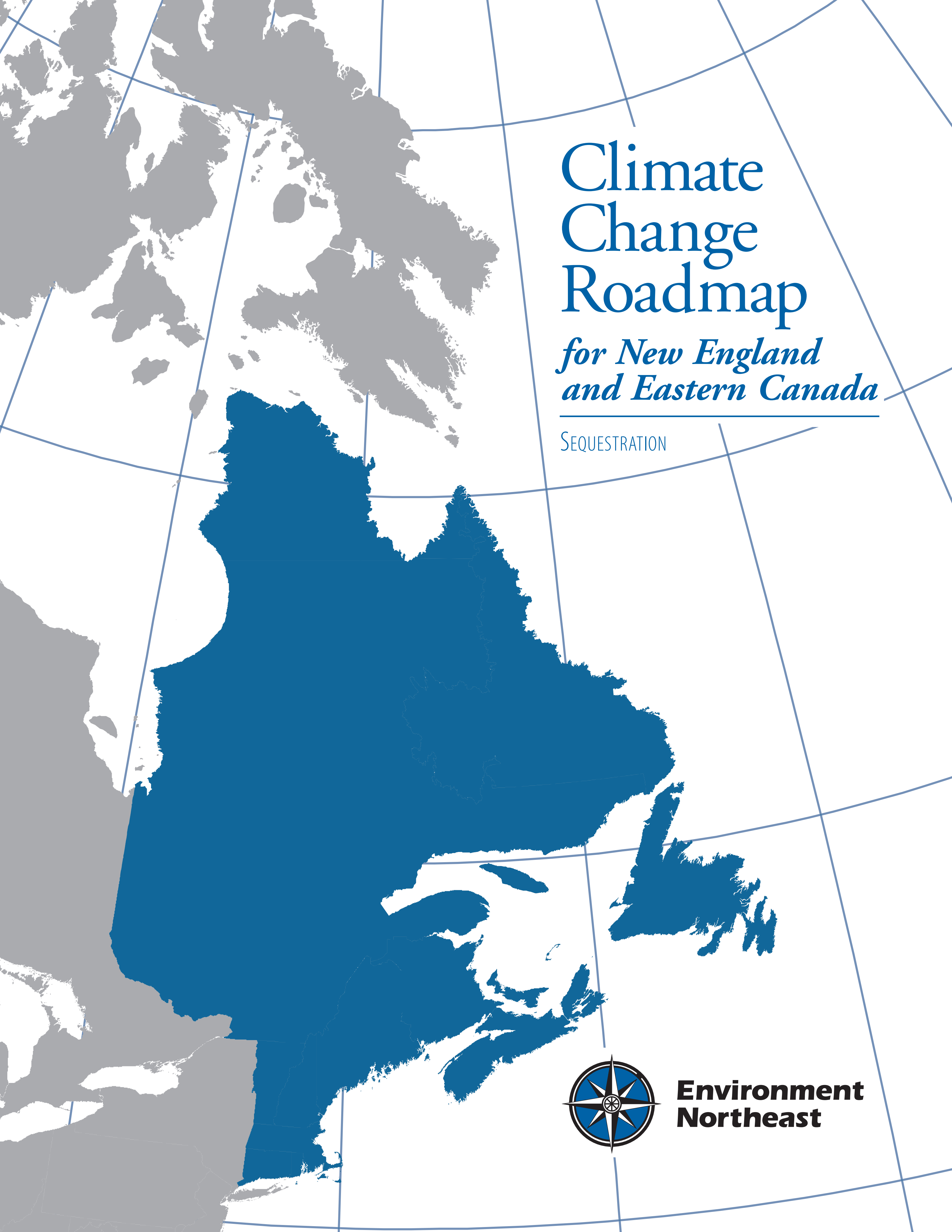

Climate Change Roadmap

for New England and Eastern Canada

SEQUESTRATION

Environment Northeast

Chapter 3: Sequestration

Introduction

A wide range of changes in land and forest management practices and treatment of industrial sources of CO_2 could potentially reduce or avoid carbon releases, increase the annual volume of carbon removed from the atmosphere and expand the amount of terrestrial and geologic carbon storage, or “sinks.” We address the two primary types of carbon sequestration here: terrestrial and geologic. Terrestrial carbon sequestration involves the net removal of CO_2 or prevention of CO_2 emissions from terrestrial ecosystems that include forests, rangelands, agricultural lands and wetlands. Similar in concept, though not a CO_2 removal mechanism in itself, geologic carbon sequestration involves the storage of CO_2 in geologic formations that include oil and gas reservoirs, unminable coal seams and deep saline reservoirs. Expanding both terrestrial and geologic carbon sinks beyond “business as usual” (BAU) levels presents an important bridge opportunity to remove carbon from the atmosphere at potentially low to moderate cost.

Carbon sinks can be expanded by:

- reforesting land not currently forested (afforestation);
- modifying forest management practices to increase onsite carbon sequestration;
- minimizing carbon loss due to land conversion;
- increasing CO_2 capture and storage (CCS) in suitable geologic formations.

Terrestrial Sinks

Forests

As a significant storage site for global carbon, forests play an important role in the carbon cycle. Plants and trees convert atmospheric CO_2 and store carbon in their aboveground and belowground biomass through the process of photosynthesis. Belowground, forest soils have been shown to store a significant amount of carbon in their soil organic matter—up to two times as much carbon as found aboveground.[1]

It should be recognized that while forests, both passively and actively managed, function as “sinks” for carbon, they also serve as sources of GHG emissions. Natural biological processes, natural disturbances, and forest management activities (including harvesting and prescribed burning) all result in carbon emissions. When these actions occur, the carbon account balance shifts, resulting in a carbon loss. On the other hand, assuming a sustainability condition where trees continue to grow (and store carbon) on disturbed lands at a greater rate than they decay or are harvested, no net carbon is assumed lost from the forest over the long term.

There is a high level of uncertainty about the various estimates of forest carbon stock and sequestration rates for New England’s forests. The most recent estimates of carbon sequestration in the Northeast U.S. have been developed in a joint research project of The Nature Conservancy, The Sampson Group, and Winrock International with coordination and assistance from the USDA Forest Service.[2] Estimates

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[1] In accordance with other practitioners, inorganic soil carbon is considered inert and thus not included in this report (Heath and Smith 2000).

[2] Sampson, Neil. March 2006 Draft. Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs. Draft Part 2: Recent trends in sinks and sources of carbon.

by this group and estimates by other previous forest carbon inventory projects[3] suggest that the standing non-soil forest carbon stock[4] in New England is between 687 and 867 MMTCO$_2$e. Annual sequestration (expressed as negative emissions) in these forests is estimated at between -25.5 and -41.28 MMTCO$_2$e per year—equivalent to between 12% and 20% of the New England's current carbon emissions (206.5 MMTCO$_2$e in 2000)—from the atmosphere.

Unfortunately, forest carbon stock and sequestration estimates for Eastern Canada are difficult to come by. Province-by-province data on forest carbon stock and sequestration rates do not exist and should be developed.

Table 3.1: Estimated non-soil forest carbon stocks and annual sequestration for NE-EC[5]

Jurisdiction	Forest Land Area	Non-soil Forest Stock			Annual Emissions		
	kha	*MMTC02e*			*MMTC02e/yr (low)*		*MMTC02e/yr (high)*
Connecticut	728	241.6	to	327.1	(1.05)	to	0.98
Maine	7,164	1,807.9	to	2,683.6	4.74	to	(17.55)
Massachusetts	1,274	423.9	to	661.1	(3.89)	to	(13.46)
New Hampshire	1,950	738.1	to	937.2	(9.01)	to	(10.63)
Rhode Island	153	42.3	to	67.8	(0.12)	to	(1.31)
Vermont	1,846	686.9	to	867.0	(16.17)	to	0.59
NE Total	**13,114**	**3,940.8**	**to**	**5,543.8**	**(25.50)**		**(41.38)**
New Brunswick	6,200	N/A		N/A	N/A		N/A
NF/Lab	20,000	N/A		N/A	N/A		N/A
Nova Scotia	4,400	N/A		N/A	N/A		N/A
PEI	270	N/A		N/A	N/A		N/A
Quebec	84,600	N/A		N/A	N/A		N/A
EC Total	**115,470**	**N/A**		**N/A**	**N/A**		**N/A**

Agriculture

The potential for additional agricultural sequestration in this region on cropland and pasture land also requires more research, particularly because agricultural management varies so significantly between jurisdictions and crop types. The agriculture sector functions as a source of emissions (methane and nitrous oxide in addition to carbon) through animal and crop waste, land clearing and tillage, and measurable transportation and energy-intensive resource uses such as fertilization.

Agriculture is a primary economic driver in parts of Eastern Canada (PEI, most notably), but less so in the Northeast U.S., as seen in Figure 3.1.

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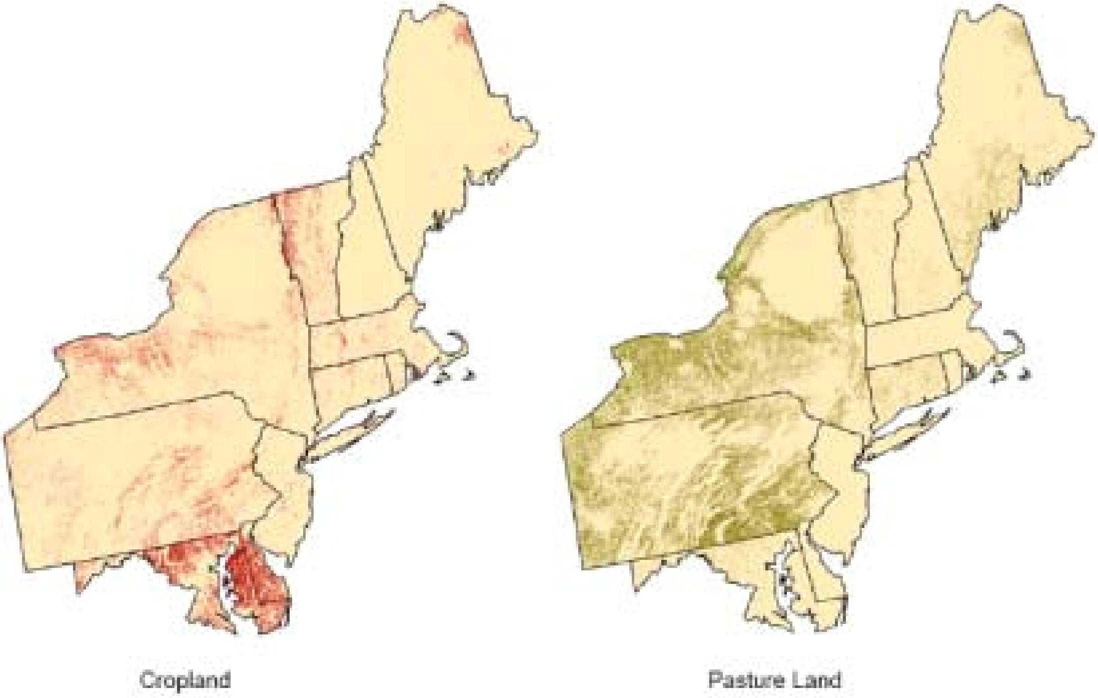
[3] USDA Agriculture and Forestry Greenhouse Gas Inventory, 2004; USDA Forest Service Forest Carbon of the US 2003; NESCAUM and EPA State Inventory Tool for New England 2001 (DATE?); Maine Greenhouse Gas Action Plan Development Process 2004

[4] The non-soil forest carbon stock is comprised of carbon in trees, the forest floor, and understory.

[5] Source for NE data: Sampson.

Figure 3.1: Cropland and pasture land in the greater Northeast region[6]



Source: Winrock International, Terrestrial Carbon Sequestration in the Northeast (2006)

Agricultural emissions vary by state. USDA data shows net agricultural soil emissions from some states (New Hampshire) occurring where there are also increases in farm area over time, while other states, such as Massachusetts, are gaining even greater acreage of farmland, but with fewer emissions than New Hampshire.[7] The variable nature of emissions from agriculture soil management as demonstrated by this case makes it difficult to develop consistent agriculture-related climate policies for the region as a whole, with more research needed on a state and regional level.

From a broad climate change perspective, agricultural activities are relatively small contributors to regional emissions and sequestration benefits. For the purposes of this roadmap, we will consider agriculture primarily as it concerns land conversion, although we do recognize the role that land abandonment may play in the biological and economic potential for lands to be afforested.[8]

Soil

Soil carbon sequestration is variable and in many cases, it may be difficult to assign specific responsibility for soil carbon loss or gain. A natural component to all ecosystems, recent studies have suggested that soils may be losing carbon due to factors caused by climate change, thus offsetting sequestration in biomass in other parts of the system.[9] Other studies describe the important role of soils in carbon storage, and we know that agricultural and soil disturbance activities strongly affect carbon storage in soils. Certain agricultural activities, including tillage, decrease carbon storage, while other farming

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[6] Winrock International. June 2006. Terrestrial Carbon Sequestration in the Northeast, Quantities and Costs. Draft Part III. Opportunities for improving carbon storage and management on agricultural lands http://conserveonline.org/workspaces/necarbonproject/Draft%20Part%20III%20Nortehast%20Carbon%20Opps.pdf.

[7] USDA. 2002. Census of Agriculture. Available at http://www.nass.usda.gov/Census_of_Agriculture/index.asp

[8] See also Winrock International.

[9] Bellamy *et al.* 2005. Carbon losses from all soils across England and Wales, 1978-2003. Nature, Vol. 437: 245-248.

activities, including no-till practices and crop rotation systems, support carbon storage.[10] Development-related activities, such as lawn cultivation and sod development, may be increasing carbon storage above natural ecosystem baselines while removal of trees and other vegetation decreases storage.

Because of many of the complexities introduced by factoring in soil carbon, we follow the convention followed by the USDA in the Agriculture and Forestry Greenhouse Gas Inventory and The Nature Conservancy, The Sampson Group and Winrock International in their Northeast Forest Carbon Project, and only estimate non-soil forest carbon in inventory estimates. Changes in soil carbon over long periods of time are assumed constant over all activities that minimally disrupt soil. As a better understanding of soil carbon dynamics develops, this source of emissions or sequestration should be factored into inventories, management schemes, and policy development.

Land Use Change

Human-induced land use changes have historically impacted and continue to directly affect GHG emissions and sequestration from natural lands over both the short and long terms. Rapid development patterns and associated land conversions from forested land are responsible for a small but growing proportion of GHG emissions in New England and Eastern Canada. These changes are critical, because once land is converted, there is no going back. When land is permanently cleared for development, stored carbon in vegetation is lost, the capacity of the future forest to continue to sequester carbon is lost and soil organic carbon levels may be reduced over the long term.

There is little consensus on quantifying the effects of development on soil and vegetative carbon. As pointed out by others, carbon losses vary according to intensity, type of development, and land use cover (*e.g.*, pavement, sod, other grasses, etc.).[11] Recent estimates suggest that land use change (development) strongly affects soil carbon emissions such that soil carbon emissions are much greater than non-soil emissions. However, these same project authors acknowledge that these estimates should be used with caution until they are validated, and in fact, these numbers do seem disproportionately large relative to the historical greenhouse gas inventory.[12]

On its own, land use change is not a substantial contributor to overall GHG emissions relative to other sectors. However, its associated development inputs have significant and related cascading effects on other sectors, including energy and transportation. As the rate of land conversion increases, so too do emissions in other sectors through energy inputs in residential and industrial systems, construction of sprawling infrastructure and increased vehicle miles traveled (VMT).

Most visibly, conversion of land is inextricably related to sprawl. Maine estimates that from 1987 to 1994, each municipality in the state built more than 100 miles of road per year.[13] The cumulative carbon impact of land use change and other development activities is measurable and significant over the long term.

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[10] As noted by the Maine Department of Environmental Protection 2004 Maine Climate Action Plan and others.

[11] Sampson.
Government of Canada. 2005 in the Canada Greenhouse Gas Inventory, 1990-2003.

[12] Sampson.

[13] Maine State Planning Office. 1997. The Cost of Sprawl. *Available at* http://mainegov-images.informe.org/spo/landuse/docs/CostofSprawl.pdf.

Table 3.2: Annual carbon loss due to land conversion from forests and croplands

Jurisdiction	**Average annual conversion from forests**	**Estimated carbon lost to conversion annually**[14]	
	ha	*MMTCO$_2$e* *Assume 100% carbon loss*	*MMTCO$_2$e* *Assume 70% carbon loss*
Northeast US (1987-1997)	24,605[15]	0.2	0.14
Eastern Canada (1996-2001, estimated)	4,956[16]	0.012	0.01
Total NE-EC	29,561	0.212	0.15

Jurisdiction	**Annual conversion from farms**	**Estimated carbon lost to conversion annually**[17]	
	ha	-	*MMTCO$_2$e* *Assume 40% carbon loss*
Northeast US (1997-2002)	11,671	-	0.003
Eastern Canada (1996-2001)	12,885	-	0.001
Total NE-EC	24,556	-	0.004

The conversion of forest and farm lands to other uses, while not a significant GHG impact in this region relative to other sectors, is rapidly changing the face of rural working lands. The conversion of forestland is up to almost 2% of total forestland per year. Not accounting for the unvalidated soil emissions estimates, conversion from non-soil forest lands (12.08 MMTCO$_2$e) has the potential to increase emissions in the NE up to almost 6% of the total regions emissions (206.5 MMTCO$_2$e) per year.[18]

Not accounting for changes in soil carbon, land use change may not be a substantial contributor to overall GHG emissions relative to other sectors. However, its associated development inputs have significant and related cascading effects on other sectors, including energy and transportation. As the rate

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[14] Maine Forest Service and Environment Northeast. 2006. Draft Carbon Report estimated carbon loss of approximately 1.3 MTCO$_2$e per ha per year.

[15] Forest data from Tables 2 and 3 in Smith *et al.* 2002. Forest Resources of the U.S. *Available at* http://ncrs.fs.fed.us/pubs/gtr/gtr_nc241.pdf ; farm data from USDA. 2002 Census of Agriculture. *Available at* http://www.nass.usda.gov/Census_of_Agriculture/index.asp.

[16] Canada State of the Forests 2004-2005, Profiles Across the Nation tables. *Available at* http://www.nrcan.gc.ca/cfs-scf/national/what-quoi/sof/latest_e.html ; forest conversion rates extrapolated from the 2003 Canada Greenhouse Gas Inventory urbanization estimates, *available at* http://www.ec.gc.ca/pdb/ghg/inventory_report/2003_report/toc_e.cfm; farm data from Bureau of Agriculture/Statistics Canada. 2001. *Available at* http://www40.statcan.ca/l01/cst01/agrc25a.htm.

[17] Maine Forest Service and Environment Northeast. 2006. Draft Carbon Report estimated carbon loss of approximately 1.3 MTCO$_2$e per ha per year.

[18] It is also worth noting that the reduction of forest where there are months of snow cover could result in less solar absorption and more reflection into the atmosphere, thereby increasing temperatures. Studies of this albedo effect by the Lawrence Livermore National Laboratory in California on forests have found that boreal forests may be warming global temperatures, while forests in tropical and mid-latitude areas tend to be cooling.

of land conversion increases, so too do emissions in other sectors through energy inputs in residential and industrial systems, construction of sprawling infrastructure and increased VMT.
Most visibly, conversion of land is inextricably related to sprawl. Maine estimates that from 1987 to 1994, each municipality in the state built more than 100 miles of road per year.[19] The cumulative carbon impact of land use change and other development activities is measurable and significant over the long term.

Geologic Sequestration

Increasing carbon dioxide capture and storage (CCS) is an attractive and potentially significant strategy to reduce and mitigate carbon dioxide emissions from power plants and other point and non-point sources. CCS makes use of the potential for natural systems to store and hold carbon dioxide over long periods of time.

The IPCC defines CCS as “a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.”[20]

Research on geologic sequestration by the U.S. DOE and others is focusing on how CO_2 behaves when stored in geologic formations and the integrity of its sequestration value.[21] Oil and gas recovery and storage in reservoirs, coal bed methane recovery, and CO_2 storage capacity in saline formations are all under investigation or in practice by DOE and others, and active recovery operations and saline injections are occurring at a number of sites across the globe.

Table 3.3: A sample of CCS projects worldwide[22]

Project Name	Project Size (MM tons CO_2 /yr)	Year Begun, to Begin	Project Summary
Sleipner	1.0	1996	CO_2 is captured from an off-shore natural gas processing platform and injected into a saline formation. Project motivated by a net tax on CO_2 emissions.
Weyburn	1.5	2000	CO_2 is captured in North Dakota and piped across the US-Canada border to the Weyburn oilfield in Saskatchewan. Significant modeling and field testing of CO_2 monitoring equipment being conducted in parallel to EOR project.
In Salah	1.2	2004	CO_2 captured from natural gas processing and reinjected to enhance natural gas recovery.
K12B	Initial inj.: 30 kt/yr 2006+: 0.4 MMt/yr Total: 8 MMt	2004	Enhanced gas recovery demo project.
Hokkaido	Injection rate: 2 t/d Total injected: 24 t	2004	CO_2 -ECBM test project. Spring 2005 wells will be refurbished (original

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[19] Maine State Planning Office. 1997. The Cost of Sprawl. *Available at* http://mainegov-images.informe.org/spo/landuse/docs/CostofSprawl.pdf .
[20] IPCC, Working Group III, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policymakers, and Technical Summary*, ISBN 92-9169-119-4, p. 2.
[21] U.S. Department of Energy. 2005. Geologic Sequestration Research. *Available at* http://www.fossil.energy.gov/programs/sequestration/geologic/ .
[22] National Energy Technology Laboratory. 2006. Carbon sequestration: CO_2 storage. *Available at* http://www.netl.doe.gov/technologies/carbon_seq/core_rd/storage.html#projects.

			cementing not satisfactory) and new more extensive CO_2 injection test planned.
CASTOR	Rate: 10 kt/yr	2004	Currently conducting pilot-scale tests of post combustion capture and case studies of four potential geologic storage sites.
Otway	Rate: 160 t/d Duration: 2 yrs Total: 0.1 MMt	Late 2005	Planned pilot-scale project. Saline formation and depleted gas field.
CO_2 SINK	Rate: 30 kt/y Duration: at least 2 yrs	2006	Project to test and evaluate CO_2 capture and storage at an existing natural gas storage facility and in a deeper land-based saline formation.

Source: National Energy Technology Laboratory, Carbon sequestration: CO_2 storage (2006)

Priorities

In general, there are four issues that need to be addressed to maximize the amount of carbon storage in the NE-EC region:

- There is limited information and differing conclusions about the capacity of the region's forest to sequester additional carbon.
- As farmland and forestland is developed to accommodate new housing, recreational uses, and commerce, GHG emissions rise and there are no requirements to minimize or offset these emissions.
- There are insufficient incentives for foresters to manage their lands in a way that maximizes long-term carbon storage (or minimizes the loss of carbon storage).
- There is almost no information about the potential for geologic carbon storage in the region and no strategic planning about how large point sources of CO_2 in the region may reduce emissions by storing carbon underground.

We identify two priorities to maximize carbon sequestration in the region:

- Priority 9 — Sequester carbon in terrestrial sinks
- Priority 10 — Capture and store CO_2 from energy and industrial sources

Carbon sequestration can provide real opportunities to sequester carbon while conserving, redefining and expanding ecosystem co-benefits. Well-designed policies will increase carbon and overall ecosystem benefits by developing carbon markets and providing appropriate financial incentives to landowners and the energy and industrial sectors.

Priority 9: Sequester Carbon in Terrestrial Sinks

By: Michelle Lichtenfels, Derek Murrow, Daniel Sosland and Michael Stoddard

Extensive forests in the region, such as those that exist in Maine, New Brunswick, Nova Scotia and Quebec and neighboring jurisdictions, can play a role in both reducing greenhouse gas emissions and storing carbon. Achieving additional sequestration or conserving sequestration capacity beyond business-as-usual can help bolster the regional forest economy, conserve forest (and farm) lands for a variety of carbon and environmental objectives, help increase the demand for sustainable forest harvest practices and products in the region, and increase market access and revenue streams for landowners producing those goods.

Sequestering carbon in terrestrial sinks is addressed in this section by improving inventory and accounting tools, improving forest management strategies with respect to carbon, and minimizing loss of carbon due to permanent land conversion.

9.1 Improve Inventory and Accounting Tools to Better Quantify and Track Forest Carbon

Summary

We recommend that officials and interested parties in the region work collaboratively to improve inventory and accounting tools regarding forest carbon. Steps toward achieving this include:

- convening an interdisciplinary team to share information and develop an accurate forest carbon inventory by conducting additional research on the carbon impacts of forest practices and land conversion, and forging agreement across jurisdictions as to the most accurate quantification methodology;
- streamlining models for use by foresters and land use planners, and considering the use of financial incentives to increase participation in the use of such models;
- dispatching the best remote sensing technology, using satellite data, to enhance transparency, standardized accounting, and lower costs;
- harmonizing legal instruments such that inventory, accounting and reporting frameworks throughout the region (and continent) are coordinated to best develop a functional, transparent, and liquid market for forest-based programs or carbon offsets.

The presence of regional and international agreements on GHG reductions makes it clear that an important opportunity exists to help develop technical solutions and shape credible infrastructure to support forest carbon offset markets. In this context, it is important to note that the economic and physical impacts of land conversion on the forest and agriculture sectors are poorly quantified at the present time.

Opportunity

Not only is there a need to clarify legal and institutional instruments around the provision of GHG mitigation services, there is a strong consensus that the practice of selling and buying carbon offsets has been hindered by technical issues and political processes, even if carbon projects are occurring in absence of compliance markets and/or standardized accounting methodologies. At this time, several technical issues exist that have not been satisfactorily resolved. These include questions such as permanence, additionality, leakage, risk, general accounting, and verification and monitoring of sequestration projects. These issues are still being addressed by the Subsidiary Body for Scientific and Technological Advice of the United Nations Framework Convention on Climate Change, the Northeast

U.S.'s Regional Greenhouse Gas Initiative (RGGI), EPA, NESCAUM[32] and others.[33] RGGI is currently attempting to address many of these issues in its model rule, which is undergoing revisions as of this writing, while other initiatives such as the Eastern Climate Registry seek to address GHG reporting requirements.[34] The presence of regional and international agreements on GHG reductions make it clear that an important opportunity exists to help develop technical solutions and shape credible infrastructure to support forest carbon offset markets.

Implementation

Implementation of this recommendation by states and provinces should include the following elements.

Quantification of Forest Carbon

Data on carbon for different forest types in the region is dispersed, and there is little consensus on agricultural and forest sector GHG emissions data in the Northeast, even despite natural resources carbon inventory data supplied by the Natural Resources Conservation Service (NRCS), USDA Forest Service, The Nature Conservancy and other non-profit organizations, and despite numerous iterations of modeling by EPA, NESCAUM and others. In Eastern Canada, there is a lack of province-by-province forest carbon inventory and sequestration (emissions) estimates for various forest types. As a result, forest carbon stock and sequestration potential are not provided in this document. The Nature Conservancy, Winrock International and The Sampson Group in their "Terrestrial Carbon Sequestration in the Northeast" project recently concluded that while USDA Forest Service data provides a suitable jumping off point for calculating changes in forest carbon, better (and more favorable) data on carbon sequestration exists and should be validated by others and used by policy makers. Furthermore, voluntary reporting of GHG emissions and sequestration by the forest industry and other actors in the forest sector has not been widely implemented for the simple reason that tracking and reporting can be costly, and there is no clear incentive for landowners to conduct these activities and/or share their data.

As noted earlier, uncertainties exist in the quantification of forest carbon stock and sequestration rates. Figure 3.2 illustrates the variability of forest carbon inventory in New England. Because wide discrepancies exist in and between jurisdictions, it is clear that additional research is necessary and agreement is needed on the most accurate methodology for quantification purposes.

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[32] H. Kaplan, NESCAUM, personal communication, October 2005.

[33] Penman, J., *et al.* (eds.). 2003. *Good Practice Guidance for Land Use, Land-Use Change and Forestry*. IPCCC National Greenhouse Gas Inventories Program. p. 19.

[34] NESCAUM. 2006. Draft Eastern Climate Registry Voluntary Reporting Requirements. *Available at* http://www.easternclimateregistry.org/documents/ECR_Draft%20Voluntary%20Requirements_May06.pdf.

Table 3.4: Non-soil forest carbon annual emissions estimates, NE

	Forest Carbon Inventory Source				
	USDA Agriculture & Forestry GHG Inventory, 2001 (2001)	**NESCAUM and EPA State Inventory Tool for New England, 2005 (2001)**	**USDA Forest Service, Forest Carbon of the US, 2003 (1997)**	**Maine GHG Action Plan Development Process, 2004 (2000)**	**Sampson, N. via the Northeast Forest Carbon Project, 2006 (2004)**
Jurisdiction	**Annual Emissions**				
	MMTCO$_2$e/yr	***MMTCO$_2$e/yr***	***MMTCO$_2$e/yr***	***MMTCO$_2$e/yr***	***MMTCO$_2$e/yr***
Connecticut	-1.30	-2.71	-1.05	N/A	0.98
Maine	-3.20	5.22	4.74	2.30	-17.55
Massachusetts	-3.40	-6.13	-3.89	N/A	-13.46
New Hampshire	-7.10	-11.82	-9.01	N/A	-10.63
Rhode Island	-0.20	0.11	-0.12	N/A	-1.31
Vermont	-11.70	-18.12	-16.17	N/A	0.59
Total	**-26.90**	**-33.44**	**-25.50**	**N/A**	**-41.38**

The variability of inventory methods also hinders quantification of forest carbon. Canada recently changed its forest inventory methods, which considerably changes the ability of policy makers to accurately represent or estimate the forest carbon inventory in each province. Even aside from this complication, data on forest carbon in Canada is difficult to come by, as noted earlier.

To resolve issues around forest carbon in the region, an interdisciplinary team with representation by scientists, government agencies, and non-profit organizations should be convened to share information and develop an accurate forest carbon inventory for the region. In particular, organizations who have initiated research in this area, including the Northeastern Station of the USDA Forest Service, U.S. EPA, NASA, The Nature Conservancy, The Sampson Group, Winrock International, NESCAUM, Environment Northeast, the Maine Forest Service and Maine Department of Environmental Protection, among others, should be engaged in this process.

Quantification of Impacts of Land Conversion on Carbon

The economic and physical impacts of land conversion on the forest and agriculture sectors are poorly quantified. The lack of information on land conversion and its carbon effects, especially in the Eastern Canadian provinces, suggests that it is a difficult phenomenon to quantify and study, and there is a strong indication that that policy decisions will not be made in absence of better data. More research is needed in this area to quantify land conversion between land cover types, and estimate the effects on carbon storage and release. Remote sensing and GIS experts, organizations involved in land conservation and protection, as well as Smart Growth advocates are well-equipped to help answer these questions and evolve research in this area.

Use of Models

As indicated above, forest management and forest inventory carbon models and decision support systems can be quite useful in forest management planning. However, models such as FVS, HARVCARB, FORCARB, CBM-CFS3 and others developed by the USDA Forest Service and Canadian

Forest Service can be quite cumbersome and difficult for local land managers to use in planning carbon sequestration activities.[35] These models should be streamlined for use by on-the-ground foresters and land use planners. Financial incentives, such as those provided for the USDA Natural Resources Conservation Service (NRCS) COMET decision-support tool in some states, may be recommended to encourage practitioners to use the models for planning purposes.[36]

Continued forest management modeling and analysis should be conducted by academic institutions and agencies supportive of better carbon information for a greater diversity of forest types in the region. An interdisciplinary team composed of staff from interested states and provinces, the CBM (Canadian modelers), and university researchers should be convened to address the suite of harvest management regimes for the entire NE-EC region.

Use of Remote Sensing

Remote sensing techniques using satellite data are already supplanting aerial photography data and broad forest inventory assessments in Canada and elsewhere in the world, although it has yet to be broadly applied due to issues of carbon sequestration project validation, scale, and cost. Current work led by Christopher Potter at the NASA Ames Research Center successfully draws upon MODIS satellite data with concurrent validation and calibration using known on-the-ground estimates of carbon.[37] Other private companies equipped with parallel technology, such as Terresense,[38] are currently engaging large industrial forest owners to help deploy remote sensing, although the relatively high costs may be a barrier at this stage.

Current limitations aside, dispatching the best remote sensing technology through applied use and research can help promote inventory efficiencies through transparency, standardized accounting methodology, and lower costs, and should be widely encouraged by policy makers.

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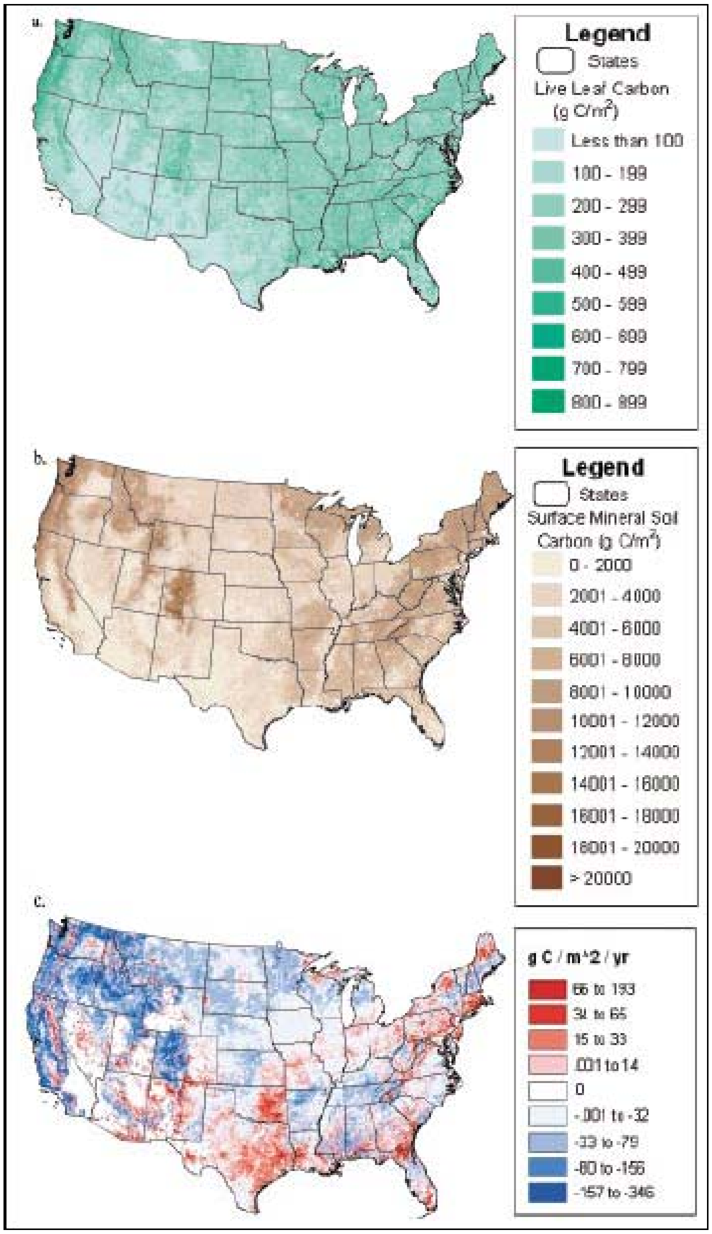
[35] For more information on the CBM-CFS3, go to http://www.carbon.cfs.nrcan.gc.ca/index_e.html.

[36] For more information on the COMET model, go to http://www.cometvr.colostate.edu/ . The Climate Change Network coordinated by the Clean Air Task Force has also developed a set of draft policy recommendations on agricultural sequestration, including the use and implementation of the COMET tool. This work is expected to be released in September 2006.

[37] Potter *et al.* 2006. Estimating Carbon Budgets for U.S. Ecosystems. Eos, Vol. 87, No. 8.
The USDA Bartlett Experimental Forest in New Hampshire was used to calibrate Northeastern data, for example. C. Potter, personal communication, March 19, 2006.

[38] Further information can be found at http://terresense.com/.

Figure 3.2: Nationwide baseline estimates from the NASA-CASA model for (a) live leaf carbon and (b) surface soil carbon pools, and (c) net ecosystem production circa late 1990s. [39]



Source: Potter *et al.*, Estimating Carbon Budgets for U.S. Ecosystems (2006)

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[39] In the NASA-CASA model, predicted surface soil amounts do not include soil carbon stored in layers deeper than 30 centimeters, which could be considerably larger. (c) Net ecosystem production (NEP) estimated as the sum of carbon fluxes for 1982–1997. Net gains of carbon from the atmosphere are shown as positive NEP values, whereas net losses of carbon from ecosystems to the atmosphere are shown as negative NEP values, both on a unit area basis. Figure from Potter *et al.*

Harmonization of Legal Instruments

It is imperative that regulators seek to coordinate inventory, accounting and reporting frameworks throughout the country in order to develop a functional, transparent, and liquid market for forest-based programs or carbon offsets. Inventory and registry tools, including the California Climate Action Registry and the Eastern Climate Registry (ECR), should continue to be coordinated and policy neutral.[40]

We recommend that policy makers and stakeholders support ECR's intention to be "neutral" to the differences between various state and regional climate policies and programs such that "a ton is a ton" across the registry and jurisdictions.

9.2 Promote Forest Management Strategies that Sequester Additional Carbon

Summary

States and provinces in the region should develop a strategic plan for research around forest carbon sequestration, silvicultural pathways and forest management regimes that can be used to mitigate the region's GHG emissions. A partial list of items meriting further research includes: the storage capacity and economics of biochar, potential effects of "leakage," certification linkages, the role of conservation easements, and carbon accounting protocols for use of durable wood products.

Recent modeling suggests that modified commercial silvicultural practices and forest management regimes (*e.g.*, modified early commercial thinning) can increase the net carbon balance on forested lands compared to business as usual harvesting practices. While the modeling indicates these carbon-friendly practices can capture carbon at a more attractive price than other carbon mitigation measures, we recognize that several important economic variables are not yet well understood. The modeling results can be improved as more work is done to develop practical procedures for implementing and demonstrating modified forestry practices for GHG sequestration and estimating the associated costs.

Establishing new pilot programs to test forest management models is an important next step in demonstrating the commercial and administrative feasibility of forest carbon projects employing modified practices. We further recommend developing programs designed to encourage landowners to sequester additional carbon at the state, provincial or regional level. These programs could serve as a stand-alone driver of modified silvicultural practices or as a bridge to carbon market opportunities that may result with the implementation of carbon cap-and-trade regulations that make forest sequestration projects eligible for tradable offsets that connect with other policies like cap and trade programs.

Carbon mitigation regimes, including mandatory and voluntary carbon trading programs, are driving interest in the potential carbon impacts of forestry and land use change. Such a program is under discussion in the RGGI proposed cap-and-trade system in the Northeast U.S., and was a component of Canada's proposed "Project Green" plan and Large Final Emitters program, which have been put on hold at the time of this writing.

Carbon-related silvicultural financial incentives have the potential to provide a supplementary stream of funding to landowners who might otherwise be inclined to sell their land for development. Considering that the entire NE-EC has 128 million hectares in managed forestland, we conclude that the potential for added carbon sequestration could be significant even if only modest increases in CO_2 stored per acre are achievable through improved forest practices.

Definitions:

Acre – 1 acre is equivalent to approximately 0.405 hectares

Afforestation – Establishment of forests on land that has not been forested for a specified period of time, *e.g.* 10 years or more

Hectare – 1 hectare is equivalent to approximately 2.47 acres

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[40] A more detailed discussion on GHG inventories and registries can be found in the Energy Chapter in Priority 4.

Reforestation – Re-establishment of trees on previously forested sites (*e.g.* post-harvest)

Silviculture – The scientific practice of forest management

Opportunity

Creating a one-size-fits-all management regime for the region's forests is, of course, impossible. New England and Eastern Canadian forests have long been managed through site-specific forest management strategies carried out by a complex set of private and public landowners. However, recognizing there will be variability among sites and landowners to act on this recommendation, we suggest that the region's forests would benefit from management designed to increase carbon benefits. The best opportunity for shifting management practices will most likely be through carbon offset programs and state-level policies that promote entry into voluntary or mandatory state or regional carbon markets. For this to happen, better baseline data and models are necessary to guide policy and market design.

The potential to manage forests for carbon benefits is a common element in most regional and international strategies designed to mitigate and reduce GHG emissions. A small but emerging market for forest carbon exists in the U.S. and Canada, driven in large part by voluntary actors and emerging compliance-driven markets. Regulatory and policy actions spurring the development of these markets include:

- the Regional Greenhouse Gas Initiative (RGGI) cap-and-trade program, which is set to reduce emissions in six Northeastern states and Maryland, effective in 2009 includes an afforestation offset type to help regulated power plants meet their reduction targets;[41] other offset types around forest management are expected to be developed at a later date;
- the international Kyoto Protocol, of which Canada is a signatory, allows carbon targets to be reached through carbon sink activities involving afforestation, reforestation, and forest management activities;
- the Asia-Pacific Climate summit, of which the U.S. is a party to discussion;
- the Canadian Large Final Emitters System (LFE), targeted at emissions reductions in energy, electricity, manufacturing, and mining sectors, proposed in 2005;
- the New England Governors and Eastern Canadian Premiers (NEG/ECP) 2001 Climate Change Action Plan;[42]
- other state climate action plans and emissions reductions targets.

The forest carbon market itself is subdivided here into active regulatory and voluntary markets, proposed markets, and registries. As of this writing, active markets include:

- the Climate Trust (Oregon), which provides compliance and voluntary offsets to members through investment in a range of offset projects;
- the Chicago Climate Exchange (CCX), which provides a voluntary, binding mechanism for members to reduce emissions and trade carbon credits;
- other voluntary brokerage and carbon fund services, including CO2e.com, Ecosecurities, Evolution Markets, and Natsource.

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[41] The Regional Greenhouse Gas Initiative (RGGI) Draft Model Rule. *Available at* http://rggi.org/modelrule.htm.

[42] With the economy-wide goal of reducing CO_2 emissions to 1990 levels by 2010, 10% below 1990 levels by 2020, and a long-term reduction of 75-80%.

Proposed markets include:

- the Canada Climate Fund, which establishes a mechanism for the Canadian government to purchase carbon offsets (first budgeted in 2005);
- the Montreal Climate Exchange, in development agreement between CCX and the Montreal Exchange (as of early 2006).

Registries include:

- the California Climate Action Registry, a voluntary program to help businesses track their emissions;
- the Eastern Climate Registry, coordinated in large part by the Northeast States for Coordinated Air Use Management (NESCAUM), and which is designed to support voluntary and mandatory GHG reporting programs.

Example: The Climate Trust, Oregon

The Climate Trust, previously known as The Oregon Climate Trust, was established in 1997 by the State of Oregon to facilitate CO_2 emissions reductions in the state. At the state level, Oregon's power plants are required to offset a substantial portion of their GHG emissions by setting aside offset funds. The Climate Trust invests these funds in a portfolio of carbon projects that reduce CO_2, including Oregon-regional projects such as the Deschutes Riparian Restoration and protection of a Lummi Indian Tribe native northwest forest. The native forest project, like many other temperate forest projects, has a 100 year project life, and in this case, prevents harvest of the forest with the goal to revert it back to old growth conditions.

For offset projects with long life-spans, as is the case with forestry, trust entities may prove critical to the success of the offset marketplace. These entities provide an important brokering mechanism for companies looking to reduce their offsets while providing non-regulatory oversight and compliance functions.

Canada's commitment to the Kyoto Protocol is uncertain. Although it is an official party to the Kyoto Protocol, the new government elected in 2006 has initially reversed course on many of the climate change plans put forward by the prior government. At the time of this writing, details about new plans or specific programs to replace those that were canceled or put on hold are not available. Thus, it is not clear what discussions could be had on the issue of including forestry inputs as part of Canada's climate change mitigation strategy. In any case, it is worth noting that the effects of the mountain pine beetle and forest fires have a strong impact on reducing the capacity of the Canadian forest as a whole to serve as a carbon sink, creating other significant non-political uncertainties at this point in time.

The Forest Resource

The Northeast U.S. and Eastern Canadian forest lands are characterized by mixed, often diverse stands of conifers and deciduous trees. In the southern part of the region, the forests are dominated by the oak and hickory forests. In the middle part of this ecoregion, forests are dominated by the northern hardwoods—maple, beech, and birch. As one moves north and east, spruce and fir become the dominant species. In parts of northern Maine and Eastern Canada, a significant portion of the land is held in spruce plantations, especially in New Brunswick.

Though over 70% of this region of the U.S. is forested, the forested area is more heavily concentrated in the northern regions of Maine, Vermont and New Hampshire.[43] About 56% of Eastern Canada is

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[43] Alig, Ralph J.; Butler, Brett J. 2004. Area changes for forest cover types in the United States, 1952 to 1997, with projections to 2050. Gen. Tech. Rep. PNW-GTR-613. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. p. 106.

forested, with a substantial portion of the non-forested area in arctic tundra, rather than developed land.[44]

Silvicultural practices—the science of growing and managing forests over time—vary significantly by forest type and factors such as land use history, elevation, maritime influence, soil types, growth rates and wood quality. In the oak/hickory mixed hardwood forests endemic to central and southern New England, silvicultural treatments focus primarily on carefully planned selective thinning regimes that provide periodic economic return to the landowner and promote natural regeneration. In the northern hardwoods of Maine and Eastern Canada, the forests are also managed through selective harvest practices. In the plantations of northern Maine and Eastern Canada, spruce and other softwood growth is promoted through planting of seedlings, a series of pre-commercial and commercial thins, and final harvest through clearcutting. Although clearcutting is uncommon in the southern part of this region, it is quite prevalent, particularly in the softwood regions of northern Maine and Canada.

Natural disturbance regimes—fire, wind, insects and disease—play an important role in the development, structure, function, and composition of forests and forest ecosystems. Though such disturbance ultimately produces a host of environmental co-benefits, such disturbances also result in the loss of accumulated forest carbon in a relatively short time period. Depending on the scale of disturbance and other synergistic effects (such as fire), natural disturbances can result in significant carbon emissions and/or reduced sink capacity, both temporary and long-term. In the forest, dead and dying trees begin to decay and respire. Outside the forest, to mitigate the economic impact of these disturbances, forest practitioners respond with silvicultural prescriptions that prevent the current and anticipated spread of insects and disease and capture stand value through early harvesting or salvage. Furthermore, as the climate changes over time, the potential for increased or shifting patterns of insects and disease can become quite important in terms of both net carbon storage (and loss) and forest management response.

In the NE-EC region, the spruce budworm, hemlock wooly adelgid and white pine blister rust are but a handful of naturally occurring insects and fungal diseases of most concern to forest managers.[45] The spruce budworm, whose outbreak occurs every 30-50 years, is arguably of highest economic concern. The last major outbreak affected over 2 million acres in the Northeast in the 1970s and 1980s, prompting significantly increased softwood cutting during that time period. Wind can also be a driving disturbance in NE-EC but such large-scale wind events are rare.

The combination of fire and insects, while not a strong natural disturbance in the region as a whole, is quite significant in Quebec as well as other parts of Canada and the U.S. Already, spruce budworm and mountain pine beetle affect large areas of forest throughout central and western Canada, making these forests even more vulnerable to catastrophic wildfire.

Disturbances such as those discussed here highlight risk management concerns around forest-based sequestration. Forest carbon sequestration and forest-based emissions are relatively measurable, but due to these kinds of natural impacts, neither is fully guaranteed. Especially in light of emerging science, risk management and mitigation issues around forest carbon must be addressed by appropriate inventory and accounting rules.[46]

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[44] Natural Resources Canada. 2005. The State of Canadian Forests 2004-2005; The Boreal Forest. http://www.nrcan-rncan.gc.ca/cfs-scf/national/what-quoi/sof/latest_e.html.

[45] Other disease agents, namely chestnut blight and Dutch Elm disease, have already eradicated those tree species in the region.

[46] Schiermeier, Q. 2006. Methane finding baffles scientists. Nature. Vol. 439:12.

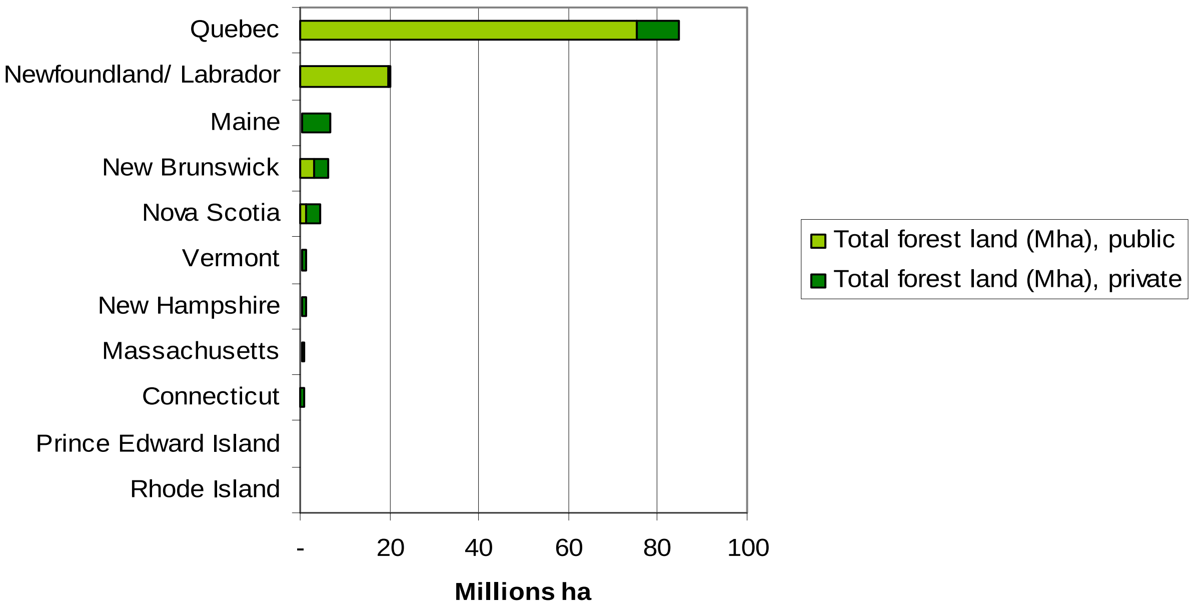
Ownership Patterns

Forest ownership patterns vary widely by jurisdiction. Ownership size strongly influences forest management strategies, transportation and wood markets. Forest ownership and parcel size can also influence the type of economic incentives required for landowners to conduct carbon sequestration activities, especially as significant efficiencies are required if carbon projects are to be economically viable and certain markets may require provision of minimum carbon tonnage.

On the U.S. side of the border, almost 90% of forests are privately owned, the majority of which are managed by small non-industrial owners who own less than 1,000 acres. In Connecticut, almost 80% of forestland is held in ownership by owners who own less than 500 acres.[47] However, farther north in Maine, where much of the state is in active timber management, 60% of the timberlands with sizes greater than 5,000 acres are privately held by individuals, companies, and timber investment management organizations (TIMOs).[48]

On the Canadian side of the border, an average of just under 50% of the forests are privately owned, but this proportion varies by province. In Quebec, for example, which holds 21% of the country's forests, almost 90% of the forestlands are publicly held. In Nova Scotia, where there is two-thirds less forestland than Quebec, only 30% of forests are publicly held.[49] In Eastern Canada, the proportion of larger industrial landowners and private woodlot owners also varies. In Quebec, there are almost eight times as many private woodlot owners as there are industrial private forest owners. These woodlot owners, as in Nova Scotia and Prince Edward Island, manage average parcel sizes ranging between 44 and 66 acres.[50]

Figure 3.3: Total forest land, NE-EC[51]



Sources: USDA Forest Service (2005), Forest Resources of the US (2002), Canadian Forest Service (2006) and State of Canada's Forests 2004-2005: The Boreal Forest

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[47] USDA Forest Service. 1998. Trends in Connecticut's forests: A half-century of change. Northeastern Research Station Publication NE-INF-143-01.

[48] Irland, L. *et al*. 2002. Working Draft. Logging in Northern Maine.

[49] The State of Canadian Forests 2004-2005: The Boreal Forest.

[50] *Ibid.*

[51] US data from USDA Forest Service, 2005. Forest Resources of the US, 2002. EC data from the Canadian Forest Service. 2006. State of Canada's Forests 2004-2005: The Boreal Forest.

Current Mandatory Regulation and Voluntary Programs on Forestry

Forest Practices Acts

Regulation of the forest industry is accomplished through a suite of compulsory and voluntary restrictions on tree harvesting.

State forest practices acts, enforced by state forest service or environmental protection departments, are present in some form in all northeast states. These regulations govern the licensing of foresters and/or loggers, tree harvest activities, regeneration of new trees after harvest, clearcuts, water quality and other environmental protection measures, and set forth notification or permit requirements prior to harvest. Some states rely heavily on certified foresters and loggers to implement established "best management practices" (BMPs). Other states, such as Maine, outline strict regulations on the size and locations of clearcuts, riparian buffers herbicide use and forest regeneration standards.

Forest practices requirements are similar in Canada. For provincially-owned lands, there exists a unique relationship between the province and private forest companies who are granted harvest rights in exchange for royalties or fees. To hold these leases, forest companies are required to follow certain provincial forest practice regulations and prepare forest management plans. Private forest owners in Canada must also follow provincial forest practices acts.

Forest Certification

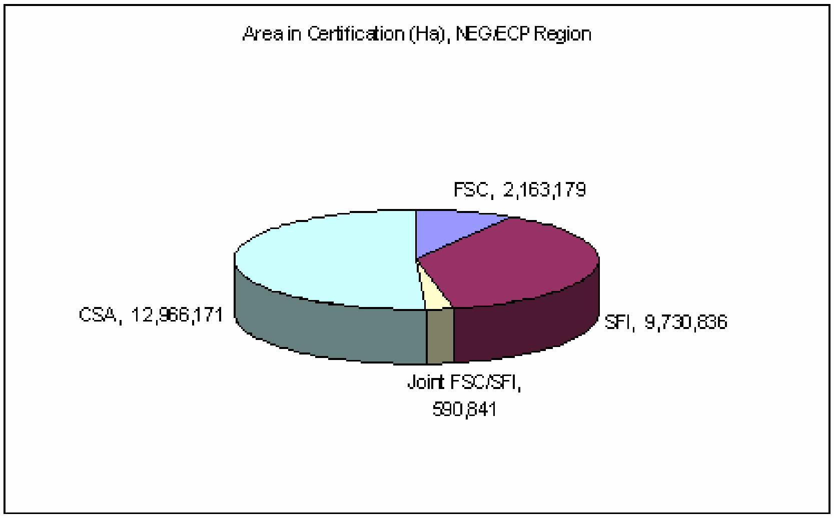
Forest certification—a voluntary, non-governmental market-driven forest management system that designates forests as "well-managed" through a third-party verification process—is common in the NE-EC region. The Forest Stewardship Council (FSC) and the Sustainable Forestry Initiative (SFI) are the most widely accepted certification schemes in North America, but the Canadian Standards Association (CSA) certifies Canadian forests as well. It is worth noting that, in the maritime region (spanning both Canada and US), different FSC standards exist across the international border, despite nearly identical forest characteristics.

All certification schemes seek to address similar social, economic and environmental sustainability issues through a series of specific and measurable criteria that are more numerous and stringent than jurisdictional forest practices regulations. It should be noted that at this point in time, certification schemes do not directly address or include carbon sequestration or GHG emissions criteria, though carbon sequestration programs are certainly compatible with and/or complementary to forest certification.

Table 3.5: Forest area in certification[52]

Jurisdiction	Area in Certification			
	FSC	SFI	Joint FSC/SFI	CSA
	ha	*ha*	*ha*	*ha*
Connecticut	288	3,173	Not avail.	N/A
Maine	145,852	2,058,489	590,841	N/A
Massachusetts	241,328	-	Not avail.	N/A
New Hampshire	117,549	35,209	Not avail.	N/A
Vermont	43,908	-	Not avail.	N/A
Rhode Island	-	-	Not avail.	N/A
Quebec	1,206,086	1,935,210	-	8,542,358
New Brunswick	5,095	3,929,000	-	-
NF/Lab	-	-	-	3,792,813
Nova Scotia	-	1,731,373	-	631,000
PEI	-	-	-	-
Sub-total	**2,163,179**	**9,730,836**	**590,841**	**12,966,171**
Grand Total				**32,358,071**

Figure 3.4: NE-EC region, forest area in certification, 2006



Sources: Canada Sustainable Forest Management Certification Status Reports, Maine Department of Conservation, and Forest Certification Resource Center

The voluntary nature of certification necessitates relatively short certification periods, with forests issued certificates every five years, and annual audits required for all landowners to ensure compliance with certification standards.

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[52] Canada data from Canada Sustainable Forest Management Certification Status Reports. Accessed 030406 at http://www.sfms.com/status.htm#status; Maine data from Maine Department of Conservation, Maine Forest Service. Accessed 040606 at http://www.state.me.us/doc/mfs/fpm/forcert.htm; CT, MA, NH, RI, VT data from Forest Certification Resource Center. Accessed 040606 at http://www.certifiedwoodsearch.org/searchforests.aspx.

The Forest Economy

The forest economies of the Northeast states and Eastern Canadian provinces vary. Although Maine's forest sector has shown relatively high returns (11-17%) over the last 4-5 years, the forest sector has been characterized as having traditionally low profitability, with a cyclical economy that contributes to difficulties in retaining working, productive forests and rural livelihoods.[53,54] The forest industry economy is sensitive to harvest levels and prices, and during weak periods in lumber and pulp and paper markets, poor stock market performance intensifies pressures on management to reduce costs and develop alternate sources of income (such as selling land for development).[55]

One result of this sensitive forest economy is that the number of firms in the forestry and wood product sector has dramatically declined over time as companies consolidate and firms vertically integrate to increase efficiencies. Currently, sawmill production in Maine and Eastern Canada relies heavily on the operation of a few dozen very large sawmills, even though there are several hundred sawmills in these regions.[56]

Removal and re-establishment of trees provides the primary, and in some cases, single source of income for forest owners in the region. Non-timber forest products (NTFPs) such as maple sugar and maple products provide an additional source of income for some land managers, but even in Canada, where NTFPs are well-tracked, the sale and management for NTFPs does not provide strong economic return in comparison to harvest. Carbon-related financial incentives, in addition to the value of timber and NTFPs, have the potential to serve as a supplementary stream of funding to landowners who might otherwise be inclined to sell their land for development.

From a broader perspective, the forest industry in Canada is an economic driver of the economy. In large part due to significant contributions of British Columbia, Canada attributed almost $33 billion of its 2002 trade surplus to the forest industry.[57] As the world's leading exporter of forest products, and one of the world's largest stores of carbon in the boreal forest, the actual and potential carbon impacts of the Canadian forest sector is tremendous. Carbon policies that benefit the eastern part of the country may also be highly adaptable to other timber regions of the country.

Implementation

Afforestation

While afforestation activities are an option for landowners in the region, there are a number of barriers to implementation on a wide scale and with a few exceptions, afforestation does not show significant project potential in the NE-EC region. This is, in part, related to a small pool of suitable candidate lands on which to conduct afforestation activities. In general, most unforested, non-urbanized land in the NE-EC is marginal forestland, prime and/or protected agricultural lands, or a strong candidate for residential and commercial development. It is also partly due to the relatively high total costs of afforestation.[58] For some of these reasons, the Maine Greenhouse Gas Climate Forestry Working Group deferred any recommendations on the potential for afforestation activities in the state climate action plan.[59]

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[53] James W. Sewall Company. 2005. Timberlands Report, Vol. 7 No. 2. http://www.jws.com/pdfs/timberlandreport/v7n2.pdf.

[54] Irland, L. *et al.* 2002. Working Draft. Logging in Northern Maine.

[55] *Ibid.*

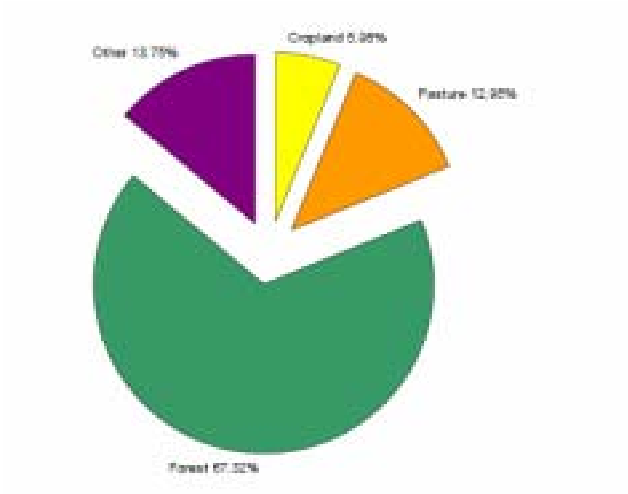
[56] *Ibid.*

[57] Natural Resources Canada, Canadian Forest Service. 2003. Forest Industry in Canada. http://www2.nrcan.gc.ca/cfs-scf/industrytrade/english/View.asp?x=11.

[58] Winrock International. June 2006. Terrestrial Carbon Sequestration in the Northeast, Quantities and Costs. Draft Part III. Opportunities for improving carbon storage and management on agricultural lands. *Available at* http://conserveonline.org/workspaces/necarbonproject/Draft%20Part%20III%20Nortehast%20Carbon%20Opps.pdf.

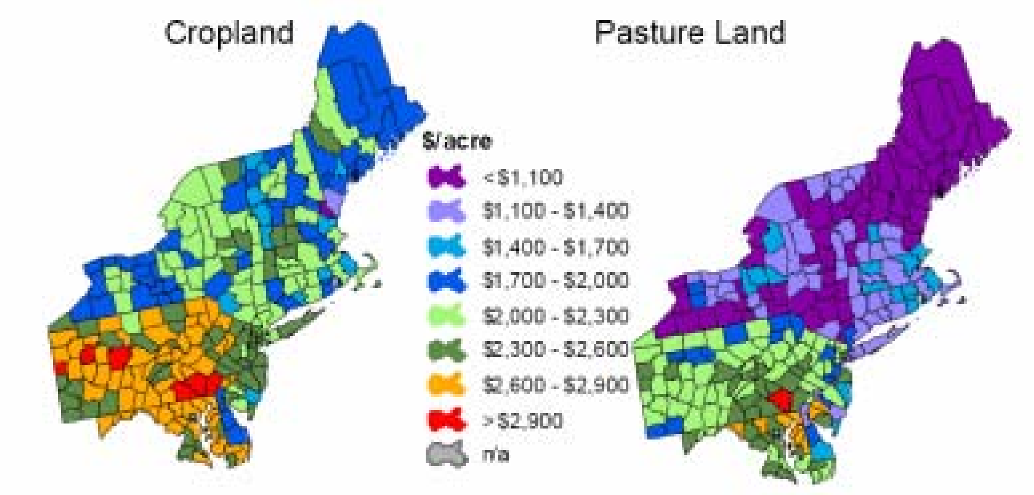
[59] Maine Department of Environmental Protection. 2004. Maine Climate Action Plan.

Figure 3.5: Main cover classes in the greater Northeast region[60]



Source: Winrock International, Terrestrial Carbon Sequestration in the Northeast, Quantities and Costs (2006)

Figure 3.6: Estimated total costs for afforestation of cropland and pasture land after 10 years



Source: Winrock International, Terrestrial Carbon Sequestration in the Northeast, Quantities and Costs (2006)

Expressed as price per ton of CO_2e, estimates of afforestation costs range between $30 and $173 for cropland, and between $14 and $179 per ton CO_2e for pasture land over a 10 year period.[61] The lowest costs are achieved in areas with the lowest land use change costs (areas where it is less expensive to buy land and change land use) and the highest rates of carbon uptake by forests.

In Nova Scotia, a 2003 study on afforestation was conducted by Nova Scotia Power and the Canadian Forest Service to assess landowner understanding and opinions on afforestation potential in the province.[62] The study found an overall willingness of landowners to participate in afforestation activities,

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[60] Winrock International.

[61] *Ibid.*

[62] Corporate Research Associates, Inc. for Nova Scotia Power Inc. and Canadian Forest Service. 2003. Afforestation study summary report. *Available at* http://www.nrcan.gc.ca/cfs/national/what-quoi/afforestation/reports/EconomicAnalysis/AfforPilots/AFCFAACSPilotReports/AFCNovaScotiaPowerIncReport.pdf.

but estimated that only 1 in 5 landowners might participate. In other regions, Canada is quite interested in conducting pilot studies and research on afforestation and reforestation, but these strategies are primarily targeted to those Canadian provinces outside the ECP that support more grassland and agricultural dependent economies.

Implement Carbon-Specific Forest Management through Silviculture

Unlike afforestation, there is ample opportunity to practice better forest management activities with respect to carbon. Modeling conducted by the Maine Forest Service (MFS) in partnership with Environment Northeast suggests that certain forest management strategies in the northern hardwood forests encourage large trees, reduce waste and mimic more natural disturbances through light-to-moderate thinning techniques while moderately improving carbon sequestration. These strategies are compared to traditional forest management strategies that promote shorter rotations and regular harvests that put more carbon into forest products than natural stands, thereby increasing emissions.

Three forest management regimes of varying intensity were modeled from a common baseline forest inventory. The business as usual (BAU) scenario was designed to mimic average current forest harvest practices in the northern hardwoods of Maine, and consisted of one heavy harvest about 40 years after the baseline year in order to create large, valuable sawtimber-grade trees. The other two regimes are light harvest regimes, with two lighter (early commercial thin) harvests scheduled over the 92 year period modeled.

Table 3.6: Description of forest management scenarios for Maine northern hardwoods[63]

Forest Management Scenario	First Harvest	Second Harvest
BAU	2045: Heavy harvest to remove all trees >5" diameter (dbh), or 28 cords/acre	N/A
ECT-5 cord removal	2004: Light early commercial thin of 5 cords/acre	2045: Commercial thin of sawtimber, all trees 5-11.1" dbh or 5 cords/acre
ECT-8 cord removal	2004: Light early commercial thin of 8 cords/acre	2045: Commercial thin of sawtimber, all trees 5-9.8" dbh, or 8 cords/acre

In the 92-year comparison between BAU practices and double-entry early commercial thin (ECT) management scenarios, ECT regimes were projected to store between 0.13 and 0.24 $MTCO_2e$ per hectare more than the BAU scenario. Modeling is particularly valuable in that it suggests a discrepancy between carbon sequestration benefits and financial returns in these forest stands.[64]

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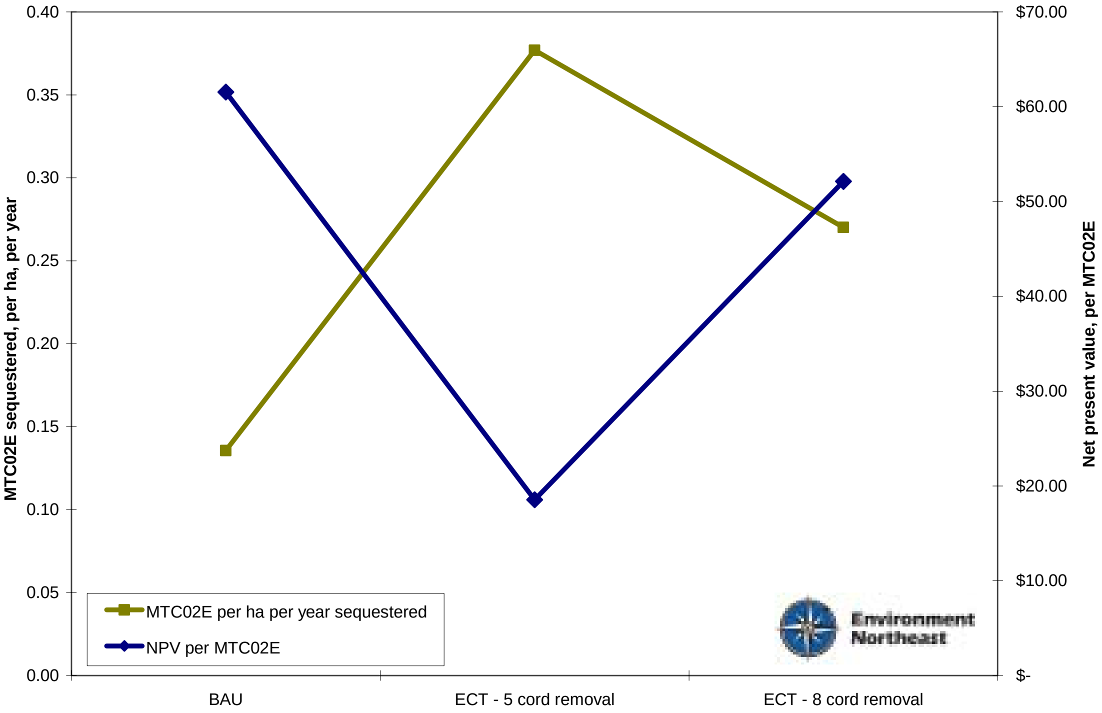
[63] Giffen, A. and Sosland, D. 2006. DRAFT: Investigating the economic and ecological potential to increase carbon sequestration in Maine forests and reduce greenhouse gas emissions. Phase I report: How management of northern hardwood poletimber stands affects onsite carbon storage and emissions, as well as atmospheric CO_2 levels.

[64] *Ibid.*

Figure 3.7: MTCO$_2$e sequestered vs. net present value for three forest management regimes[65]



BAU clearly has the greatest NPV for the landowner, thereby making it the most attractive management option currently available. However, offset markets have the capacity to pay landowners to manage in alternate ways by paying landowners for each MTCO$_2$e gained through management.

Assuming the NPVs given, landowners would theoretically need to be paid in the range of $0.31-0.78 per metric ton of carbon to switch management regimes. We are skeptical that landowners will change regimes so cheaply, and additional analysis must be conducted to determine what the additional costs of providing offsets might be. These numbers also do not reflect the full cost of changing management scenarios, as there are additional costs not modeled here that include, but are not limited to transaction costs and full verification and monitoring costs.[66]

The challenges to changing the management paradigm to favor greater carbon benefits are large. The forest sector is composed of a complex set of actors that are motivated to manage forests for a number of objectives. For many of the small non-industrial forest owners—woodlot owners, for example—forest management actions are spurred by aesthetics and recreational targets such as passive recreational opportunities or wildlife management. Their capacity to efficiently respond to carbon markets is low, especially as they lack economies of scale.

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[65] Giffen, A. and Sosland, D.

[66] To date, research on estimates of transaction costs for forest carbon projects have been relatively limited. In a study of transaction costs for farmland conversion in Mexico, transaction costs ranged between 6% and 45% of total costs. Milne, M. 2002. Transaction costs of forest carbon projects. Report submitted to the University of New England as part of the ACIAR Project ASEM/1999/093. *Accessed at* http://www.une.edu.au/carbon/CC05.PDF.

Larger forest owners in the industrial sector, while operating at economies of scale, also function in a very capital intensive sector that is relatively slow to respond to short-term policy measures.[67] Industrial owners respond to shareholder demand to manage for profit, and subsequently, they may or may not be motivated to manage their forests for their long term productivity over 100+ years.

Considering that the entire NE-EC has 128 million hectares in managed forestland, it is not difficult to see that the potential for added carbon sequestration is high. Even if we make a rough estimate, if 10% of all NE-EC managed forestland nets carbon gains averaging 0.13 MTCO$_2$e per acre (beyond BAU), that is equivalent to almost 1.72 MMTCO$_2$e per year of additional carbon sequestered, or 159 MMTCO$_2$e over the lifetime of the forest.

Research

States and provinces in the region should develop a strategic plan for research around forest carbon sequestration, silvicultural pathways and forest management regimes that can be used to mitigate the region's GHG emissions. A partial list of items meriting further research includes: the storage capacity and economics of biochar, potential effects of "leakage," certification linkages, the role of conservation easements, carbon accounting protocols for use of durable wood products

Implement Pilot Programs

Pilot programs should be implemented to test forest management models and determine that forest carbon offset projects in the area are scientifically credible and economically feasible. Pilot projects will help demonstrate the commercial feasibility of carbon projects in the region, illustrate the most efficient blend of carbon benefit versus cost, and lead to a better understanding of the costs of project implementation and monitoring. The results of such pilot programs will provide tangible scientific and procedural lessons learned, and help prove the viability of forest management as a carbon offset type and facilitate the development of additional offset protocols for RGGI or other cap-and-trade mechanisms in the future.

Preferably, a pilot would be undertaken on land that had significant historical forest inventory data.

Develop State Programmatic Opportunities

As long as there is no compliance-driven market for forest-management-based forest carbon offsets, there is an opportunity for state-level entities to develop strategic programs designed to encourage landowners to sequester additional carbon, either as a stand-alone program or as a bridge between carbon market opportunities.

Such an arrangement would help reduce transaction costs while supporting the forest economy and rural prosperity. The long term goal should be to provide incentives to move landowners and forest managers towards management and harvest practices that increase the quantity of carbon sequestered in the region's forests.

As noted previously, in many areas of the Northeast region, the greatest amount of forestland is in the hands of small non-industrial forest owners. These forest owners are unlikely to manage their timberlands singularly for carbon. Additionally, they are highly unlikely to enter the carbon market in the absence of an adequate policy infrastructure, especially in light of the high cost of monitoring and verification for carbon.

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[67] WBCSD. 2005. The sustainable forest products industry, carbon and climate change: Key messages for policy-makers. 20 Dec 2005. *Available at* http://www.wbcsd.org/plugins/DocSearch/details.asp?type=DocDet&ObjectId=MTc0MDU.

A state-level program would fill this gap and serve as an aggregating function for small landowners to help defray and underwrite costs associated with verification and monitoring of forest carbon. While the details of such a program will ultimately require refinement to ensure that no perverse incentives or adverse leakage effects occur, there are a number of options available to regulators. These may include tax incentives and/or rebates, payments for carbon sequestered above a pre-determined BAU or baseline inventory, payments or credit for wood products created and opportunities to engage landowners in sustainable forest practices or management practices that open up lands for public benefits. Wisconsin, for example, has had success with its state-level Managed Forest Law and bundled certification program. This program is carefully designed to aggregate small landowners under a state-managed verification program, and rewards the greatest tax benefits to landowners who open a certain proportion of their lands for public recreation.[68]

We recommend that any state level program be designed with future carbon markets in mind, especially the potential future opportunities under RGGI. The program may be structured in a way that does not preclude future inclusion in a RGGI market, or it may be a unique opportunity for proactive state agencies to foster state-level action on forest sequestration opportunities.

At the same time, state-level programs offer a proven forum for providing technical assistance to landowners, many of whom are unaware of the potential for forest carbon sequestration on their property. Education efforts can be built into discussions around state policies and facilitate by a variety of engaged forest sector stakeholders—forest products councils and associations, small woodlot owners associations, Society of American Foresters, industry organizations, non-governmental organizations and others.

9.3 Minimize Carbon Loss from Land Conversion

Summary

We recommend that states and provinces:

- establish a Carbon Neutral Growth Program to reduce or mitigate land conversion in moderate to large scale residential and commercial development;
- create a Carbon Neutral Growth Conservation Fund to invest in carbon offsets or conservation easements.

A carbon mitigation program for land development projects should reach certain existing municipal permitting requirements, thresholds or site plan reviews. Where development of forest or farmland is proposed, we recommend states and provinces employ the following steps to reduce or mitigate the projected carbon impacts of land conversion:

- calculate the difference between the baseline land-use carbon storage potential over a specified time frame and the amount of carbon storage expected to be maintained on-site following development;
- offer developers multiple paths for compliance with carbon mitigation requirements, such as reconfiguring the development plan, purchasing carbon offsets from other projects or paying an alternative compliance fee to an entity that invests it in carbon offsets or a Carbon Neutral Growth Conservation Fund.

The clearing of land for residential development may remove as much as 50-67% of above ground biomass and its associated carbon, while removing 22-25% soil carbon. In New England the rate of land conversion from rural agriculture and timber land to residential and commercial development is estimated at 1,724 acres (698 hectares) per week, while the Eastern Canadian provinces are estimated to be converting at a slightly lesser rate of 817 acres (331 hectares) per week. “In certain parts of the region, conversion of forest and farm land through development threatens carbon loss as well as the viability of sustainable working forests.”

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[68] Wisconsin Department of Natural Resources. 2006. Forest Tax Law Program. *Accessed 041706 at* http://www.dnr.state.wi.us/ORG/LAND/forestry/ftax/Index.htm.

Summary *(continued)*

Local jurisdictions can influence carbon impacts from land conversion by means of zoning and land use regulations, tax programs, and conservation easements.

Land development practices that retain open space and vegetation have been found to reduce costs of land clearing from business as usual costs of $2,000 per acre down to $726-821. The carbon savings from avoided clearing were estimated to be 53.35 tons of carbon per acre.

Opportunity

Both forests and cropland are vulnerable to disturbance through management practices and land use changes, which disturb surface soils and release carbon rapidly through respiration. It is estimated that clearing of land for residential development removes 50-67% of above ground biomass and its associated carbon, while removing 22-25% soil carbon.[69] Mitigating the effects of land clearing will help avoid sequestration losses, while providing a market mechanism to ensure re-investment in other carbon projects.

In New England the rate of land conversion from rural agriculture and timber land to residential and commercial development is estimated at 1,724 acres (698 hectares) per week, while the Eastern Canadian provinces is estimated to be converting at a slightly lesser rate of 817 acres (331 hectares) per week.[70] The number of acres of land in agriculture in New England is decreasing in every state with the exception of Maine, and every province except New Brunswick.[71] In New England, the forest area is estimated to be decreasing at a rate of almost 2% a year, and the farmland decreasing at almost 0.7% per year, presumably to fuel the growing demand for developable land. Eastern Canada's forest area is estimated to be decreasing at only 0.004% per year, but its farm and pasture lands are disappearing at almost 0.3% per year.[72]

As can be seen in Figure 3.8, land conversion is drastically changing the face of farm and forest lands in the region. In Barnstable County, Massachusetts, conversion resulted in the development of almost 4,000 acres of land over a 28 year time period, and further contributed to landscape fragmentation.

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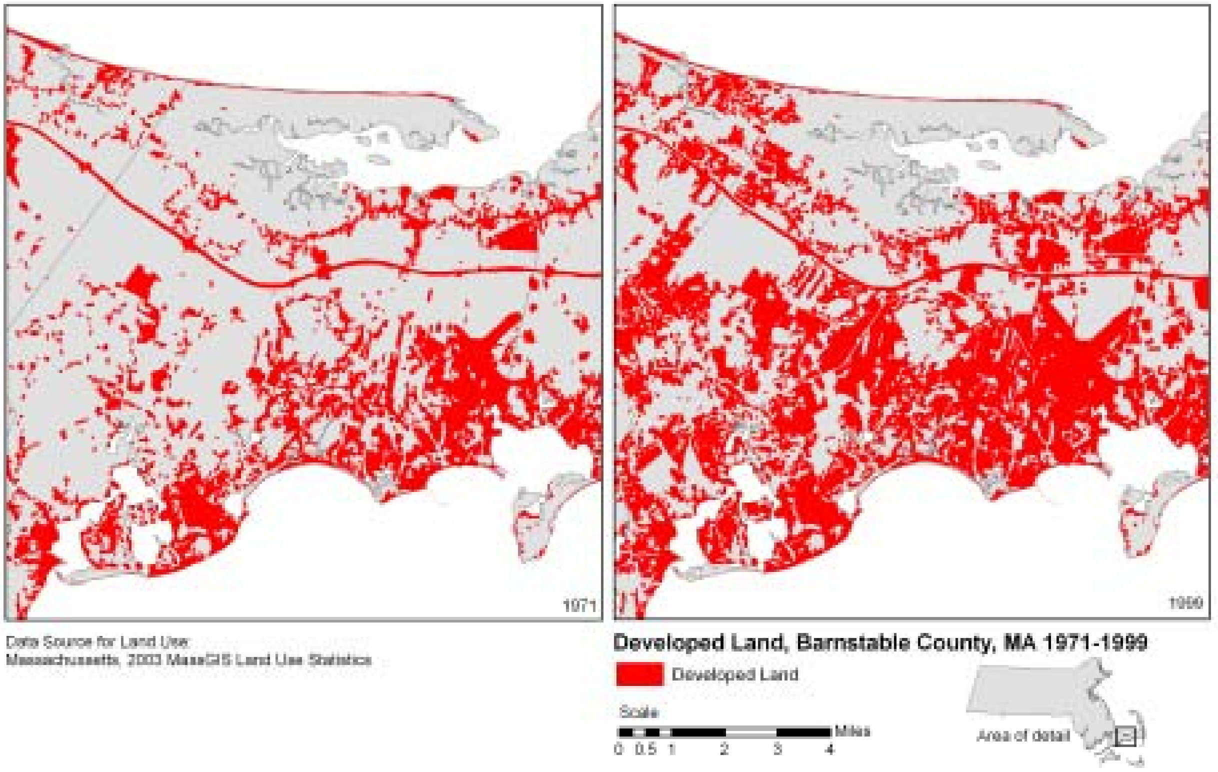
[69] AFWG Baseline v.7 p 39, Canada Greenhouse Gas Inventory. 2000. p 74.

[70] Cropland data from USDA. 2002. Census of Agriculture; timberland data from USDA Forest Service, Forest Resources of the US, 2002.

[71] USDA. 2002. Census of Agriculture; Government of Canada, 2001. Census of Agriculture.

[72] *Ibid.*

Figure 3.8: Land use change, Barnstable County, MA, 1971-1999



Data Source for Land Use:
Massachusetts, 2003 MassGIS Land Use Statistics

The challenges to forest and farm protection are many, and the implications of conversion clearly reach far beyond carbon sequestration. Population pressures, the rising costs of holding land, and increased global competition make it increasingly difficult for landowners to sustain a land-based livelihood. Biodiversity, watershed concerns, and other environmental services are also strongly impacted by land use changes that cause fragmentation and other adverse effects.

Especially near growing metropolitan areas, forestland is more valuable as commercial or residential real estate than as forest. At an average price of almost $360 per acre in Maine for large parcels of forestland, timberland is an attractive investment for both timber investment management organizations (TIMOs) and prospective developers alike, although the price of land increases exponentially the closer one is to metropolitan areas.[73] In Maine, next to timber sales, subdivision of lake front views and conservation easements are top non-timber revenue generators on timberlands.[74] In growing areas like southern Maine and New Hampshire, conversion of forest and farm land to urban uses is a lingering threat to the loss of carbon, as well as a viable forest-based economy.

Current Mandatory and Voluntary Land Regulation and Protection Programs

Zoning and Regulations

Most local jurisdictions have some form of land use and zoning regulations designed to preserve environmental quality and aesthetics, though regulations vary considerably by geography. Zoning restrictions and conditions on location of infrastructure, density of housing units, and retention requirements for vegetative cover on new developments all have capacity to promote forest protection

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[73] James W. Sewall Company. 2005. Timberlands Report, Vol. 7 No. 2.

[74] *Ibid.*

and retention of carbon benefits. Delineation of forest or agricultural zoning districts can also help prevent development in these districts, and is a commonly used tool in many rural municipalities. Agriculture and timberland conversion regulations, as well as urban growth boundary designations have also played a hand in restricting land conversion.

The Northeast U.S. has a long history of using local land use regulations to achieve a wide variety of public benefits. By contrast, grassroots movements in other areas of the country suggest that restrictions on development patterns may loosen as local governments become required to compensate landowners who challenge their right to build.[75] Although it is unlikely that similar restrictions on land use regulations will occur in the Northeast U.S., issues around "takings" are trends worthy of notice.

In any case, while local rules and regulations can effectively guide local development and often help to maintain vegetation and open space benefits, the same standards are not necessarily strategic for the purposes of retaining the carbon sequestration values of the land.

Tax Programs

Tax credit programs are a common method to help provide incentives to maintain land in agriculture or working forest. While tax credit programs do not fully compensate land owners for the ecological value provided, they do provide an often necessary financial incentive to retain certain ecosystem values.

In Maine, the Tree Growth Tax Law is a municipal tool designed to tax forest land at a rate based on its productivity rather than its fair market value (*e.g.*, shore frontage or development value) and provide financial penalties when the land is converted to other uses. This voluntary program helps to relieve the tax burden of owning working forest land, encourages maintenance of a working forest economy and helps dampen land conversion. Maine's voluntary Forest and Open Space tax law is similarly designed to keep land in farming and other agricultural activities. In 2002, 5.6% of total farmland acreage was enrolled in this program in Maine.[76]

Other municipalities employ the use of voluntary tax credit programs to encourage conservation. In 2003, Manitoba began a pilot initiative to encourage farmers to retain various ecological values (including sequestration) on their land.[77] Benefits were estimated at over $1 per acre, which more than paid for the tax credit awarded to farmers.

Conservation Funded Measures

Private and public protection of forest and farmland is commonly accomplished through a variety of public and private conservation tools. Purchase of development rights and conservation easements—legal agreements between a landowner and a land trust or government entity—permanently limits development/conversion of land and may govern other uses. Outright purchase of land by conservation groups also prevents conversion of land. However, these measures are traditionally targeted toward protection of priority lands for biodiversity, recreation, cultural and historical reasons. These tools have not been widely applied to lands specifically to promote carbon sequestration. However, especially as emerging carbon offset opportunities propose requirements for permanent conservation easements, the demand for easements is expected to grow.[78]

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[75] For example, Oregon Measure 37, passed in 2004 by Oregon votes, provides "just compensation" to private property owners if land use regulations restrict the use of the property and reduce its fair market value.; alternately, in lieu of compensation, the measure allows for the government to "remove, modify or not apply" the regulation. Text and more information about the measure *available at* http://www.oregon.gov/LCD/measure37.shtml#Text_of_the_Measure.

[76] Allen and Boyle. 2000. Farm Property Taxes in Maine. Maine Agriculture and Forest Experiment Station. http://www.umaine.edu/mafes/elec_pubs/miscrepts/mr418.pdf

[77] Canada National Roundtable on the Environment and the Economy. 2004. Case study: Agricultural landscapes. http://www.nrtee-trnee.ca/eng/programs/Current_Programs/EFR-Energy/Case_Studies/EFR_Case-Studies-Agriculture_E.htm#section1_4_2

[78] Regional Greenhouse Gas Initiative. 2006. RGGI Draft Model Rule. http://www.rggi.org/modelrule.htm

Unfortunately, protection of forestland through conservation easements is difficult to fund adequately, particularly because competition for protection funding is high and often appropriated for priority lands that secure a suite of environmental values. For buyers, conservation easement negotiations can have high costs, ranging anywhere between $39.42 and $750 per acre for forestland in New England.[79] Conservation efforts are also hindered by the inability to compete with development dollars, since developers are often willing to spend more on land than conservationists are able to afford.

There is growing recognition that conservation efforts can only begin to compete with development through carefully designed co-revenue and tax streams that capitalize on a whole host of environmental benefits. As the suite of market-based conservation mechanisms grows, so too does the opportunity to apply market approaches to land conversion and carbon sequestration.

Implementation

Implement a Carbon Neutral Growth Program

We recommend that states and provinces establish a Carbon Neutral Growth program to reduce or mitigate land conversion in moderate to large scale residential and commercial development. Assuming that average annual conversions from forest and farms remain the same, if only 10% of cleared land were retained in forest and farms, total emissions reductions between 53 and 496 MMTCO$_2$e by 2050 may be achieved. However, as noted in previous sections, while this figure may seem quite large, there are many uncertainties associated with forest land and cropland carbon inventories, and these figures should be used with caution. Regardless of these uncertainties, this also prevents over 274,000 ha from being developed and complements other carbon sequestration opportunities proposed in this document.

Table 3.7: Regional Land Conversion and Estimated Carbon Loss

Jurisdiction	**Average Annual Land Use Change (ha)**			**Average Annual Emissions from Land Use Change (MMTCO$_2$e)**				**Carbon Savings if 10% of Land is Retained in Forest and Crop Land (MMTCO$_2$e)**	
	From Forests	**From Cropland**	**Total**	**Non-soil Forest**	**Forest Soil**	**Non-Forest Soil**	**Total**	**Non-soil, Total by 2050**	**Soil Carbon, Total by 2050**
NE Total	-24,605	-11,671	-36,276	12.08	92.14	20.54	124.77	53	496
EC Total	-4,956	-12,885	-17,840	N/A	N/A	N/A	N/A	N/A	N/A

Note: Negative emissions indicate sequestration.

Sources:

NE forest land change data (1997-2002) from USDA Forest Service 2002. NE cropland data (1997-2002) from USDA Census of Agriculture 2002; EC cropland change data (1996-2001) from Statistics Canada 2001; EC forest land change data extrapolated from cropland changes using the 2003 Canada Greenhouse Gas Inventory urbanization estimates; Non-soil forest emissions calculated using 2002 forest conversion estimates from USDA and forest stock data from Sampson 2006 (Note that this number assumes 100% non-soil forest biomass removal); Forest soil and non-forest soil estimates (1987-1997) from Sampson 2006; Non-forest soil includes conversion from: hay, other rural land, set-aside lands, pasture, and woody crops.

Current efforts to conserve forest and farm land for their carbon value are limited to a highly selective group of investors and projects. The current system of land-use regulations does not address carbon. As with recommendations to promote higher density residential developments, retaining specific levels of biomass on developed land is difficult in practice because of the highly dispersed rules and regulations guiding local development and their enforcement. Traditional development regulations specify as little as 8-15% open space retention, which does not necessarily specify forestland. Incentives to retain existing

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[79] Peterson, T. 2004. DRAFT – Forestry options costs memo to the Maine DEP..

natural vegetation onsite are few, excepting, of course, the cost of clearing that drives retention of biomass.

Land clearing can be relatively expensive for developers — it is estimated to cost $2,000-4,000 per acre in Maine.[80] However, residential and commercial developers already have the opportunity to reduce clearing costs and maximize saleable land through clustered residential or "conservation" designs that preserve forestland and open space. Reduced impact development has resulted in reduced costs of land clearing from $2,000 per acre down to $726-$821.[81] Carbon savings from avoided clearing were estimated to be 53.35 tons of carbon per acre.

A carbon mitigation program implemented at the local level would save developers money through avoided land clearing costs and avoided mitigation activities, while providing environmental co-benefits. As with wetland or conservation mitigation banking, a carbon neutral growth program would provide incentives for developers to retain natural vegetation and allow them to choose the most effective strategy to mitigate their carbon impact with the least cost option.

It is important to avoid perverse incentives in local policies, and any carbon mitigation program should avoid creating unintended consequences and leakage problems associated with potentially altered siting decisions as the result of this regulation.

Example: Mitigation Banking

Growing international attention is being given to the role of mitigation banking in recognizing the economic value of these ecosystem services while delivering environmental benefits. Arguably the most well developed market-based approach to conservation, the market for these services is estimated at more than $1 billion a year, according to the Katoomba Group.[82] Initially pioneered as an EPA wetlands-mitigation program, it is being used as a model policy nationally and internationally.

In 1995, California pioneered an official policy on conservation banks, intended to deal with the growing difficulties of managing endangered species through the complex process of incidental take permitting. Through the policy, mitigation credits can be created, held, and sold among developers. Often, greater ecological benefits are created off-site than at the development site, while allowing developers the flexibility to move forward with their projects, and financially rewarding landowners who provide ecological benefits.

More recently, the government of Australia launched a "Biodiversity Banking" initiative in 2005 to conserve biodiversity, and other countries are considering following in the footsteps of the U.S. model as well.

The primary difference between mitigation for habitat or wetland values with mitigation for carbon, however, is that carbon knows no boundaries. Unlike other ecosystem services, carbon sequestration benefits as they pertain to the atmosphere are not relegated to site-specific actions. For this reason, a carbon mitigation program can be used effectively toward the goal of no net loss of carbon, and developers can use this to their advantage in determining the lowest cost mitigation option.

Although it might be desirable to implement a large-scale carbon mitigation program at the state scale, very few states in the Northeast have broad, overarching land use legislation. With the exception of Vermont's state development scheme, all New England states rely heavily on local town and city governments to guide planning decisions.

A carbon mitigation program should reach certain existing municipal permitting requirements, thresholds, or site plan reviews. For example, the City of New Haven requires a site plan to be submitted

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[80] Maine NRCS field office, as per Peterson, T. 2004. Cost Estimates for Forestry Greenhouse Gas Options, a draft memo to the Maine DEP.

[81] NOAA Coastal Services Center. Alternatives for Coastal Development: One Site, Three Scenarios, 2004. In Peterson.

[82] Katoomba Group. 2006. Ecosystem Marketplace Mitigation Mail. Vol. 1, No. 1: March 14, 2006

to the city government for, among other uses, “Any change of use of a property that involves 8 or more dwelling units, 10,000 or more square feet of gross building area, or 20 or more parking spaces.”[83] The site plan also requires detailed maps that would provide a useful tool for the City Plan Commission to assess potential carbon impacts onsite. Alternately, Planned Development Units and/or Planned Development Districts may provide the appropriate trigger for this policy.

Example: Sonoma County Timberland Conversion Ordinance

In March 2006, the Sonoma County Planning Board of Supervisors passed a local ordinance to establish permit requirements and standards for certain activities that would convert timberland in certain zoning districts to other uses, while prohibiting conversion from timber to agricultural uses in the most productive classes of forestlands. For major conversions, two acres of timberland in the local area must be preserved for each acre converted through conservation easement and minimum stocking standards.

Although this measure is not time-tested, it shows innovative potential to prevent conversion while increasing ecosystem and economic benefits.

The goal of these requirements is to exempt small renovations and projects and certain classes of land-use activities including forest management and ecological restoration. Decision-makers, should, however, be aware of potential loopholes in such a policy and ensure that parcel fragmentation and other undesirable consequences are avoided.

We recommend that states and provinces employ the following strategies to reduce or mitigate the projected carbon impacts where development of forest or farmland is proposed:

1. Science-based methodology should be used to determine the amount of carbon sequestered on site and the amount of carbon likely to be lost to development. Because development generally reduces carbon storage onsite, there should be as much as incentive as possible to retain existing vegetation and carbon capacity. The amount of mitigation offsets required of the developer would be calculated as the difference between the baseline land-use carbon storage potential over a specified time frame and the amount of carbon storage expected to be maintained on-site following development. Land conversion from farms and forests should assume a certain loss of sequestration as determined by the best available science at the time of the regulation’s passing. If the land was previously in working forest, accounting will reflect the balance of net carbon sequestered over time. Carbon stored in wood products offsite could be considered as an optional carbon pool for accounting purposes, assuming reliable methodologies were developed.

2. The regulation could be structured in a number of ways to mitigate on-site carbon loss and to achieve the desired carbon sequestration benefit over time. Developers could:
    a. Re-configure the project to avoid loss of carbon
    b. Invest in a certified carbon offset project as defined by RGGI or other appropriate carbon offsets markets that ensure “high quality” offsets.
    c. Pay a fee to an administrative entity or Trust in lieu of mitigation., which would solicit, contract, and administer carbon projects using these payments - not unlike The Climate Trust (See, Example: The Climate Trust). This fee could be set at the annual average carbon offset price as determined by existing markets plus an appropriate administrative fee.

3. Where fees are paid in lieu of mitigation, the fee could be allocated to a Carbon Neutral Growth Conservation Fund, described more below.

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[83] New Haven City Plan Commission. 2004. 2004 Interim Site Plan Guidelines. http://www.cityofnewhaven.com/CityPlan/pdfs/Regulations/2002SPRGuidelines.pdf

Create a Carbon Neutral Growth Conservation Fund

A Carbon Neutral Growth Conservation Fund would return (*e.g.*, through payment of mitigation fees) some portion of the money made in land development to the land use sector. The program could stimulate investment in agricultural and forest carbon sequestration projects in the region, administering funds for regional conservation easements dedicated to conserving the carbon sequestration potential on the land. The program could be used alone or in conjunction with other conservation finance strategies designed to provide payments for environmental co-benefits. This mechanism serves an unmet need to secure conservation funding for carbon sequestration and development of forest carbon offset markets.

The Carbon Neutral Growth program is highly dependent on the creation of standardized carbon offset project accounting protocols and subsequent market development. It is also intended to draw substantially on the emergence of a regional carbon market in the New England states and Eastern Canadian provinces, while providing market opportunities outside the region as well.

As described previously in this section, current efforts to conserve forest and farm land for their carbon value is limited to a highly selective group of investors and projects, and protection of our natural lands is accomplished through a range of conservation finance tools at the state and federal level. Each tool aims to protect one or more ecosystem benefits that include:

- Open space
- Working farms
- Working forests
- Biodiversity
- Recreation
- Cultural heritage
- Historical value

Many state and federal grant programs allocate funding based upon the greatest likelihood of these benefits being provided, although some, like the U.S. Forest Service's Forest Legacy program, allocates funds only to priority working forests that provide these benefits. Thus far, conservation easements have not yet been widely applied to lands specifically to promote carbon sequestration, even though their intent to maintain the capacity of the land to provide a host of environmental co-benefits is, indeed, implicit. There are, however, models, such as that set forth by The Pacific Forest Trust, that seek to combine provision of forest carbon offsets with conservation easements, with both managed by the Trust itself.[84]

As the Pacific Forest Trust points out, provision of conservation easements is often funded through the sale of carbon offsets, in another illustration that the co-benefits to providing carbon go hand-in-hand with other public values.

Another key driver for such a program is Draft Model Rule language for the afforestation offset type in the Regional Greenhouse Gas Initiative. To qualify as a project, a permanent conservation easement must be secured on the property, presumably to help provide reasonable assurances that carbon offsets provided are "real, surplus, verifiable, permanent and enforceable."[85]

The economic punch to carbon offset easement standards is that the purchase of conservation easements can be expensive, costing anywhere from $39.42-750 per acre for forestland in New England.[86] The cost of conservation easements and land acquisitions has also been estimated at $0.21-

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[84] Pacific Forest Trust. 2006. *More information available at*: http://www.pacificforest.org/services/forever.html.

[85] RGGI offset proposed criteria, *see also*, California Forestry Protocol.

[86] Peterson.

5.97 per ton of CO_2.[87] Furthermore, the same proposed offset standards require that, in the case of forestland, the land be certified as well as managed by FSC, SFI or other accredited forest certification programs. Initial costs of FSC certification for 1,000 acres of land are estimated at $10,000, with an annual audit cost of $2,000.[88] A 100,000 acre parcel may require a $17,000-20,000 initial upfront cost, with annual audit costs up to $5,000 or more. It seems clear that even though carbon offset projects ultimately recover their initial investment over time, additional conservation dollars can help drive investment in carbon offset projects by securing a pre-identified pool of funding specifically targeted to easements for carbon.

To support the goal of establishing an additional conservation fund, the pool of additional conservation finance dollars necessary to help establish carbon projects should be examined. Additional research needs to be done to quantify the true costs of securing conservation easements and forest certification, and determine the economic feasibility of carbon offset projects in the region. A carbon neutral growth conservation fund can only be effective if established with sufficient financial resources and managed by a credible third-party organization.

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[87] *Ibid.*

[88] John Gunn, Director of Forest Stewardship and Research, The Trust to Conserve Northeast Forestlands, personal communication.

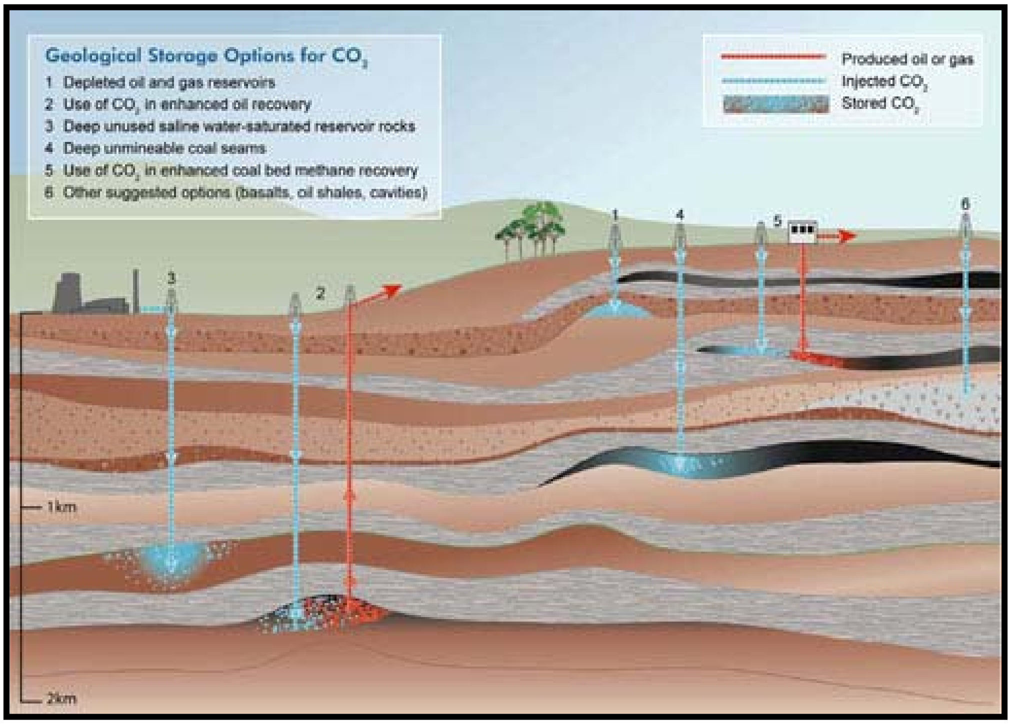
Priority 10: Capture and Store Carbon Dioxide from Energy and Industrial Sources

By: Michael Stoddard

Carbon dioxide capture and storage uses existing technologies that are already employed in various industrial applications, and are cost-competitive with the many promising climate change mitigation options. For these reasons, many scientists and climate change experts consider carbon dioxide capture and storage (CCS) an important opportunity to reduce GHG emissions.[84]

As noted previously, the IPCC defines CCS as “a process consisting of the separation of CO_2 from industrial and energy-related sources, transport to a storage location and long-term isolation from the atmosphere.”[85]

Figure 3.9: Geologic storage options for CO_2 [86]



Source: CO2CRC, in IPCC, *CO_2 Capture and Storage Summary*

CO_2 can be stored in underground geologic formations the most suitable of which are oil and gas reservoirs, unminable coal seams, and deep saline formations. Theoretically, CO_2 can also be released in deep ocean waters or fixed into inorganic carbonates and stored for hundreds of years.

Observations of existing storage sites and modeling indicate that the fraction of CO_2 permanently sequestered in properly selected and managed geological storage sites is “very likely to exceed 99% over

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[84] Carbon storage is considered a critical element in three of the 15 options enumerated as potential “stabilization wedges” by Pacalaw and Sokolov, “Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies,” *Science*, Vol. 305, August 13, 2004, p. 968-972.

[85] IPCC, Working Group III, *Special Report on Carbon Dioxide Capture and Storage: Summary for Policymakers, and Technical Summary*, ISBN 92-9169-119-4, p. 2.

[86] *Ibid.*, Figure SPM.4.

100 years and is likely to exceed 99% over 1,000 years" and that "the vast majority of the CO_2 will gradually be immobilized by various trapping mechanisms and … could be retained for up to millions of years."[87]

Globally, there is a very large potential capacity to store CO_2 so that it will not be released into the atmosphere for long periods. The most recent estimates reported in the IPCC's *CO2 Capture and Storage* are that the global technical potential for geologic storage is at least 2,000 GtCO2 (or 545 GtC).[88]

Table 3.8: Worldwide capacity of potential CO_2 storage reservoirs[89]

Sequestration option	Worldwide capacity (orders of magnitude estimates) in gigatons of carbon (GtC)
Ocean	1000s
Deep saline formations	100s–1000s
Depleted oil and gas reservoirs	100s
Coal seams	10s–100s
Terrestrial	10s
Utilization	<1 GtC/yr

1 GtC = 1 billion metric tons of carbon equivalent. Worldwide total anthropogenic carbon emissions are approximately 7 GtC per year.

Source: Herzog, "What Future for Carbon Capture and Sequestration?" (2001)

Table 3.9: Carbon capture and storage price ranges[90]

2002 Cost ranges for the components of a CCS system as applied to a given type of power plant or industrial source. The costs of the separate components cannot simply be summed to calculate the costs of the whole CCS system in US$/$tCO_2$ avoided. All numbers are representative of the costs for large-scale, new installations, with natural gas prices assumed to be 2.8-4.4 US$ GJ and coal prices 1-1.5 US$ GJ (references omitted).

CCS system components	Cost range	Remarks
Capture from a coal- or gas-fired power plant	15-17 US$/$tCO_2$ net captured	Net costs of captured CO2 compared to the same plant without capture.
Capture from hydrogen and ammonia production or gas processing	5-55 US$/$tCO_2$ net captured	Applies to high-purity sources requiring simple drying and compression.
Capture from other industrial sources	25-115 US$/$tCO_2$ net captured	Range reflects use of a number of different technologies and fuels.
Transportation	1-8 US$/$tCO_2$ transported	Per 250 km pipeline or shipping for mass flow rates of 5 (high end) to 40 (low end) $MtCO_2$ yr (footnote omitted).
Geologic storage*	0.5-8 US$/$tCO_2$ injected	Excluding potential revenues from EOR or ECBM.
Geologic storage: monitoring and verification	0.1-0.3 US$/$tCO_2$ net injected	This covers pre-injection, injection, and post-injection monitoring, and depends on the regulatory requirements.
Ocean storage	5-30 US$/$tCO_2$ net injected	Including offshore transportation of 100-500 km, excluding monitoring and verification.
Mineral carbonation	50-100 US$/$tCO_2$ net mineralized	Range for the best case studied. Includes additional energy use for carbonation.

* Over the long term, there may be additional costs for remediation and liabilities.

Source: IPCC, *CO_2 Capture and Storage Summary*

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[87] IPCC, *CO_2 Capture and Storage Summary*. p. 13, which defines "very likely" as a probability between 90 and 99% and "likely" as a probability between 66 and 90%.

[88] IPCC, *CO_2 Capture and Storage Summary*. p. 11.

[89] Herzog, H. "What Future for Carbon Capture and Sequestration?" *Environmental Science and Technology*, Vol. 35, Issue 7, April 1, 2001, pp 148A-153A.

[90] IPCC, *CO_2 Capture and Storage Summary*.

Storing CO_2 appears to be a viable option for climate mitigation. As Table 7 from the IPCC report suggests, CO_2 can be captured for $5 – 115 per ton, transported 250 km for between $1 and $8 per ton and then geologically stored and monitored for under $10. When compared to other climate mitigation options, CCS could be very competitive in the right circumstances.

10.1 Build a Regional Framework for Long-Term Carbon Dioxide Capture and Storage

Summary

While large federal programs carry the early burden of researching basic science and economics of CCS, the NE-EC region can focus on its own unique needs and opportunities by creating a framework for long-term carbon capture and storage. The region should develop a plan that includes:

- regional inventories of sources, potential storage locations, and estimates of geologic storage capacity;
- pilot programs;
- timely adoption of a regulatory framework;
- further research on the science, impacts and opportunities for storage in oceans, mineral carbonation, and industrial uses.

Under any future scenario in which carbon emissions are restricted, if states and provinces of the NE-EC region want to preserve the option of building new coal or biomass plants to achieve low-cost fuel diversity and energy independence, then this region will need its own carbon storage infrastructure. Similarly, any large industrial CO_2 emitters who may be subject to regulatory carbon constraints may want to consider carbon storage options.

Preliminary mapping shows significant potential storage sites in the unminable coal seams around Nova Scotia, as well as other underground geologic formations that need further study off-shore from Rhode Island to Labrador. The capacity of CO_2 that could be stored in geologic formations in the region is not yet known.

Opportunity

The leader of the Lawrence Livermore National Laboratory's Carbon Management Program recently recommended a plan of action to California, a state that is taking steps to prepare for future CCS deployment.[91] Key features of this CCS plan are to:

1. Identify and characterize the key geological formations appropriate for potential long-term storage
2. Characterize, compare and evaluate the economics and performance of various techniques to capture, transport and store CO_2
3. Identify and develop technologies for deployment of carbon capture and storage that are particularly appropriate for the (local) energy and industrial system
4. Identify the necessary components of a stable regulatory framework that would foster and facilitate carbon sequestration technologies, including:

    - site selection protocols;
    - development of standards for site performance;
    - protocols or rubrics to manage failure or leakage;
    - an identification of the key stakeholders in the area and development of a process for their involvement.

We recognize that New England and Eastern Canada are lacking some of the features that make other areas of North America the early candidates for research and development of CCS infrastructure and testing of geologic storage sites. Large oil production wells and unminable coal seams in proximity to

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[91] S.J. Friedmann, Testimony for the California Assembly Utilities and Commerce Committee, April 3rd, 2006.

large point sources of CO_2 are prime targets for early CCS pilot projects. The most promising of these sites are found around the traditional oil, gas and coal producing regions of the continent, such as Alberta, Wyoming, Texas and West Virginia, although there are also significant unmined coal seams and natural gas formations around Nova Scotia.

Businesses, policymakers and residents of the region have a stake in building a framework for future carbon storage. Under any future scenario in which carbon emissions are restricted, if states and provinces of the NE-EC region want to preserve the option of building new coal or biomass plants to achieve low-cost fuel diversity and energy independence, then this region will need its own carbon storage infrastructure. Similarly, any large industrial CO_2 emitters who may be subject to regulatory carbon constraints may want to consider carbon storage options. As prerequisites to building and developing such an infrastructure, the region must identify where CO_2 could be stored and have a regulatory framework in place to govern the system. Currently, this region has none of the necessary data, research or infrastructure in place.

The U.S. DOE's Regional Carbon Sequestration Partnerships Program is one important avenue in North America "to validate and deploy carbon sequestration technologies."[92] The DOE's preliminary work should take the burden of the early stages of developing technologies and a regulatory framework for carbon storage off of the New England and Eastern Canadian region.

The region can focus instead on its own unique needs and opportunities and initiate a plan that includes:

- regional inventories of sources, potential storage locations, and estimates of storage capacity;
- pilot programs;
- timely adoption of a regulatory framework;
- further research on the science and opportunities for storage in oceans, mineral carbonation, and industrial uses.

Implementation

Inventories

As a first step, the region needs to develop an inventory of geologic formations suitable for potential long-term CO_2 storage. The DOE Regional Partnerships program is not going to do this, since the Northeast is the only region in the U.S. that is not currently participating.

The inventory should identify locations of relevant geologic formations and characterize their location, capacity, and how porous, permeable and secure the formations are. For examples of how such inventories have been made, the region can look to:

- NATCARB, a network of regional carbon sequestration atlases for the United States used to identify the most promising storage opportunities;[93]
- assessment of the Alberta Basin;[94]
- Australia's GEODISC National CO_2 Storage Assessment program.[95]

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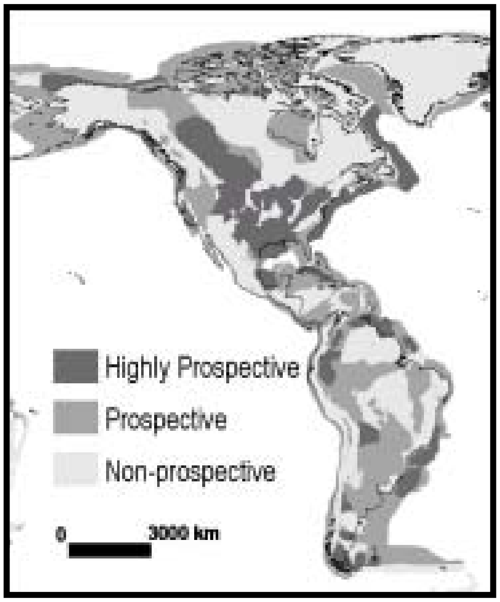
[92] This program began in 2003 to bring together federal and state agencies, academics and private sector entities representing 216 organizations from 40 states, three Indian nations and four Canadian provinces. The program aims to "determine the most suitable technologies, regulations, and infrastructure for future carbon capture, storage, and sequestration…" http://www.netl.doe.gov/technologies/carbon_seq/partnerships/partnerships.html.

[93] http://www.natcarb.org/.

[94] http://www.ags.gov.ab.ca/activities/CO2/CO2_main.shtml, Alberta Geological Survey, Alberta Energy Research Institute, Alberta Energy & Utilities Board.

[95] http://www.co2crc.com.au/RESEARCH/research_storage.html and http://www.apcrc.com.au/Programs/geodisc_back.htm; *See also* Off-shore potential study, C.M. Gibson-Poole *et al.*

Figure 3.10: Prospective geologic formations in the Americas[96]



Source: IPCC, *CO_2 Capture and Storage Summary*

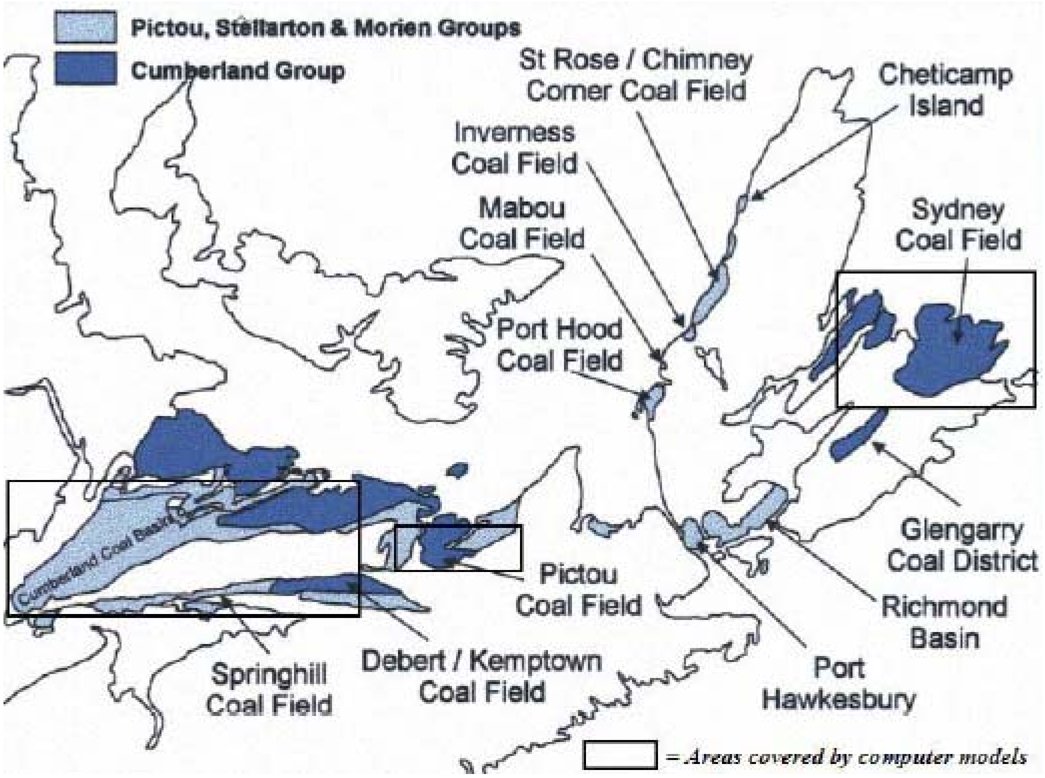
There is reason to believe that geologic formations suitable for CO_2 storage exist in the region. As the figure above shows, the under-sea floor along most of the Atlantic Coast has been labeled a “Highly Prospective” storage area, a characterization reinforced by the fact that there is natural gas production off-shore in Nova Scotia. Also in Nova Scotia are some of the region’s only significant coal deposits. Most of them are not viewed as commercially viable for production of coal, but they could indicate viable CO_2 storage locations.

Figure 3.11 shows a map of selected coal fields in Nova Scotia and locations where preliminary computer modeling to determine the potential of CO_2 storage has been completed. The data collected from the study was run through geologic models of the area to determine the storage capacity CO_2 and to determine whether the CO_2 would be in a gaseous, liquid or supercritical phase.

“Assessing a basin’s potential for geological sequestration of carbon dioxide: an example from the Mesozoic of the Petrel Sub-basin, NW Australia” *CO2 Sequestration: Petrel Sub-basin*, pp. 440-463.

[96] IPCC *CO_2 Capture and Storage Summary*, Figure SPM.6b, p. 8.

Figure 3.11: Potential for CO_2 Storage in Nova Scotia[97]



Source: Hughes, *Assessment of Nova Scotia Coalfields* (2004)

Subsequent to this study, Nova Scotia Power, a member of the consortium of companies pursuing CCS in Canada, began seeking funding to conduct further investigation and pilot projects to test the potential storage capability of these unminable coal seams. The utility has formed a collaboration with Energy at Dalhousie (University) to conduct the study, and has also had conversations with MIT's Carbon Sequestration Initiative and Environment Northeast about the potential benefits of cooperating and sharing information within the region.[98]

The inventory of potential storage sites should include data that will inform future project developers, stakeholders and regulators as to the following three characteristics:

- *Injectivity* -- so that large volumes can be injected at a high sustained rate. This requires permeable strata.
- *Capacity* -- the formation can contain large volumes of CO_2 (tens of millions of tons). This requires large pore volumes.
- *Effectiveness* -- the site must trap and store CO_2 with little to no leakage over long time periods.[99]

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[97] Hughes, J.D., *Volume 1: Assessment of Nova Scotia Coalfields for Production of Coalbed Methane and CO2 Storage in Deep Coal Seams*, Geological Survey of Canada – Calgary, Natural Resources Canada
March, 2004, p. 5.

[98] Information on the Massachusetts Institute of Technology Carbon Sequestration Initiative can be found at http://sequestration.mit.edu/CSI/index.html.

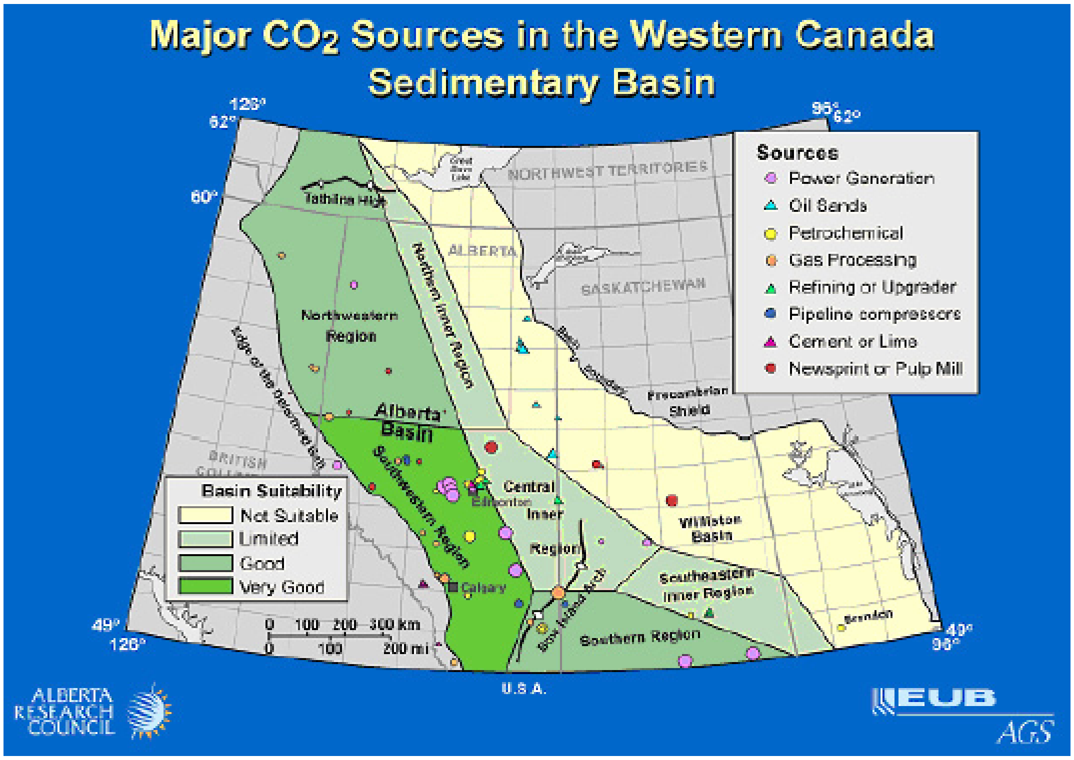
[99] Friedmann, Testimony for the California Assembly Utilities and Commerce Committee, 2006, p. 2.; *see also*, Herzog, H.J., Drake, E.M., and Adams, E.E., *CO2 capture, reuse, and storage technologies for mitigating global climate change*, Massachusetts Institute of Technology, Cambridge, MA, 1997; *and* Bachu, S., "Sequestration of CO2 in geological media: criteria acceptance and approach for site selection in response to climate change," *Energy Conversion and Management*, v. 41, 2000, pp. 953-970.

As a second step, an inventory of current large point sources of CO_2 in the region should be created that is updated as new sources are proposed. Examples of sources that could provide an economical stream of CO_2 are:

- coal or other fossil power plants;
- petroleum refineries;
- fertilizer, cement or lime manufacturers;
- advanced coal bed methane recovery sites.

Third, a regional map indicating potential storage sites and large CO_2 sources should be created, as well as the potential locations of transportation infrastructure (e.g., pipeline, ship) by which the compressed CO_2 could be moved from source to sink. The figure below shows the results of a CCS initiative to map large sources and suitable storage sites in the Western Canada Sedimentary Basic in Alberta.[100]

Figure 3.12: Major CO_2 sources in the western Canada Sedimentary Basin[101]



Pilot Programs

An NE-EC regional initiative should set out to develop a program of pilot projects to demonstrate specifically how CO_2 capture, transportation or storage would work in the region. These demonstrations will be important to raise awareness and build familiarity with CCS among large point source emitters and the general public. They will help in-region engineers develop expertise in handling, maintaining and monitoring the transportation and storage systems. Pilot projects will also offer insights into how the region's regulatory framework might be developed to ensure appropriate siting and permitting, establish monitoring and verification protocols, and protect health and the environment.

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[100] Alberta Research Council, The CANiCAP Program: Planning Options for Technology and Knowledge Base Development for the Implementation of Carbon Capture and Transportation Research, Development and Deployment in Canada, April, 2005, p. 35. Report available at http://www.nrcan.gc.ca/es/etb/cetc/combustion/co2trm/pdfs/canicap_report_final.pdf

[101] *Ibid.*

Pilot projects for CO_2 capture could be implemented in any place where there is a potentially large source of CO_2 that is, or could be, segregated. In addition to any new gas or coal plant, other possible sites for piloting CO_2 capture technology include large industrial manufacturers, petroleum refineries, the coal beds of Nova Scotia, and the region's large biomass energy plants.

One possible starting place for pilot projects is in Nova Scotia, where, as mentioned previously, Nova Scotia Power has expressed an early interest in exploring various aspects of CCS. Nova Scotia has a large fleet of coal-fired power plants, and its significant unminable coal resources and proximity to potential suitable geologic sites and may warrant further investigation.

CSS pilot projects and the components of a CCS infrastructure will be costly and take considerable time to develop. We therefore recommend states and provinces enlist the help of a wide range of stakeholders, including representatives of the region's universities, energy companies, state agencies and environmental groups. We further encourage interested parties to consider a wide array of potential financial resources to support pilot projects. Offsets programs and funds used to commercialize clean energy resources could assist in the early development of the CCS infrastructure. Also, the region should reach out to the federal government for funding and guidance to support these projects.

Regulatory Framework

There are certain aspects of CCS that may pose novel issues for the general and climate change regulatory frameworks in the region. Jurisdictions, in particular those that are home to potential storage sites, will likely need to add to their regulations: site selection protocols; standards governing the integrity, monitoring, and storage duration of storage sites; requirements for handling leaks or storage failures; and protocols for awarding offsets or the appropriate measure of carbon sequestration credit.

Example: Establishing Regulatory Authority for CCS Infrastructure, Texas

In 2005, the state of Texas gave authority to three state agencies – the Water Development Board, the utility commission (Railroad Commission), and the Commission on Environmental Quality – to develop new review and permitting rules for potential CCS projects.[102]

Further Research

Finally, there are other types of carbon storage that could potentially be appropriate for use in the NE-EC region, but each would need extensive research before taking any action toward implementation. The IPCC's *CO_2 Capture and Storage Summary* identifies ocean storage, mineral carbonization and industrial use as ways carbon might theoretically be stored.

One area for study is the functionality and impacts (especially on marine organisms) of CO_2 in oceans. Oceans naturally store carbon dioxide taken out of the atmosphere, but it is theoretically possible to inject CO_2 directly from the source and store it in deep waters. Adding CO_2 to oceans increases the acidity near the injection point (and over time, across larger areas of the ocean), and studies performed on very small scales have observed harmful effects on marine organisms. The IPCC notes that "The chronic effects of direct CO_2 injection into the ocean on ocean organisms or ecosystems over large ocean areas and long time scales have not yet been studied."[103]

Another area for study is mineral carbonation. Chemical reactions between CO_2 and certain materials can produce carbonates, such as magnesium carbonate and limestone, that are stable over very long periods

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[102] Texas H.B. 2201, An act relating to implementing a clean coal project in the state, passed in 2005.

[103] IPCC *CO_2 Capture and Storage Summary*, p. 35.

of time. In this state, the carbonates can be disposed of as solid waste, or in some cases (and at smaller scales) put to industrial uses.

The IPCC has identified several research tasks that need attending to in the field of mineral carbonation, including:

- “assessments of the technical feasibility and corresponding energy requirements at large scales;”
- “the fraction of silicate reserves that can be technically and economically exploited for CO2 storage;”
- “the environmental impact of mining, waste disposal and product storage;”
- “finding process routes that can achieve reaction rates viable for industrial purposes and make the reaction more energy-efficient.”[104]

Finally, there are various ways that CO_2 can be captured and put to some industrial use (such as adding carbonation to beverages). In many cases, these uses do not store carbon for any significant period of time, but rather displace the need for other sources of CO_2 to be used. The IPCC has observed that the long-term climate impacts of such uses “can be evaluated correctly only by considering proper system boundaries for the energy and material balances of the CO_2 utilization processes, and by carrying out a detailed life-cycle analysis of the proposed use of CO_2.”[105]

It is our recommendation that academic or other research institutions in the region identify the most important of these issues and commence a long-term program of research and reporting their findings.

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[104] *Ibid.*, p. 37.

[105] *Ibid.*