect to carbon sinks for meeting their respective Kyoto Protocol carbon reduction targets. The study examines various proposed government policies to stimulate the forest sector to achieve carbon sequestration by promoting ARD and forest management under Articles 3.3 and 3.4 of the Kyoto Protocol. It also touches on the establishment of a reporting system for the IPCC inventory report under Article 5.

The general finding is that Japan plans to rely most heavily on forest and biological sinks to meet its Kyoto targets, largely through CDM. Sinks are likely to play a modest role for Canada, although the role has been increasing. For the European Union, the role of sinks is likely to be even smaller, with sinks playing no role for some EU countries, such as Sweden. However, the final decisions have not been made for any of these countries and the actual role of sinks remains to be determined. All three regions anticipate some use of forest sinks in meeting Kyoto targets (Table 7). However, a recent assessment of the situation in these three regions reveals that only the European Union has reduced carbon emissions since 1990 (Table 8). Both Japan and Canada have increased emissions substantially and both will require substantial reductions if they are to meet their Kyoto targets.

Table 7. Forest Sink Use: Potential and Anticipated

Country	% Kyoto target reduction allowed by forest sinks	% Kyoto target reductions anticipated
European Union	3%	2%
Japan*	65%	50%+
Canada	18%	8–10%

* To achieve only the 6% reduction.

Source: Amano and Sedjo (2003).

Table 8. Kyoto Situation: European Union, Japan, and Canada

Country	Forest Sink CAP	Kyoto Protocol target as % of 1990 base	Actual 2003 % of 1990 base*
European Union	8.9 Mt	-8.0 %	-1.4 %
Japan	13 Mt	-6.0 %	+12.8 %
Canada	12 Mt	-6.0 %	+24.2 %
USA*	50 Mt	-7.0 %	+13.3 %

*For comparison, not a party to the Kyoto Protocol.

Source: IPCC 2005. http://www.climatechange.gc.ca

Section III: Prospects for Forest Carbon Sinks in the Post-Kyoto Era

With the of the Kyoto Protocol compliance period of 2008–2012 approaching, analysts and policymakers around the world are beginning to consider how to evaluate the effectiveness of the Kyoto Protocol and are anticipating the post-Kyoto world. Criticisms of the Kyoto Protocol are many, including the characterization of it as overly inflexible and concerns about cost containment (Bodansky et al. 2004). There also is concern that the current protocol discourages the participation of major countries, especially the United States (Egenhofer et al. 2004; JMETI 2004). Additionally, there is widespread recognition that the continuation of a Kyoto-type process without involving China , India, Brazil, and other major countries of the developing world in the emissions targeting process would not only almost surely ensure that the United States will not participate but would be fundamentally futile for meeting long-term targets.

This section of the report first reviews current and emerging thinking on the role that forest sinks might play in climate policy arrangements in the post-2012 period. The report examines important new and ongoing work on institutions and trading arrangements that may be useful in successfully exploiting forest sequestration potentials. Second, we follow the development of mechanisms for providing credit and trading mechanisms for carbon offset credits (for some recent work, see Sedjo and Marland 2003, 2004). The ability to freely trade these credits in established markets it important to providing additional flexibility in the use of forest sinks and will make them much more attractive for future use.

The Post-Kyoto Era

It is clear that no matter what the fate of the Kyoto Protocol, countries will continue to undertake substantial activities to address the continuing problem of global climate change and, in particular, global warming. There are many post-Kyoto possibilities. One is that the Kyoto targets will be largely missed and the entire approached will be viewed as highly flawed. This could result in a new approach that is very different. Such an approach would recognize the limitations of the current protocol in it ability to achieve the targets, the very high costs associated with achieving the targets, as well as the difficultly in gaining the participation of major countries, particularly the United States. It would also recognize the absence of substantive participation by much of the developing world, including China, India, and Brazil. At the other extreme, the Kyoto Protocol may proceed successfully through the 2008–2012 compliance period with most of the targets achieved and countries demonstrating that the costs

need not be prohibitive. A successor agreement may be reached that has many features in common with the Kyoto Protocol, with updated targets and the involvement and active participation of many of the countries not now involved.

In any event, the development of the current Kyoto Protocol and efforts to achieve the targets will provide the world community with a new understanding as to the strengths and weaknesses of the protocol. This new understanding can provide the basis for efforts to create a post-Kyoto climate program. This paper tries to anticipate the role that forest sinks might play in post-Kyoto arrangements.

Participation of the United States and Major Developing Countries

It is clear that future climate agreements should try to ensure the active participation of the United States. The absence of U.S. participation in the Kyoto agreement reflected concerns both by the Bush administration and the U.S. Senate, which has the responsibility of ratifying international agreements. Prior to the 1997 meeting at Kyoto, the Senate made it clear—by a 95 to 0 vote—that it expected broad and substantial participation by both developed and developing countries. The decision in Kyoto not to require carbon reduction targets for developing countries ensured that the Senate would not ratify the agreement. Additionally, the Bush administration was fundamentally hostile to the targets in the agreement, believing them overly costly to achieve. Third, there was concern about the effects of meeting the targets on the competitiveness of U.S. manufacturing. Some analysts suggest that alternatives to the Kyoto Protocol be carefully considered with an eye to future reengagement of the United States (Tjernshaugen 2005). Whereas the Kyoto Protocol largely emphasized conservation to meet carbon reduction targets, the United States has pursued a fundamentally different approached, one which emphasizes energy technology research toward the end of developing new, carbon-reducing technologies. Examples include the International Partnership for the Hydrogen Economy and the Methane to Markets Partnership. A conservation approach and an energy technology approach are, of course, not mutually exclusive.

It is unlikely that any president could get the Senate to ratify a Kyoto-like agreement that did not involve China, India, and Brazil in a major way. Thus, at a minimum, United States participation in future Kyoto-like agreements will require much broader developing world involvement and participation.

The Rationale for the Continued Use of Forest Sinks

Although certain countries (particularly those in the European Union) are resistant to the use of biological and forest sinks, there is a compelling rationale for their continued role in addressing climate change. It has long been recognized that forest sinks offer among the most efficient, low-cost ways of addressing atmospheric carbon. As noted previously in this report, recent studies indicate that the use of sinks very substantially reduces the costs of meeting long-term GHG atmospheric targets. Additionally, the technology currently is available. Finally, many of the proposed activities, such as tree planting, provide other substantial non-carbon environmental benefits.

However, forests and biological sinks do not allow for unlimited sequestration of carbon. Thus, at best, forest sinks can be just one of a set of instruments used to mitigate the build-up of carbon in the atmosphere. Nevertheless, the amount of carbon that can be captured in forest and biological sinks at a reasonable cost is very substantial—up to 20 percent of excessive emissions over the next 50 years, according to the Third Assessment Report of the IPCC (2001). Also, forest sinks involve the utilization of techniques and technologies already well developed. The global community knows how to plant and grow trees. These approaches could be used in the near term, over the next two to five decades, while improved technologies are developed to address the carbon problem over the longer term. Thus, it would not be rational for the world to ignore the potential of forests for sequestering carbon as a vehicle to address the problem global warming.

Forest sinks also offer an opportunity to address other important social issues. Ignoring the sequestration potential of forest sinks would also involve ignoring the array of potential damages from continued deforestation. Tropical deforestation and degradation are widely recognized as a problem through the tropical world.

Additionally, geo-political realities almost guarantee a continued role for forest sinks. Major countries such as the United States, Canada, Australia, and perhaps Russia, will probably insist that forest sinks be part of any broad international agreement on carbon mitigation. Also, China, India, and Brazil could well find forest sinks a useful vehicle for helping them reduce emissions in any future agreement. Should the world community chose to proceed in the post-Kyoto period without large formal arrangements, an unlikely prospect, major countries could still use forest sinks as a tool to meet their nationally determined goals, as demonstrated in the role for sinks in the proposed McCain–Lieberman legislation in the United States (see below).

Finally, in articulating a strategy for Europe, Tjernshaugen (2005) argues for including a well-functioning emissions trading system, which will strengthen the hand of U.S. proponents of similar regulatory approaches. The existence of emissions trading systems creates opportunities for parallel trading systems involving permanent and temporary biological carbon sequestration (Sedjo and Marland 2003).

Some Possible Extensions of Forestry

There are a number of possibilities for extending the modes for utilizing forestry to sequester carbon. Some forest sinks are not included in the Kyoto Protocol as it is currently interpreted. One area that is ignored is long-lived wood products, such as lumber and building materials. Currently, it is assumed that once a tree is harvested, all of its carbon is released. This approach assumes that the net stock of carbon in long-lived wood products is unchanging. In fact, about one-half of the harvested industrial wood goes into wooden products with extended lives. Hence, the carbon remains captive for years, decades, and even centuries. Credit could be given for the sequestration of this carbon. However, it must be recognized that while new wood materials are being added to the stock of wood products, the stock also is experiencing releases as wood decomposes, is burned, or otherwise releases carbon.

Another area for consideration is existing natural forests. Although the Kyoto Protocol does not recognize avoided deforestation as worthy of carbon credits, such avoided deforestation ultimately may be a necessary part of maintaining a livable world in which GHG emissions are managed. For example, Papua New Guinea has proposed that carbon credits be provided for protecting existing native forests.[9] Thus, in examining role of forestry in the post-Kyoto efforts to control carbon, a wider perspective, including incentive credits for preserving existing forests, should be considered. This wider perspective could generate social benefits, both through carbon emissions mitigation and through other social and environmental benefits associated with forests.

Such an approach would begin with the development of a country forest carbon baseline. Credits could then be generated by various programs that would result in forest sequestration above the baseline. The baseline could be constructed by using the estimate of the forest and its carbon at some time point. Alternatively, an intertemporal baseline might be constructed by projecting the forest carbon through time and providing credits for amounts sequestered in

[9] FCCC/CD/2005?misc.1 11 November 2005.

excess of baseline levels. Care must be taken, however, in establishing the baseline. The smaller the area involved, the larger the likely leakage. Thus, the baseline probably should involve a forest area at least as large as that of the country.

COP 9 and Forest Sinks

Among the important outcomes of COP 9 were decisions on the technical rules for sink projects in the CDM. In the Marrakech Accords at COP 7, the parties agreed to allow afforestation and reforestation projects under the CDM but did not agree on the detailed rules for such projects. In Milan, the parties adopted a decision setting forth the modalities and procedures for sink projects in the first commitment period, with the treatment of sink projects under the CDM for the second period to be decided as part of the second commitment period negotiations.

The main issue has been how to address the non-permanence of sink projects. In particular, if a sink project is destroyed, such as when a forest burns down, who should be liable—the project developer, the host country, or the holder of the Certified Emission Reductions (CERs)? The COP 9 makes the holder liable by making CERs generated from sink projects of limited duration. The decision defines two types of CERs: temporary CERs (tCERs), which are valid for only one commitment period, and long-term CERs (lCERs), which are valid for the project's full crediting period. Sink projects can have a crediting period of either 20 years, with the possibility of two renewals up to 60 years total, or 30 years with no renewal.

CERs cannot be banked and thus both types must be used for the commitment period for which they were issued and both must be replaced by another credit (assigned amount units [AAUs], emission reduction units [ERUs], or CERs) prior to their expiration. Project participants can choose which of the two types of CERs to use. In practice, the two approaches are similar. The tCERs will be reissued if a sink project still exists; however, lCERs will need to be replaced before the end of the crediting period if monitoring indicates that the sequestration from a sink project has been reversed.

The COP 9 also addressed the issues of additionality, leakage, and uncertainties regarding socioeconomic and environmental impacts. The agreement also defines small-scale projects, which are eligible for fast-track approval, as those that results in net anthropogenic sequestration of less than 8 kilo tons of carbon dioxide annually and are developed or implemented by low-income communities or individuals. Modalities for small-scale projects were considered in COP 10.

Concerns with Forest Sequestration and the Kyoto Protocol

A concern with the role of forest sequestration in the Kyoto Protocol is the issue of distribution of forest carbon benefits and equity among nations. On the one hand, it is necessary to create an agreement that is perceived as fundamentally fair so as to encourage broad participation. For example, the U.S. decision not to participate in the Kyoto Protocol was, in part, the result of its perception of unfairness that the European Union was allowed credit for activities that were already underway and, therefore, not additive.[10] For instance, East German energy improvement initiatives and the United Kingdom's switch from coal to natural gas were credited, while credits were severely constrained for the large amount of carbon captured each year in existing managed forests in the United States—which was based on the assumption that this was not additive. Ensuring future perceptions of fairness may involve the substantive participation of major developing countries, such as China, India, Brazil, which are likely to have an interest in utilizing biological and forest sequestration.

The Clean Development Mechanism

Many smaller countries, however, do not have significant potential for forest sequestration and thus have little interest in this approach. The more active utilization of forest CDMs could be one vehicle to stimulate interest by the smaller industrial countries. The CDM provides for Annex I nations (industrial nations with specific targets) to cooperate with non-Annex I nations to undertake carbon mitigation projects in developing countries for credits. However, the CDM as presently structured appears to have several flaws. First, by limiting the maximum credit for forest CDM projects to one percent of the total requirement of the industrial country, the Kyoto Protocol severely restricts the use of such an approach. A number of industrial countries, such as Japan and The Netherlands, appear to be interested in a broader use of forest CDMs, both for meeting carbon targets and as a vehicle to further global sustainable forestry. A second concern with the CDM is its limited acceptance of proposed projects thus far and the almost complete absence of acceptance of forestry projects.[11] As of November 28, 2005, the CDM pipeline contained 477 projects, according to the UN Environmental Programme's (UNEP) Risoe Centre. Of these, 66 have requested registration and 36 are registered. At this point, only one afforestation project was approved.

[10] The Kyoto Protocol calls for activities that can be used as "credits" toward meeting a country's GHG mitigation target to be "additive" in the sense that they would not have occurred in a business-as-usual situation.

[11] Sometimes referred to as (afforestation/reforestation) AR-CDM activities.

One of the problems seems to be that the CDM views additionally in forestry very narrowly. A given site is viewed as having a given productivity potential. Thus, it is either economically viable, and therefore doesn't qualify for the CDM, or it is not economically feasible, in which case it may qualify but is uninteresting to investors. However, productivity and output in forestry can be measured at different levels depending on the management regime and the type and volume of inputs utilized. Thus, a site that is marginally economically viable could be made to be more productive (and sequester more carbon) by the addition of more management inputs. Thus, economically viable sites could fit into the CDM program if credit were provide for the additional carbon induced by the carbon credit over and above that generated in the absence of carbon credits.

Trexler and Broekhoff (2006) suggest that much of the problem with carbon offsets for forestry in the CDM is related to the question of additionally. They suggest that this question needs to be treated as a statistical problem, recognizing that some areas may be included that are not additional, while other areas may be excluded that are really additional.

Overall, the CDM seemed to get off to a very slow start, with most of the original proposals being rejected. It is also notable that the methodologies in the CDM guidebook developed by the UNEP do not include any tree or biological projects. Thus, overall, a major mechanism for biological sequestration does not appear to be functioning effectively. How well it will function over a longer period remains to be determined.

Post Kyoto: Some Broad Considerations

There seems to be a growing consensus that the Kyoto Protocol suffers from a number of defects and that the recognition these defects is likely to provide the basis for post-2012 changes in climate change offsetting activities.

There is also an emerging consensus that the ultimate "solution" is technological. For example, Dr. Scott Barrett, Professor of Environmental Economics and International Political Economy at John Hopkins University, specializes in the strategy of negotiating international environmental agreements. His thesis is that we must seek a treaty that does not rely on enforcement but rather encourages a technological solution to the problem of climate change.

Barrett says that the Kyoto Protocol faces three possible fates: not entering into force, entering into force but with significant noncompliance, or entering into force with compliance, but failing to succeed in its stated goals because it does not change behavior. The first possibility

has not occurred, as Russian ratification ensured that the agreement would come into force. The second fate, significant noncompliance, remains to be seen. Some observers believe that many major countries will fall far short of meeting the designated targets (van Kooten 2003) because the protocol has inadequate measures to constrain behavior. The third possibility also is related to the inherent inadequacy of the treaty, which does not consider situations such as the lack of developing country targets and the distribution of "hot air" credits, which do not represent any real additional benefits to the atmosphere. Because of these weaknesses, and the factor that Kyoto is very short-term, while climate issues are long-term, Barrett suggests that we must find a solution that creates new markets and leverages measures for economic improvement. However, further difficulties arise with the public's disinterest in the issue and the different effects climate change will have on geographically disparate nations.

A similar focus on technology is presented by Dr. Raymond Kopp, of Resources for the Future. Kopp summarizes the relationship of government policy to technological development from an economist's viewpoint and asserts that we must encourage desired behavior, such as alternative technological solutions. As wide agreement exists that the best solution to the problem of climate change is new, non-carbon-based technologies, it is necessary for the government to encourage growth in the right directions by overcoming market failures, such as spillover from R&D. Another economic hurdle is the existing carbon-based capital, which will be expensive to replace.

Other perspectives came out of the Resources for the Future/Institute for Global Environmental Strategies meeting held in Washington, DC, in February of 2004, which involved American and Japanese participants. A common view expressed by the Americans, but not readily embraced by all the Japanese present, was that the Kyoto Protocol might be of limited usefulness. One participant noted that the Kyoto Protocol has difficult targets, is top-down in nature, and is too strict in its requirements. Some argued that for the United States to play a major role internationally, it would need a consensus about climate change and a well-developed domestic climate policy, something that does not have. The proposed McCain–Lieberman legislation was used as an example of the type of legislation that would provide the United States with a well-articulated domestic policy. Also, there was support for the view that an effective approach might be to forge agreements among sub-global groups, perhaps consisting of a handful of the major climate players, that need not involve a majority of the world's countries. The view was also expressed that climate policy should be undertaken within the context of the priorities of the developing world, perhaps in concert with development

programs. Also, it was noted that different countries might approach the climate issue with different, but useful, tools.

A report from the Pew Center on Global Climate Change, based on the Climate Dialogue at Pocantico, stated that "we need all the major economies engaged," and that "we must broaden the international effort with new approaches that give countries more flexibility and produce real results" (Pew 2006).

Finally, it should be noted that smaller, regional efforts to reduce GHGs could be an alternative to a Kyoto-type global approach. For example, in July 2005, Australia, China, India, South Korea, Japan, and the United States signed an independent agreement, the Asia–Pacific Partnership on Clean Development and Climate, which promotes the use of new technologies and more efficient vehicles to reduce the emission of GHGs. The pact does not adopt specific emissions reduction targets (*Nature* 2005). Also, within the United States, a number of states and regions have unilaterally undertaken various GHG emissions control programs.

Section IV: Options for Sinks in a Post-Kyoto World

Approaches to addressing carbon sinks may need to be revisited in the post-Kyoto period. Three alternatives are possible: the Kyoto Protocol system can continue largely unchanged, the system can be simplified, or new modalities can be developed. There is also the question of how once-registered Kyoto forests will be treated in the post-Kyoto period. Although COP 9 indicated that once modified, the forest would be modified indefinitely,[12] it is not clear how binding the provisions of the current Kyoto Protocol will be on activities and agreements in the post-Kyoto period, since the any post-Kyoto agreement will almost surely be negotiated de novo. Obvious considerations for a post-Kyoto agreement could involve a restructuring of both Articles 3.3 and 3.4, as well as of the CDM.

The Basic Approach

This section of the paper examines the features that would likely accompany a modification of the Kyoto Protocol in the post-Kyoto period, with a focus on the implications for forest and biological sequestration. Three alternative future scenarios are summarized below and presented in detail in Appendix B. This section examines briefly the implications for minimal, moderate, and large modifications in the existing arrangement that involve movement toward either a single, multilateral agreement or toward regional and bilateral agreements. A number of alternative sets of assumptions regarding the success of carbon markets and the advance of emissions reducing technologies are applied each of these alternatives.

Minimal Modification of the Kyoto Protocol

A minimally modified post-Kyoto Protocol essentially would continue Article 3.3, the "Kyoto forest," and Article 3.4, forest management. Article 3.3 addresses ARD, with time dimensions for when afforestation must begin and limits on carbon credits to the compliance period. Presumably, forests that were established during the acceptable period before and during the Kyoto Protocol compliance period would be allowed to sequester carbon during the subsequent compliance period. If the new countries participating in any new protocol were

[12] For example, COP 9 agreed that CDM forests could constitute a sink for a maximum of 30 years with no baseline review (the tCER) and up to 60 years with a baseline review every 20 years (the ICER).

added to list of countries in appendix B, their forest areas would most likely be added to the global area of the "Kyoto Forest."

Article 3.4 is likely to need to be rethought. Currently, some countries have rather large managed forests that are experiencing positive net biological growth; clearly, substantial amounts of carbon are being sequestered by these forests. However, much of this would probably occur without a carbon program. The question is, how much of the additional carbon reasonably can be viewed as additive? In the Kyoto Protocol, countries were given credit for 15 percent of the growth of their managed forests, with no credits or debits associated with unmanaged forests. This approach assumes that management promotes 15 percent of the incremental addition in forest growth. However, exceptions—based obviously on political, not scientific considerations—providing for larger amounts of credit were negotiated for some countries, such as Russia. The question for a future agreement is how much sequestration would be allowed for the various countries from forest management?

Moderate Modification of the Kyoto Protocol

Article 3.3, the Kyoto forest, does not give credit for protecting existing forests, although loss of forests can generate debits. This article becomes more complex if the countries with carbon targets were expanded to include developing countries, some of which are currently experiencing tropical deforestation. If the current system were applied to the next compliance period, these countries could incur carbon debits for forest losses that might occur beyond some to be determine base period.

One approach for initially involving tropical countries might be to allow them positive carbon credits for reduction in the rates of deforestation below some baseline level. This would allow them to maintain sovereignty over their lands, while providing a positive incentive to control deforestation. A related approach would be to provide carbon credits for acceptable restoration for forests deemed degraded.

Another element under discussion for revision relates to the treatment of carbon in long-lived wood products. Under the current accounting rules, carbon is treated as though it were released at the time of harvest independently of what the wood will be used for and the longevity of any wood products.

Large Changes to the Kyoto Protocol

While the nature of climate programs in the post-Kyoto world remains to be determined, the early activities suggest that there is likely to be a continued major role for forest sinks even if the Kyoto Protocol is modified radically. However, a radical departure from the Kyoto Protocol may involve increased carbon control efforts on an individual country or regional basis. A precursor of country climate mitigation behavior outside or beyond the Kyoto Protocol might be found the McCain–Lieberman legislation proposed in the U.S. Senate. Although this legislation has not passed, it is likely to provide the template for future legislative efforts that will undoubtedly be undertaken. The legislation was strictly domestic effort and did not mention the proposed Kyoto targets. Additionally, this legislation did not provide many opportunities for biological sequestration. However, a different bill (the Carper bill), has generous provisions for biological sequestration. Thus, proposed legislation may include serious domestic carbon reduction targets and fully embrace the use of carbon sinks. Similarly, some states have carbon-reducing provisions that allow for biological sequestration.

Additionally, there are notions of tying climate programs to economic development programs whereby forestry would be used to mitigate carbon in the developing world. To the extent that more individual and regional sub-global arrangements are made, this suggests greater discretion in programs and projects by individual regions and counties and could allow countries that desire forest sequestration programs to undertaken these for formal or informal credits.

Section V. The Scenarios

Appendix B presents three types of international arrangements that might be developed to respond to a continuing climate problem in the post-Kyoto world. The role that biological and forest carbon sequestration might undertake in each of these systems is examined below. Each of these scenarios assumes that a different set of circumstances will prevail in the post-Kyoto world and examines the possible implications of these assumptions and issues related to the efficacy of these approaches. Specific assumptions are made as to the function of emissions trading and the expectation of the success of technological change in mitigating the increase of GHG emissions.

For each scenario, the likelihood that biological carbon sequestration will be important is explored. The necessary conditions under which carbon sequestration is likely to be important are laid out and compared with the conditions that would prevail if carbon sequestration is unlikely to be unimportant. Time profiles also are considered, so that conditions are identified that would determine whether sequestration would be more important at the beginning or end of a hundred-year period. The analysis also makes assumptions about the rate at which new carbon-reducing technologies are developed, how this development is likely to affect prices, and how the carbon markets are likely to respond to these price changes.

The three scenarios are presented schematically in Appendix B. The scenarios begin with assumptions about the development of the DETS and the success of carbon emissions reduction technologies. Scenario A is largely an extension of the existing Kyoto Agreement, assuming that DETS work well and have links among them but are not wholly unified. The technological solution brings only limit results, a long-term commitment is made to controlling emissions by most of the world, and developing countries are involved and equity concerns adequately addressed. Scenario B assumes that DETS work poorly and that technology provides only modest improvements. Scenario C assumes that DETS work poorly, but there is widespread optimism that substantial technological innovations will address much of the climate problem.

Other assumptions that vary by scenario involve the nature of international agreements, considerations of equity between developed and developing countries, and equity within the group of industrial countries and within the group of developing countries. Scenario A stresses the DETS market and Scenario B recognizes the need for climate control, although the private sector is reluctant to participate fully, while Scenario C takes an optimistic view of the ability of technology to address the climate issue and assumes that the international agreement focuses

primarily on R&D and innovative technology. A fourth set of assumptions focus on considerations of equity between developed and developing countries. Scenarios A and B deal with equity through the differentiation of country emissions targets or differentiation of policies and measures between industrial and developing countries. In Scenario C, industrial countries have no concern for equity, although equity concerns are important for the developing countries. A fifth set of assumptions concern equity within the group of industrialized countries and also within the group of developing countries. Finally, a set of assumptions concerns movement toward either a single multilateral agreement or toward regional and bilateral agreements.

The implications of these various scenarios and the respective assumptions on how these various scenario regimes are likely to deal with adaptation, and the implications for the positions that various countries will take are all to be analyzed. Specifically, the United States, Japan and other Annex I countries, Russian, the G77, and China are all to be analyzed.

Scenario A: Carbon Market Scenario

This section examines Scenario A in detail, while the following section summarizes all three scenarios with a view toward the implications for the viability of using forest carbon sequestration. An important focus is on the incentive systems available to promote forest carbon sequestration.

Scenario A has many features that might be characterized as an extension of the existing Kyoto agreement. In this scenario, it is assumed that DETS work well, with regional trading systems linked to each other, forming the elements of an international trading system and movement toward a single, multilateral emissions trading agreement. While technology continues to improve, there are no unexpected breakthroughs in carbon-controlling technology. In this situation, a long-term climate agreement is desired in part because this is viewed as necessary for the DETS to continue to provide incentives for long-term commitments to carbon reduction and sequestration. Developing countries, as well as industrialized countries, are given carbon reduction targets, but targets for developing countries may be moderated based on some set of equity considerations. As more countries have targets, the uniformity of G77+China group begins to break-up, as many of these countries are brought into the industrial group with specific reduction targets.

The next question is what would be the implications of Scenario A on biological and forest carbon sequestration activities? These activities are desirable since they offer

opportunities for large volumes of low-cost carbon sequestration, they can be measured and monitored effectively, and they offer important opportunities for cross-country equity (Bodansky et al. 2004).

Assuming that the mechanisms of JI and CDM continue in the post-Kyoto period, these mechanisms would be available to use for biological sequestration, as well as other applications. Thus far, the CDM has been limited in its application due to what some consider are overly stringent additionally requirements. In addition, the use of forestry CDMs has been constrained by a limit in the current Kyoto Agreement whereby a maximum of one percent of a country's targeted reductions can be met by CDM forest sequestration projects. Obviously, a future agreement could have less stringent requirements and either raise or eliminate the cap on the maximum allowable sequestration limit. Such an agreement would provide for more potential CDM forestry projects. Alternatively, a future agreement could be more stringent and allow fewer opportunities for forest sequestration.

Trading Markets and Carbon Offsets

A second element of this scenario involves the extent to which carbon could be sequestered through forest management and traded in markets as carbon off-sets. The current DETS for the most part applies to the creation of certified reductions in emissions, which occur if a firm or a country has a surplus in emissions reductions. There currently exist a number of markets that trade emissions pollution credits, such as in sulfur dioxide and carbon dioxide. Similarly, a market could be established in "carbon offsets," such as forest carbon sequestration credits, which could be traded between individuals, among firms and/or countries (see Marland et al. 2001). These systems would allow them to trade or sell surplus offsets to their counterparts that have carbon emissions deficits that they wish to meet through. Such a system would involve the creation of a CER procedure to ensure that the offsets meet the criteria that they are measurable and additional. In addition, such a system would require periodic monitoring. It has been recognized that such a system need not be permanent. The COP 9 distinguished between permanent CERs, a long-term lCER, and a temporary CERS, the tCER, for the first commitment period of the Kyoto Protocol (2008–2012). The tCERs are valid for only one commitment period of five years. The lCERs apply to sink projects that have credits for a period of 20 years, with the possibility of two renewals of up to 60 years or 30 years with no renewal. Note that while the lCERs imply finite credits, the credits will continue well beyond the end of the existing Kyoto Protocol.

Other types of arrangements would be possible and may be incorporated into future international climate agreements. For example, a rental arrangement has been suggested that would continue for the period during which the forestry project continues to sequester carbon, which could be either a long or a short period (see Sedjo and Marland 2003).

Although a carbon offset system might involve only an offset provider and user, to be useful a workable system would probably require that there be a well-functioning DETS addressing carbon emissions reduction. Under those conditions, an offset trading system could function in parallel with the DETS, with buyers having the opportunity of acquiring either permanent or temporary credits. Why might a firm want a temporary credit? It is cheaper and might be appropriate should a firm have capital constraints. Also, the firm might believe that an innovative technology is likely to be developed that would substantially reduce the need for and value of permanent credits. Thus, the least cost way of addressing the emissions reduction problem might be to purchase cheap temporary credits until the market value of the expensive permanent credits fell due to the effects of the new technology. Although scenario A assumes a general view of modest technological improvement, not all participants in the market need share this view. So speculation and hedging would be expected.

Questions have arisen as to the problems with measurement, monitoring, and certification. However, with a DETS market, a forest offset market appears quite feasible (Sedjo and Toman 2001). Also, if there were several well-functioning regional DETS markets, one would expect that linkages could form a global trading system.

Technology

The assumption in Scenario A is that technology will continue to address emissions but no unforeseen breakthrough will occur. Under this assumption, the global community will continue to rely heavily on conservation and the tools at its disposal. The absence of important technological breakthroughs probably would necessitate the increased use of biological sequestration and the provision of additional incentives for biological and forest sequestration. The judgment of the sinks chapter in the IPCC Third Assessment Report (2001) was that biological sequestration could mitigate up to 20 percent of the likely excess emissions of carbon over the first 50 years of the twenty-first century at reasonable costs. Also, from a political point of view, there are a number of countries that probably would want to rely substantially on forest sinks, including the United States, Canada, Australia, Russia, and perhaps China, Brazil, and India. However, some regions, such as the European Union, which was shown above to

have little capacity to utilize carbon sinks, are likely to have little interest in their use. A third assumption developed involves international agreements, with Scenario A stressing the DETS market. Other assumptions of Appendix B that are covered briefly in this report include a fourth set of assumptions that focuses on considerations of equity between developed and developing countries.

Scenario A deals with equity through the differentiation of country emissions targets or differentiation of policies and measures between industrial and developing countries. To the extent that developing countries commonly have more potential forest area, biological and forest sequestration may provide a more equitable way to allow developing countries to meet GHG targets at low cost, thereby enhancing developed–developing country equity. A fifth set of assumptions concerns equity within the group of industrial countries and also within the group of developing countries.

The Role of Biological and Carbon Sequestration under the Scenarios: A Summary

Scenario A

Under scenario A, both industries and developing countries largely will utilize biological sequestration to achieve their emissions reduction targets of GHG with relatively cheap costs. If the firms might not expect that an innovative technology will likely be developed that would substantially reduce the need for and value of permanent credits, then the least cost way of addressing the emissions reduction problem would be to purchase cheap temporary credits until the market value of the expensive permanent credits fell due to the effects of new technology. However, the world's forest resources are not equally distributed. Only several countries enjoy enough carbon credits derived from forest sequestration to significantly affect their reduction targets. Countries that do not have enough forest resources will request simple and reliable modalities of CDM/JI to utilize forest resources in other countries. Well organized and stable DETS are necessary to promote CDM/JI projects and the usage of temporal carbon credits derived from biological sequestration until the development of innovative technologies for emissions reduction, because a forest ecosystem usually needs more than five years to produce carbon credits after tree planting starts.

Scenario B

In Scenario B, the emissions trading system fails. Thus, the role of biological and carbon sequestration is reduced under scenario B. If industrialized countries also suffer from the failure to develop innovate technologies for emissions reduction, governments might consider domestic forest resources as substantial tools to satisfy emissions reduction targets, although not relying on a emissions trading system. While forests are basically managed as timber resources, timber production might reduce carbon stock in the forest ecosystem within a short period like a commitment period of the Kyoto Protocol. Some governments may control forest operations to ensure carbon sequestration and to avoid emissions caused by timber harvests. As forestry CDMs need at least five years to obtain carbon credit after the establishment of new forests, investors will hesitate to use forestry CDMs under a poorly functioning DETS. They might be concerned about future demand for temporary CERS in the absence of a well-organized emissions trading market.

Many developing countries are faced with severe deforestation caused by rapid population growth and poverty. Developing countries might insist that their efforts to limit deforestation be evaluated as carbon emissions reductions. This requires a net-net accounting system as an appropriate method to assess their efforts to fight deforestation and the degradation of forest resources. The industrialize countries, which have stable forest resources, may show small differences in their sequestration amounts between a commitment period and base year, so they might prefer a gross-net accounting system.

Scenario C

The main role of biological carbon sequestration in industrial countries is as an alternative measure to mitigate global warming until innovative technology is developed. If DETS are poorly functioning, that limits the ability and efficiency of financial incentives to promote biological sequestration to mitigate warming. If, in addition, an innovative technology drastically reduced GHG emissions, this would be a substitute for biological sequestration, as well as many other GHG-reducing activities. The result would be to depreciate the value of various carbon-reducing activities. Thus, incentives for these activities would be reduced as countries with targets would not need to rely on biological carbon sequestration measures to achieve carbon reduction targets.

However, deforestation in tropical areas is one of the major factors accelerating global warming and also is viewed as undesirable in itself. Thus, international agreements covering

tropical countries might adopt the protection of forests and reinforce forest sequestration in developing countries that have not effective opportunities for industrial emissions reduction. One approach would be to provide a baseline established on the basis of business as usual, with credits provided for performance that improved above the baseline trend.

Section VI: Summary and Conclusion

Although it is still too early to fully assess the successes and failures of the Kyoto Protocol, some preliminary conclusions can be drawn. Major successes of the Kyoto Protocol include its ability to get the world to focus on the issue of global warming; to think about and develop approaches and policies that might address the issue; to induce researchers to examine more closely the various aspect of the global climate system and the role that humans play in that system; and to create an environment where governments and private entities work toward developing technologies that can mitigate GHG emissions. Kyoto has attempted to muster broad international cooperation in reducing emissions.

An obvious disappointment of the Kyoto process has been its inability to fully engage all of the major developed countries, such as the United States and Australia, in the process. A related disappointment has been the limited substantive involvement of major developing countries. These two disappointments are related. A major stumbling block for the United States was the absence of a number of major developing nations, particularly China, in the group of countries that had specific emissions targets. If future climate agreements could add additional major countries, such as China, India, and Brazil, to the list of active (target oriented) participants, it might also be able to enlist the active participation of the United States. Many of these countries have achieved substantial development over the intervening 23 years between 1990 and 2013 and thus will be appropriate candidates for active participation.

References

Amano, Masahiro. 2003. Presentation at the FRI, January 28, Tsukaba, Japan.

Amano, Masahiro. 2006. Personal communication with the authors, March 17.

Amano, Masahiro, and Roger A. Sedjo. 2003. Forest Carbon Sinks: European Union, Japanese, and Canadian Approaches. Discussion Paper 03-41. Washington, DC: Resources for the Future.

Anderson, Soren, and Richard Newell. 2004. Prospects for Carbon Capture and Storage Technologies. *Annual Review of Environmental Resources* 29(2):1–02.34.

Barrett, Scott. 2003. Presentation at the "Trans-Atlantic Co-operative Research Conference on Climate Change and New Energy Technologies: Policies, Agreements and Processes to Protect the Global Climate," October 7, Washington, DC.

Bodansky, Daniel, Elliot Diringer, Jonathan Pershing, and Xueman Wang, 2004. Strawman Elements: Possible Approaches to Advancing International Climate Change Efforts. Washington, DC: Pew Center for Global Climate Change.

Canada, Government of. 2005a. Moving Forward on Climate Change: A Plan for Honouring Our Kyoto Commitment. http://www.climatechange.gc.ca/kyoto_commitments (accessed December 20, 2005).

Canada, Government of. 2005b. Elements of the Plan: Sustainable Agriculture and Forest Sectors http://www.climatechange.gc.ca/kyoto_commitments/c3.asp#s5 (accessed December 20, 2005).

Canada, Government of. 2005c. Recent Updates. http://unfccc.int/files/essential_background/

background_publications_htmlpdf/application/pdf/key_ghg_data_web.pdf (accessed December 5, 2005).

Denmark, Government of. 2002. Methodological Issues: Land Use, Land-Use Change and Forestry Views, available at http://www.unfccc.de.

Egenhofer, Christian, Norika Fujiwara, David Kernohan, and Tom Brewer. 2004. The future of the international climate regime: The contribution of "regional approaches" towards an

international climate change agreement." Centre for European Policy Studies, International Forum for Environmental Issues, March 3–5, Tokyo, Japan.

European Community. 2005. Future Action on Climate Change: A Stakeholder Consultation on the EU's Contribution to Shaping the Future Global Climate Change Regime. http://europa.eu.int/comm/environment/climat/future_action.htm (accessed February 9, 2005).

Fischer, Carolyn, Francisco Aguilar, Puja Jawahar, and Roger Sedjo. 2005. Forest Certification: Toward Common Standards. Discussion paper 05-10. Washington, DC: Resources for the Future.

Greenhouse Gas Emission Reduction Trading Pilot (GERT). Nd. See http://www.GERT.Org

Grubb, Michael. 2002. The UK Climate Change Programme: Structuring national investment for the global future. Presentation to Resources for the Future, November 19, Washington, DC.

Greaker, Mads. 2002. Conversation with Research Fellow, Statistics Norway, at Resources for the Future, December 3.

Haitus, Erik. 2005. "Canada Moves on Domestic Emissions Trading." *Australasian Emission Trading Forum Review* October/November.

Hull, Judith, and Tony Lempriere. 2002. "Implementation Issues For The Creation of Offsets in the Agriculture and Forestry Sectors for Use in a Potential Canadian Domestic Emission Trading System. Paper delivered to the Forestry& Agriculture Greenhouse Gas Modeling Forum Workshop #2: GHG Mitigation, October 8-11, Shepherdstown, WV.

Hyde, William. 1980. *Timber Supply, Land Allocation and Economic Efficiency*. Baltimore, MD: John Hopkins Press.

Intergovernmental Panel on Climate Change (IPCC). 2001. Technological and Economic Potential of Options to Enhance, Maintain, and Manage Biological Carbon Reserves and Geo-engineering. In *Climate Change Mitigation: 2001* (Third Assessment Report, Working Group 3). Cambridge: IPPC, 301–344 .

IPCC. 2001. *Third Assessment Report of the IPCC (*Vol. 3). Cambridge: IPCC.

Japanese Ministry of Economy, Trade, Industry (JMETI). 2002. The New Climate Change Policy Programme (tentative translation). Tokyo: JMETI

JMETI. 2004. Sustainable Future Framework on Climate Change. Tokyo: JMETI.

Kopp, Raymond. 2003. Presentation at the "Trans-Atlantic Co-operative Research Conference on Climate Change and New Energy Technologies: Policies, Agreements and Processes to Protect the Global Climate," October 7, Washington DC.

Lonnsteadt, Lars. 2003. Presentation at the Forest Research Institute, January 28, Tsukaba, Japan.

Marland, Gregg, Kristy Fruit, and Roger A. Sedjo. 2001. Accounting for Sequestered Carbon: The Question of Permanence. *Environment Science and Policy* 4(6):259–268.

Messussen, Frank. 2002. Personal conversation with F. Messussen, Consular, Cabinet Minister of Federal Defense and Environment, and authors, October 24.

National Institute for Environmental Studies/Institute for Global Environmental Strategies. 2003. Climate Beyond 2012: Incentives for Global Participation December, National Institute for Environmental Studies and Institute for Global Environmental Strategies. Japan.

Nature. 2005. "Critics deride climate pact as excuse for inaction." August 4, p. 617.

Oppenheimer, Michael, and Annie Petsonk. 2004. Reinvigorating the Kyoto System, and Beyond: Maintaining the Fundamental Architecture, Meeting: Long-Term Goals. Presented at Climate Change Agenda: Council On Foreign Relations, September 20–21, New York, NY.

Ott, Herman E. 2003. Warning Signs from Delhi. http://www.wupperinst.org/Sites/home1.html (accessed March 20, 2004).

Petroula, T. 2002. Sinks as an option to meet CO_2 emission reduction targets in Europe. Report 500005001/2002. The Netherlands: RVIM.

Pew Center on Climate Change. 2003. COP 9: Milan. http://www.pewclimate.org/what_s_being_done/in_the_world/cop_9_milan.cfm (accessed March 19, 2004).

Pew Center on Climate Change. 2003a. Beyond Kyoto: advancing the international effort on climate change. http://www.pewclimate.org/global-warming-in-depth/all_reports/beyond_kyoto/index.cfm (accessed March 20, 2004).

Pew Center on Global Climate Change. 2006. Agenda for Climate Change. http://ealert.pewclimate.org/ctt.asp?u=439660&l=116713 (accessed February 2, 2006).

Reilly, John. 2006. The Role of Non-CO_2 GHGs in Climate Policy: Analysis Using the MIT IGSM. Presentation at EMF 21–Multigas, Mitigation and Climate Change Meeting, January 31, Washington, DC.

Resources for the Future/Institute for Global Environmental Strategies. 2004. Climate Policy in the US and Japan. Conference sponsored by RFF and IGES, February 11–12, Washington, DC.

Rose, Steven. 2006. Global Land and Disaggregate Greenhouse Gas Emission Data. Presentation at EMF 22—Land Modeling Working Group Meeting, February 2, Washington, DC.

Schlamadinger, Bernard. 2002. Personal conversation with authors, February 20.

Sedjo, Roger. 1997. The economics of forest-based biomass supply. *Energy Policy* 25(6): 559–566.

Sedjo, Roger A. 2004. "Beyond Kyoto." http://www.rff.org/ rff/NEWS/Features/ Beyond-Kyoto.cfm (accessed December 23, 2004).

Sedjo, R.A., and K.S. Lyon. 1990. *The Long-Term Adequacy of World Timber Supply*. Washington, DC: Resources for the Future.

Sedjo, Roger, Brent Sohngen, and Robert Mendelsohn. 2001. Estimating Carbon Supply Curves for Global Forests and Other Land Uses. Discussion paper 01-19. Washington, DC: Resources for the Future.

Sedjo, Roger A., and G. Marland. 2003. Inter-trading Permanent Emissions Credits and Rented Temporary Carbon Emissions Offsets: Some Issues and Alternatives. *Climate Policy* 2(3): 435–444.

Sedjo, Roger A., and Gregg Marland. 2004. Renting Temporary Carbon Emission Offset. Paper presented to the 7th Electrical Utilities Environmental Conference, January 22, Tucson, AZ.

Sedjo, Roger A., and Michael Toman (eds.). 2001. Can Carbon Sinks be Operational. Discussion paper 01-26. Washington, DC: Resources for the Future.

Sedjo, Roger, Joe Wisniewski, V. Alaric Sample, and John D. Kinsman. 1995. The Economics of Managing Carbon via Forestry: An Assessment of Existing Studies. *Environment and Resource Economics* 6(2): 139–165.

Stavins, R., and K. Richards. 2005. The Cost of U.S. forest-based carbon sequestration. Washington, DC: Pew Center on Global Climate Change.

Sugiyama, Taishi, Kristian Tangen, Henrik Hasselknippe, Axel Michaelowa, John Drexhage, Jiahua Pan, Jonathan Sinton, and Arild Moe. 2004. Where to next? Future steps of the global climate regime. Briefing paper presented at the 10th Conference of the Parties to the UN Climate Convention, December 16, Buenos Aires.

Tjernshaugen, Andreas. 2005. United States participation in future climate agreements: An assessment. Policy note 2005:01. Oslo: Center for International Climate and Environmental Research.

Trexler, Mark C., and Derik J. Broekhoff. 2006. A Statistically Driven Approach to Offset-Based GHG Additionality Determination: What Can We Learn?" *Sustainable Development Law & Policy* (forthcoming).

van Kooten, G.C., C.S. Binkley, and G. Delcourt. 1995. Effect of Carbon Taxes and Subsidies on Optimal Forest Rotation Age and Supply of Carbon Services, *American Journal of Agricultural Economics* 77: 365–374.

van Vuuren, Detlef. 2003. Presentation to the EMF 21— Multiple-Gas Mitigation & Climate Change, May 29, Copenhagen, Denmark.

Appendix A: Global Forest Carbon Sequestration under Various Price Scenarios

Appendix figures are drawn from the report "Estimating Carbon Supply Curves for Global Forests and Other Land Uses," by Roger Sedjo, Brent Sohngen and Robert Mendelsohn, Report prepared for the US Department of Energy and appearing as RFF Discussion Paper 01-19, April 2001.

Figure A.1

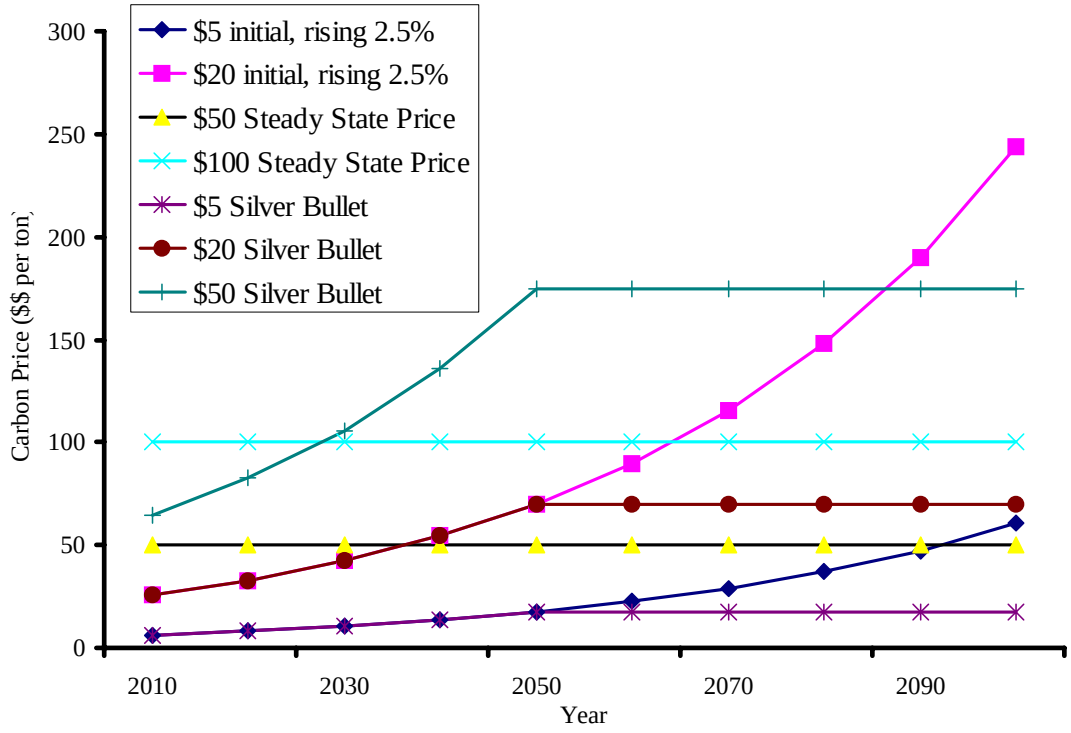


Figure A.2

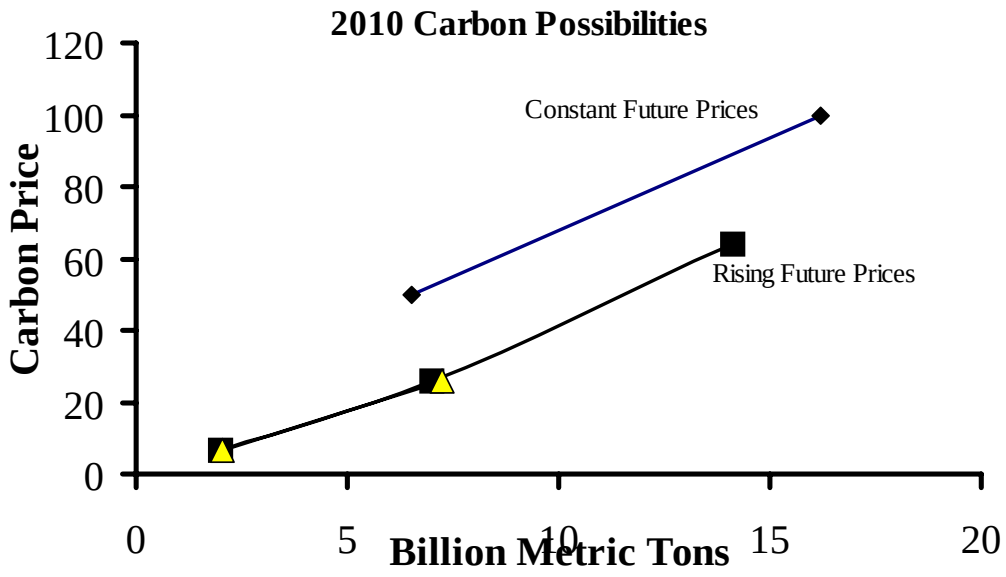

2010 Carbon Possibilities
Carbon Price
120
100
80
60
40
20
0
Constant Future Prices
Rising Future Prices
0
5
10
15
20
Billion Metric Tons

Figure A.3

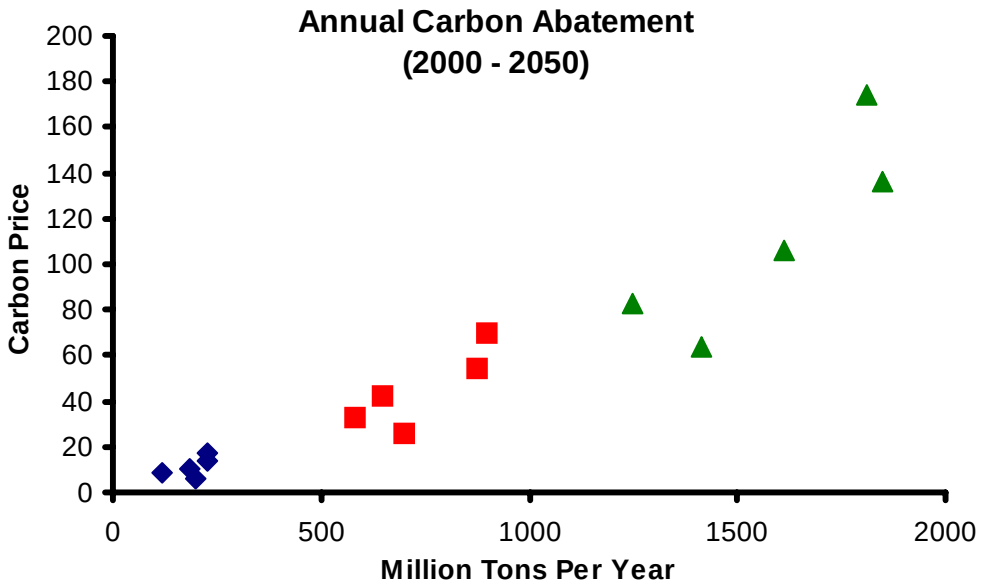
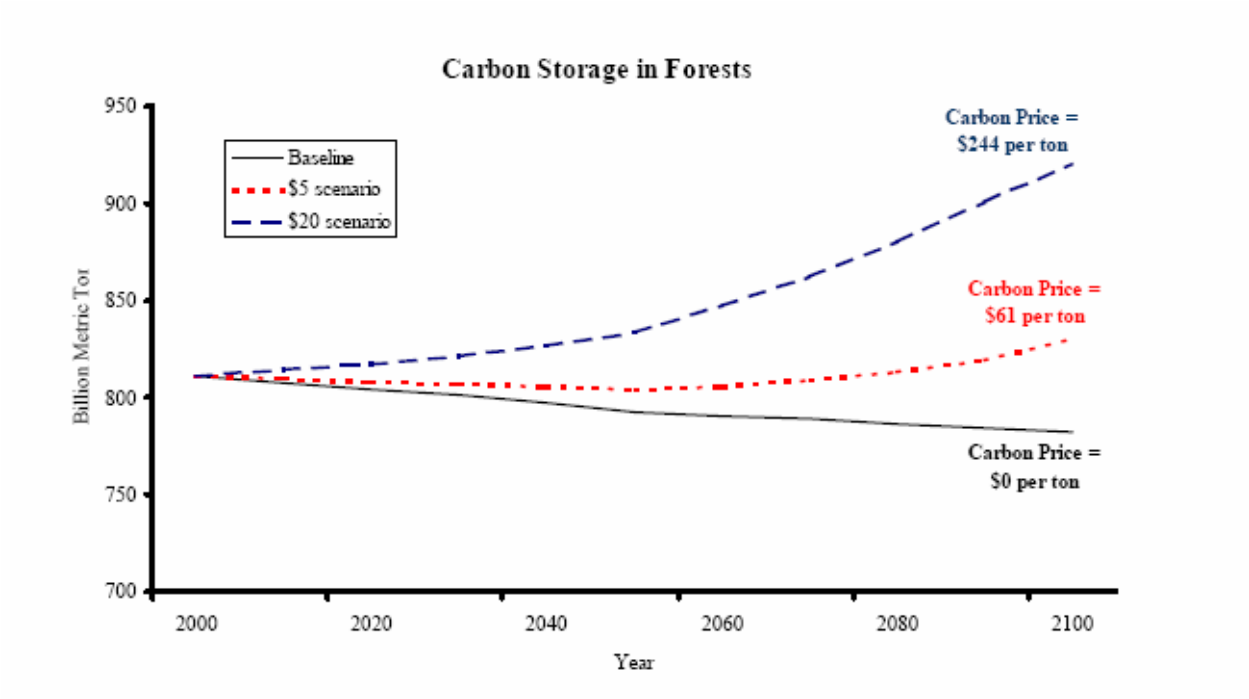

Annual Carbon Abatement
(2000 - 2050)
Carbon Price
200
180
160
140
120
100
80
60
40
20
0
0
500
1000
1500
2000
Million Tons Per Year

Figure A.4


Carbon Storage in Forests
Billion Metric Ton
950
900
850
800
750
700
2000
2020
2040
2060
2080
2100
Year
Baseline
$5 scenario
$20 scenario
Carbon Price = $244 per ton
Carbon Price = $61 per ton
Carbon Price = $0 per ton

Appendix B: Three Scenarios

Characteristics of Three Scenarios

	Scenario A Carbon Market Initiative	Scenario B Government Initiative Policies and Measures	Scenario C Technology Optimist
Uncertain Driving Force 1: Development of domestic emissions trading systems (DETS)	**DETS develops globally** European Union (EU) regional DETS fully successful. Other countries, such as Canada, Russia, and Japan, link their DETS with the EU. Some relatively developed non-Annex I countries also become interested in joining the group. United States becomes interested as some key developing countries join the DETS.	**DETS fails** EU regional DETS fails. Emissions allowances have been distributed mainly according to grandfathering rule, and not many firms need to buy or sell their allowances. Other developed countries prefer to use money domestically rather than paying to other countries. Developing countries oppose DETS, as it may be advantageous for wealthy countries.	**DETS fails** EU regional DETS fails. Emissions allowances have been distributed mainly according to grandfathering rule, and not many firms need to buy or sell their allowances. Other developed countries prefer to use money domestically rather than paying to other countries. Developing countries oppose DETS, as it may be advantageous for wealthy countries.
Uncertain Driving Force 2: Expectation for technological solution	**Technology solution pessimistic** A considerable level of technology R&D continues but within the expected level. These technologies are not sufficient to stop a rapid growth of global GHG emissions. Increasing number of experts insist that changes in human behavior and in social systems are the key to mitigating GHG emissions.	**Technology solution pessimistic** A considerable level of technology R&D continues but within the expected level. These technologies are not sufficient to stop a rapid growth of global GHG emissions. Increasing number of experts insist that changes in human behavior and in social systems are key to mitigating GHG emissions.	**Technology solution expected** Expectation for technological solution of climate change problem increases. More and more experts insist that some significant technological innovation will occur in the next several decades, which may drastically change the current situation, such as the pattern of energy consumption.

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Call for international agreement: on climate or something else?	**Call for climate protection (to enhance carbon market)** For DETS to be stable, it is necessary that the mechanism is expected to exist for a long period of time. Those that are supportive of maintaining DETS may take the lead in the negotiation. They may emphasize the threat of climate change so that countries agree to emissions limitation targets on the condition that DETS is available. Such targets could be of any kind as long as DETS is workable.	**Call for climate protection** Private sector is not interested in climate mitigation, as it doesn't see any benefit out of it. However, the world recognizes something needs to be done for climate mitigation, and governments start negotiating on an international agreement for the purpose of taking action against climate change.	**Call for R&D of innovative technology** Countries/firms that are likely to benefit by technological diffusion may take the lead in the negotiation. They may emphasize the threat of climate change, but an agreement merely on technology may suffice to meet their expectations.
Consideration on **equity between developed and developing countries**	**Seek an equitable solution by differentiation of emissions targets or carbon- free market may dominate the system.** Countries/firms that are likely to benefit from emissions trading may take the lead in setting emissions targets for developing countries as well. Developing countries insist on consideration of their equity concerns. This negotiation may end up with developing countries accepting a loose target, or a dynamic target, or not accepting a target but a wider use of CDM.	**Seek an equitable solution by differentiation of policies and measures.** Developed countries seek a multilateral climate regime that involves major, if not all, developing countries. Developing countries emphasize equity concerns between North and South. This negotiation may involve a tradeoff between "developing countries committing to certain commitments" and "developed countries offering a certain funding or technology transfer mechanisms."	**No concern for equity in industrialized countries/ concern from developing countries' side.** Countries that are likely to benefit from technological diffusion may not be interested in ensuring equity within the regime. Developing countries would strongly urge a response to equity concerns. The leader country may wish to involve developing countries if that is more beneficial. In that case, negotiations may include some kind of mechanism for developing countries. If the leader prefers not to involve developing countries in the regime at all, developing countries may insist on technology transfer (CDM is likely to fail if DETS fails).

	Scenario A Carbon Market Initiative	Scenario B Government Initiative Policies and Measures	Scenario C Technology Optimist
Consideration on **equity among developed countries and among developing countries**	**Seek an equitable solution by differentiation of emissions targets or inequitable condition among developing countries.** Countries/firms that are likely to benefit from emissions trading may take the lead in setting emissions targets for all countries. Developed countries get into a similar negotiation observed during AGBM negotiation up to COP3. Similar negotiation also may be seen among developing countries, which may end up with breaking up of G77+China group.	**Seek an equitable solution by differentiation of policies and measures.** Industrialized countries discuss various options to mitigate climate change and their concern would be how to ensure equity among commitments of industrialized countries. Similar strategy could be suggested for developing countries. Diversity of developing countries becomes disadvantage for G77+China. As Annex I countries become more interested in equity, they try to involve relatively developed developing countries, which loosens G77+China group.	**No concern for equity among industrialized countries/concern among developing countries.** Countries that are likely to benefit from technological diffusion may not be interested in ensuring equity among industrialized countries, as market-oriented system is more beneficial for dominating the market. This may be similar for developing countries. Those countries that may benefit from technology transfer may not be interested in the concerns of small, developing countries that are not likely to benefit from such technology.
Move toward **single, multilateral agreement or regional / bilateral agreements**	**A single multilateral agreement or linkage between regional agreements.** Countries/firms that are likely to benefit from DETS may prefer all countries to participate under a single rule. DETS would be more active with participation of developing countries. Countries/firms that are likely to take the lead in technology may or may not be interested in having all countries in one regime. Developing countries can participate in the regime either by DETS or by CDM.	**A single multilateral agreement.** Countries prefer all countries to participate in the regime in order to ensure equity between North and South, among industrialized countries, and among developing countries. Participation of all countries is also important in order to have coordinated policies and effective measures, without one industry or one country losing its competitiveness.	**Linkage between regional agreements.** Countries that are likely to take the lead in technology may or may not be interested in having all countries in one regime. The preference would differ according to what type of technology is the focus. If it is to be sold mostly in developing countries, the leading country will prefer to have the participation of the developing countries. If the technology is to compete among industrialized countries, the regime would require participation of industrialized countries only.

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How would the regime deal with adaptation?	Countries/firms that are likely to benefit from DETS may prefer all countries to participate under a single rule. In order to involve developing countries, adaptation may become an important agenda. On the other hand, if industrialized countries are opposed to discussing adaptation, most developing countries may stay out of emissions caps and utilize only CDM.	Countries prefer all countries to participate in the regime. Thus, if developing countries start emphasizing adaptation issues, this may become part of an agenda for a tradeoff for developing countries' participation.	Countries that are likely to take the lead in technology may not be interested in adaptation issues. These countries may not be interested in having all countries in one regime, so if developing countries start emphasizing adaptation issues, leading countries may prefer an agreement only among major countries, without including adaptation. Failure of DETS is followed by failure of CDM, and developing countries may lose opportunities for technology transfer.
Position of the United States			
Position of the European Union			
Position of Japan and other Annex I countries			
Position of Russia			
Position of G77+China			
Position of China or India			
Position of other major developing countries or groups			

Initial Assumptions:

As this scenario exercise only address the future up to about one decade from now, the following conditions are considered as not uncertain:

- Population growth in each country, economic growth in developed countries (there will be no unexpected growth or decline);
- Emissions trend (there will be no unexpected growth or decline);
- Climate (there will be some extreme events in some parts of the world, but there will be nothing like "The Day after Tomorrow");
- People's awareness toward climate change (many people have heard of the problem, but there is no general perception of urgency).