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CARBON SEQUESTRATION AND CO_2 EMISSIONS CREDITS: A MARKET-BASED FOREST CONSERVATION PROGRAM FOR NEW JERSEY

prepared for

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Executive Summary

The goal of the work reported here is a conceptual design and preliminary assessment of a program to sequester carbon in the growth of trees and thereby generate carbon dioxide emissions credits that may be sold in the near future to utilities and industries that seek to purchase such credits to offset their consumption of fossil fuels. This research project is a first step in designing and implementing this market-based forestry conservation program. The findings of this study provide information necessary for the design of a program and the support of the justification to do so. The intermediate objectives set to reach this goal are

1. searching for and retrieving information to construct the aforementioned program,
2. formulating a program appropriate for forestlands in New Jersey, and
3. assessing the potential impact of this program in terms of the possible increase in carbon sequestration and value of the carbon dioxide (CO_2) emission credits generated.

Six generic opportunities have been identified for carbon sequestration projects in New Jersey. Of these six, good management of private and public forestland offers by far the most widespread opportunity for carbon sequestration projects—across some part of more than a million acres. Perhaps surprisingly, urban forestry may also offer nearly as widespread an opportunity for projects—across some part of nearly 650,000 acres. Afforestation and reforestation projects and short-rotation woody crops (both of which may compete for much the same land base) and Atlantic white-cedar restoration projects offer smaller but still significant opportunities—several tens of thousands of acres each. The potential area of future riparian buffer restoration projects cannot be determined based on the information readily available, though the need is acknowledged to be large.

A market-based carbon sequestration and CO_2 emissions credits program is both possible and politically acceptable. The principal elements of such a market-based carbon sequestration program are the various stakeholders involved in the transactions and the terms and conditions of the agreements to buy and sell CO_2 emissions credits, including the definition of the basic commodity. Of all the stakeholders needed for carbon sequestration projects in New Jersey, only the role of intermediary, an entity representing the best interests of landowners and aggregating landowners together to amass large blocks of emission credits for sale, is lacking at this present time. Customary and usual commercial terms and conditions generally are available for the sale of emissions credits. The market for selling CO_2 emissions credits is far from mature; nonetheless, there exits a nascent market for selling CO_2 emissions credits from projects in New Jersey.

The amount of land available in New Jersey for each of the generic opportunities is identified. The acreage in each opportunity is then distributed according to the forest types found in New Jersey. Using data and methodology provided by Richard Birdsey, the amount of carbon stored in each forest type is calculated and used, in turn, to calculate the total tonnage of carbon sequestered for each opportunity. Using rules developed as a result of the Kyoto Protocol, the near-term opportunities for carbon sequestration are reforestation/afforestation and Atlantic white-cedar restoration projects, which together could generate more than thirty-nine million tons of CO_2 emissions credits, currently worth nearly eighty million dollars. Gross emission credits payments for these two types of carbon sequestration projects are calculated to be nearly eight hundred dollars per acre, which can be twice the cost of reforesting that acre. On this basis, carbon sequestration projects can stimulate sustainable rural development in New Jersey.

Acknowledgements

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Introduction

Since the onset of the industrial revolution and the accompanying increase in human populations, the global atmospheric concentration of carbon dioxide (CO_2) has risen from about 270 parts per million to the present level of about 350 ppm. The increase is due, in large part, to combustion of fossil fuels and the clearing of forested land for agriculture and other uses. The consensus of much of the scientific community is that the increase in CO_2 levels will result in global warming and a rise in mean sea level.

Scientists predict that global warming will alter global weather patterns, increasing variability in precipitation patterns, causing more severe droughts, and spawning an increased number of severe storms. People in densely populated areas will likely be exposed to longer, more severe periods of unhealthy levels of air pollution during the longer, hotter summers. A rise in mean sea level could result in increased beach erosion and loss of wetlands, greater vulnerability of human habitations built along the shore line, and greater intrusion of salt water into groundwater sources of drinking water.

Sequestering carbon—that is, conversion of atmospheric CO_2 into carbon bound in the growth of biomass—is one of the several ways proposed to reduce the increased atmospheric concentration of CO_2 and thus diminish the effects of global warming. Forests are an important sink for carbon: in the leaves, stems, branches, boles, and roots of trees and other plants in the forest; in the organic litter (dead plant material) found on the forest floor; and in organic matter entrained in the soil. The amount of carbon that New Jersey forests currently sequester could be increased (1) by reducing the loss of forest lands to nonforest uses and (2) by application of forestry management techniques to increase the overall accumulation of carbon in forests.

What underlies the work reported here is the concept of a market-based forestry conservation program. The centerpiece of this new program would be the production and sale of a marketable commodity, CO_2 emission credits, from forest lands. These CO_2 emission credits would be purchased by utilities, industries, and others to offset CO_2 emissions from burning fossil fuels. The revenues from the sales of CO_2 emission credits would economically benefit land owners, hence rural communities, by financing the various forestry treatments consistent with good management practices that would, in turn, support optimum tree stocking and growth on forest land and by providing an economic disincentive to clear forest land for nonforest uses.

The goal of the work reported here is a conceptual design and preliminary assessment of a program to sequester carbon in the growth of trees and thereby generate CO_2 emissions credits that may be sold in the near future to utilities and industries that seek to purchase such credits to offset their consumption of fossil fuels. This research project is a first step in designing and implementing this market-based forestry conservation program. The findings of this study provide information necessary for the design of a program and the support of the justification to do so. The intermediate objectives set to reach this goal were

1. searching for and retrieving information to construct the aforementioned program,
2. formulating a program appropriate for forestlands in New Jersey, and
3. assessing the potential impact of this program in terms of the possible increase in carbon sequestration and value of the CO_2 emission credits generated.

Task 1. Identification and Description of Program Elements

The first step in the first task was to retrieve information that could be used to construct the carbon sequestration and CO_2 emissions credit program described above. A standard literature search and a search of materials, including information available on the internet produced a wealth of information. An annotated bibliography of the sources of information identified and information retrieved may be found in the appendix at the end of this report. In review, the information retrieved seems to fall into a few broad, mostly distinctive categories:

- **Climate change and greenhouse gases** – government agencies (U. S. Global Change Research Center and New Jersey Office of Innovative Technology and Market Development) and nonprofit organizations (Pew Center on Global Climate Change);
- **Carbon sequestration research** – government agencies (USDA's Northern Global Climate Change Research Program, New Jersey Forest Service, and Minnesota Department of Natural Resources), university research (Bruce McCarl at Texas A&M University), and nonprofit organizations (Winrock International Institute and World Resources Institute);
- **Assistance to landowners** – government agencies (U. S. Forest Service and the National Agroforestry Center) and nonprofit organizations (Forest Trends);
- **Commercial carbon sequestration project development** – private companies (American EnviroTech, Environmental Synergy, Forest Securities, and National Carbon Offset Coalition); and
- **Carbon emission offsets trading** – private companies (EcoSecurities Limited, Emissions Credits International, etc.).

Initial consideration of these categories, sources of information, and the information retrieved would appear to cover all aspects of a market-based carbon sequestration program for New Jersey, from planting trees through good forest management to selling CO_2 emission credits.

Landell-Mills and Porras point to a number of market opportunities for sequestering carbon in forests, including "reforestation/afforestation (including agroforestry) to increase carbon sequestration, improved forest management (e.g. reduced impact logging) both to increase sequestration and reduce emissions, conservation and protection against deforestation to cut emissions, and substitution of sustainably produced biomass for fossil fuels to cut emissions."[1] Five potential approaches to a carbon sequestration program are appropriate for forest lands in New Jersey. These differ principally according to forest management practices and goals. These five are (1) applying good forest management practices to existing forestlands, (2) afforestation or reforestation, (3) agroforestry practices, including riparian buffers and biomass plantations, (4) Atlantic white-cedar restoration, and (5) urban forestry. Each of these potential carbon sequestration programs is discussed below.

Applying Good Forest Management Practices to Existing Forestlands

Applying good forest management practices to existing forestlands to increase carbon sequestration could have by far the broadest impact on forestlands in New Jersey of five approaches There are about

001 Landell-Mills, Natasha, and Ina T. Porras. 2002. Silver Bullet of Fool's Gold? International Institute for Environment and Development. London. pp. 72-73.

1,288,200 acres of privately owned forestland in the State of New Jersey.[2] Based on measurement of stocking rates, about eighty-six percent or 1,109,000 acres are classified as moderately or fully stocked. It is some portion of these acres where managing for carbon sequestration might be accomplished at little or no additional change to, hence cost of, forest management. If, on the other hand, the revenues from selling CO_2 emissions offsets are ample enough to finance additional forest management for the forestlands that are poorly stocked or overstocked, then some portion of an additional 165,000 acres also might be managed for carbon sequestration.

There are nearly 588,000 acres of publicly owned land in the state of New Jersey.[3] Counties and municipalities own nearly 59,000 acres and federal government owns about 54,000 acres. The remainder is owned by the State, including nearly 195,000 acres of State Forest and about 280,000 acres in land that is not State Forest. Assuming (1) that all state-owned land, totaling 475,000 acres, might be available and (2) that the same relationship between moderately or fully stocked forest land and total forestland applied to private forestland also applies to public forestland, then about 409,000 acres of state-owned forestland might be managed for carbon sequestration to generate CO_2 emission credits for sale.

Forestland owners who already are actively managing their forestlands to maintain healthy forest growth, whether the original goal is timber or environmental services (wildlife conservation, watershed protection, or aesthetics), may find that additionally managing for carbon sequestration requires little or no change from their pre-existing management practices. If this is the case, then forestland owners may expect additional revenues from selling carbon dioxide emission offsets with little attendant increase in management costs. In addition, if timber is the principal management goal, then the longer rotations associated with carbon sequestration projects may actually work to increase timber value, when trees left unharvested for longer periods of time can and do grow larger.

However, there is active, ongoing debate concerning the terms of the Kyoto Protocols and the findings of the subsequent Conferences of the Parties as to whether pre-existing carbon sinks may be counted as an offset to future carbon dioxide emissions. Those arguing against this position point out that counting existing grasslands, forestlands, and such would offset much of the CO_2 emissions reductions required of some countries by the Kyoto Protocols—for example, half of all of the reductions required of the United States and Canada—violating the spirit of the Protocols.

At first, only afforestation and reforestation projects were to be included as allowed activities under the Kyoto Protocols. First proposed at the Sixth Conference of Parties held in Bonn (COP 6) and then adopted at the Seventh Conference of Parties (COP 7) held in Marrakech, "forest management", "cropland management", "grazing land management" and "revegetation" were also accepted as allowed activities so long as these forms of management occurred after 1990. The definition of forest management finally adopted was "a system of practices for stewardship and use of the forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner."[4]

Afforestation and Reforestation Projects

To date, carbon sequestration projects in the United States and elsewhere have been based on either afforestation or reforestation projects. Afforestation is the practice of planting trees on land that has not

002 Griffith, Douglas M., and Richard H. Widmann. 2001. Forest Statistics for New Jersey: 1987 and 1999. Resource Bulletin NE-152. USDA, Forest Service, Northeastern Forest Experiment Station. Table 5, p. 28.
003 *ibid.* Table 5, p. 28.
004 www.frim.gov.my/Hutanasli2/drjenny/COP6%20PtII%20LULUCF%20outcomes.htm

been forested for some extended period of time—fifty years according to the sixth Conference of the Parties to the UN Framework Convention on Climate Change.[5] Reforestation is the practice of planting trees on forestland within some shorter period of time after the timber was harvested or otherwise removed. Thus, the management of afforestation or reforestation projects requires forest re-establishment (reseeding, replanting, regeneration, etc.) in addition to whatever forest management practices are proper for managing exiting forestlands. The only widespread environmental criticism of afforestation or reforestation follows a concern that natural forest might be replaced by a plantation of one or a few species of fast-growing trees to the detriment of the biodiversity or long-term environmental sustainability of the forest.

One might expect afforestation or reforestation projects on some portion of the land classified as nonstocked timberland, pasture, or cropland. According to the latest forest survey for New Jersey, there are 20,600 acres of nonstocked timberland, 68,400 acres of pasture, and 616,300 acres of cropland.[6] If, for the sake of argument, eighty percent of the nonstocked timberland, twenty percent of the pasture, and five percent of the cropland was (re)planted as forest, then almost 61,000 acres would be available for afforestation or reforestation projects.

Interpolating data concerning growing stock and growing stock removals from the latest forest inventory for New Jersey,[7] the amount of timberland harvested throughout New Jersey in 1999 was the equivalent on average of nearly 22,000 acres per year. Some portion of this acreage per year also would be available for reforestation projects.

Agroforestry

Agroforestry combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy and sustainable land-use systems.[8] All agroforestry practices—alley cropping, forest farming, silvopasture, windbreaks, land application/disposal of agricultural waste water, short-rotation tree crops, and riparian buffers—to some degree lend themselves to carbon sequestration. All have the potential for conserving soil and growing trees. Conserving soil acts to minimize CO_2 into the atmosphere while tree growth takes up carbon from the atmosphere and stores (sequesters) that carbon over time in the accretion of woody biomass. Of particular interest to this research are riparian buffers and short-rotation woody crops.

Trees grow rapidly, storing carbon, in riparian zones due to favorable moisture and nutrient conditions. When suitable trees and shrubs grow in these moist environments they can filter out excess nutrients, pesticides, animal wastes, and sediments coming from adjacent or agricultural activities.[9] In fiscal year 2002, the State of New Jersey provided funding of more than three million dollars for thirty five separate riparian studies, plans, and restoration projects. In the northern region of the State, twenty-six projects resulted in 43,370 feet of restored buffers.[10] No estimate could be found of the overall opportunity for the enhancement or replacement of riparian buffers, but the need is acknowledged to be large.

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005 www.frim.gov.my/Hutanasli2/drjenny/COP6%20PtII%20LULUCF%20outcomes.htm
006 Griffith, Douglas M., and Richard H. Widmann. 2001. *op. cit.* Table 1, p. 25, and Table 8, p. 30.
007 *ibid.* Table 38, p. 59; Table 42, page 63; and Table 46, p. 67.
008 www.unl.edu/nac/agroforestry.html
009 Ruark, Greg. 2001. Agroforestry and the Carbon Cycle. from Kimberly Stuhr (ed.). *Inside Agroforestry.* Quarterly published by the USDA National Agroforestry Center. Fall/Winter 2000/2001. p. 2.
010 Riparian buffers are measured in lineal feet of waterfront (lake or pond) or bank (stream bank or riverbank).

Short-rotation woody crops might be used for establishing riparian buffers, as well as for windbreaks, living snowfences, timberbelts, and agricultural and community wastewater treatment areas.[11] Short-rotation woody crops are tree crops that are grown at higher planting densities and on shorter rotations than conventional timber crops and that are planted in rows and cultivated in somewhat the same sense as are agricultural crops. Most woody crop development to date has focused on two crops, hybrid poplars (crosses of cottonwoods and aspens) and hybrid willows. Depending on planting density, rotation length, crop, and location, average yields of woody crops may range from four to ten tons (dry-weight basis) per acre per year.

Short-rotation woody crops might be established, grown, and harvested in New Jersey as a source of woody biomass that could be used as solid fuel or a biofeedstock for the production of liquid fuels, ethanol in particular, or other petrochemicals. The use of woody biomass as a fuel directly or indirectly as a feedstock for synthesizing liquid fuels or other petrochemicals all would result in the reduced consumption of fossil fuels and the subsequent reduction the CO_2 generated through the consumption of those fossil fuels.

To date, the only known short-rotation woody crop planting in New Jersey are trial plots, including the one established and maintained for research purposes at the New Jersey Forest Resource Education Center. There remains considerable uncertainty concerning establishing, growing, and harvesting short-rotation woody crops in New Jersey, but one of the chief impediments to establishing large-scale plantings more widely across the state is the lack of a suitable market for woody crops. The banning of the gasoline additive MBTE and its subsequent replacement with ethanol might well provide impetus for a cellulose-to-ethanol industry which, in turn, would require a supply of woody crops as a raw material.

If short-rotation woody crops are ever to be established on a wide scale across New Jersey, it is likely that at least initially the land chosen for woody crops will be from the same land as might be chosen for afforestation or reforestation projects—namely, nonstocked timberland, pasture, and marginal cropland. Thus, short-rotation crops might be established on some portion of the 61,000 acres identified for afforestation or reforestation projects.

Atlantic white-cedar Restoration

One special case of riparian zone restoration unique to New Jersey is the Atlantic White-Cedar Restoration Initiative. Atlantic white-cedar forests are located in New Jersey principally in the Pinelands region in Atlantic, Burlington, Cape May, Monmouth and Ocean counties. It is estimated that at one time there may have been as many as 115,000 acres of Atlantic white-cedar in New Jersey, but there are now fewer than 30,000 acres remaining.[12]

The decline of Atlantic white-cedar can be traced to a number of causes, some the direct or indirect result of human activities and others natural causes unconnected to human activities. The greatest decline due to the actions of humans is likely the harvesting of Atlantic white-cedar and the lack of proper regeneration afterwards. Agricultural and urban development and suppression of wildfires have also contributed to the decline, as has natural forest succession and the increase in salinity of groundwater in some areas.

To counter the decline, the New Jersey Forest Service formed an Atlantic white-cedar Steering Committee in 1995 to undertake he Atlantic white-cedar Restoration Initiative. This initiative was as-

011 Kuhn, Gary A., and W. J. Rietveld. 1998. Opportunities for Growing Short-Rotation Woody Crops in Agroforestry Practices. Agroforestry Notes, AF Note 10. National Agroforestry Center. Lincoln, Nebraska.

012 www.state.nj.us/dep/parksandforests/forest/njfs_awc_initiative.html

signed five goals: (1) to facilitate communication and encourage cooperation among agencies, researchers, private landowners and the public; (2) to explore and demonstrate approaches for restoration and sustainability and increase the acreage of Atlantic white-cedar; (3) to provide a management model for the Atlantic white-cedar resource; (4) to increase Atlantic white-cedar seedling or rooted cuttings production; and (5) to develop Best Management Practices for Atlantic white-cedar.

It is unlikely that all of the 85,000 acres lost can be restored. Nonetheless, there are ample opportunities for restoring Atlantic white-cedar, including restoration of certain shrub dominated sites back to Atlantic white-cedar; restoration of abandoned agricultural sites (cropland, cranberry bogs, and pasture); restoration of wildfire sites; and so forth.[13]

Urban Forestry

Urban forestry is the practice of maintaining urban forests, which are the aggregate of all vegetation and green spaces within communities. Urban forests provide shade, beauty, and habitat for urban wildlife. "Properly planted trees and other urban vegetation can reduce heating and cooling costs, intercept and store rainwater, [and] improve air quality...."[14]

Tree shade reduces air temperature and the amount of radiant energy absorbed and stored by built surfaces.[15] Cooler air temperatures help reduce the need for summertime air conditioning. Reducing the use of air conditioning directly reduces demand for electric power. Reducing demand for electric power translates directly into less power generated, reducing consumption of water and nonrenewable fossil fuels and reducing output of power plant air emissions. Reducing air emissions improves air quality.

Some trees absorb some air pollutants directly from the air, likewise improving air quality. All healthy, growing trees take up carbon dioxide. As trees (and other woody plants) grow, there is an net increase in the carbon sequestered in the growth of their woody parts and in the soil where the trees grow. Lowering the ambient levels of atmospheric carbon dioxide reduces impact of greenhouse gases on global warming.

Urban forests also help improve water quality. Tree crowns intercept and temporarily hold rainfall, slowing the rate of storm runoff. Tree roots tend to loosen soil and make it more porous, increasing the amount of rainwater that soil can absorb. Tree roots also act to intercept and hold sediment and to take up nitrogen and phosphorous that may be dissolved in groundwater.

According to the 2000 Census of the United States, New Jersey is the most densely populated of all the fifty states.[16] The six most populated counties in New Jersey[17] account for nearly half the State's human population (4,048,478 people in the six counties) and slightly more than one-eighth of the State's total land area (1,005.43 square miles in the six counties).[18] The average population density of the six counties together is slightly more than the population density of Bergen County, which by-and-large is a suburb of New York City. Bergen County does, indeed, include some urban and some rural areas, but it is by and large one megalithic suburb. If these six counties can be used as a surrogate for urban and suburban areas in the State, then there are more than 640,000 acres of land where urban forestry might be practiced.

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013 Mylecraine, Kristin A., and George L. Zimmermann. 2003 (2nd edition). Atlantic white-cedar Ecology and Best Management Practices. New Jersey Forest Service. Trenton, New Jersey.
014 wcufre.ucdavis.edu/whatwedo/urbanforestry.html
015 wcufre.ucdavis.edu/research/studies.asp?TopicID=3
016 www.factfinder.census.gov/bf/_lang=en_vt_name=DEC_2000_SF1_U_GCTPH1_US9_geo_id=01000US.html
017 Bergen, Essex, Hudson, Middlesex, Passaic, and Union
018 www.factfinder.census.gov/bf/_lang=en_vt_name=DEC_2000_SF1_U_GCTPH1_ST2_geo_id=04000US34.html

Task 2. Conceptual Design of a Market-Based Program

The goal of the second task is to formulate a market-based carbon sequestration and CO_2 emissions credits program appropriate for forestlands in New Jersey. The foundation for this activity is the opportunity to generate additional revenues from forestlands in order to provide landowners greater income from their woodlands and to finance better forest management. Such a program should encourage landowners to maintain, restore, and manage healthy, sustainable forest ecosystems and it should sustain economic development—that is to say, promote sustainable forest-resource-based economic rural development.

A Market-Based Approach

Why should this carbon sequestration program necessarily be market based? Geoffrey Heal observes there are three ways people may be persuaded to conserve the natural environment. "One, people may make choices that conserve the environment because society instructs them to do so and will penalize them if they disobey. This is the essence of the regulatory approach, the one most widely used to date. Two, people may make choices that conserve the environment because they believe as a matter of principle that this is how they should act; it is consistent with their views on what matters in life and how one should run one's life. Environmental activists are usually in this category. Three, people may choose environmentally conservative strategies because these options are in their economic self-interest. The prices they face fully reflect the social costs of their actions, and they are naturally led by the invisible hand to make conservative choices."[19]

Mr. Heal informs us that "[t]he market mechanism is an extraordinary sophisticated and versatile social institution: it cannot solve all economic problems, but when it works it does so well and simply and elegantly. It creates no fuss and little bureaucracy, and is essentially self-managing."[20] In this way, a market-based CO_2 emissions credits program is possible. During the last few decades, Federal government policy has been much in favor of deregulation, including telephone service, airlines, trucking companies, and electric and gas utilities. So too, market-based programs are considered to be politically acceptable.

Whether this carbon sequestration program is market based or not, it certainly will exist within the broader context of society where government regulation and education will play their respective roles. None of these means—market, government regulation, or education—is mutually exclusive of the others. "In reality, not only are markets and governments interdependent, they should also be seen in a broader context which takes into account the cooperative systems of governance and resource utilisation."[21] It is in this context that a market-based carbon sequestration program is examined.

The impetus for this market-based program is a concern over the increase in atmospheric concentrations of CO_2 due to human activities (principally from the combustion of fossil fuels and from deforestation) and a growing belief that this increase in atmospheric concentrations in CO_2 and other greenhouse gases (GHG) is contributing to global warming. Despite the ongoing debate concerning the causes and effects of global warming, general agreement has been reached by most nations of the world that reducing CO_2 and other greenhouse gas emissions is a prudent course of action.

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019 Geoffrey Heal. 2000. Nature and the Marketplace—Capturing the Value of Ecosystem Services. Island Press. Washington, D. C. p. 129.
020 *ibid.* p. xi.
021 Landell-Mills, Natasha, and Ina T. Porras. *op. cit.* pp. 2-3.

"So while there is general agreement on lowering emissions, the question is how. A simple way to cut GHG emissions is for governments to mandate that each "emitter" reduce their emissions by a set percentage. The problem with this reduction method is emitters may have varying costs to reduce emissions, so forcing all to reduce equally may not be the most cost-effective means of achieving the desired goal.

A solution to this problem is to set an overall reduction level for the economy as a whole and let the free market choose the most cost-effective way to achieve the reductions. One way to do this is through GHG emissions trading. The term "emissions trading:" simply refers to the buying and selling of "emissions credits." One GHG emissions credit (also referred to as offsets, permits, and allowances) would authorize the holder to emit one unit of GHGs – for example one ton of carbon dioxide. Credits could be bought and sold in private transactions or on an exchange that resembles the stock market. The market establishes a supply-demand equilibrium price for the emissions credits, which provides emitters with the information they need to determine if it is more cost-effective to reduce their emissions or buy credits from someone else who has already done do."[22]

There are several ways that greenhouse gas emissions may be traded, including cap and trade, offset trading, and open market.[23] Pertinent to this research are the offset trades, where one party has or otherwise generates emissions credits which are then offered for sale to others who purchase the credits in lieu of reducing their own emissions. In this specific case, credits or offsets are generated when emissions are removed from the atmosphere, as happens in carbon sequestration. This is the essence of a market-based carbon sequestration and CO_2 emission credits program.

A market is defined by the conditions of supply and demand. In this case, demand is driven by concern for global warming and the build up of greenhouse gases, carbon dioxide in particular. Supply is motivated by those seeking additional income form their forestlands. The principal elements of such a market-based carbon sequestration program are (1) the various stakeholders involved in the transactions of buying and selling and their respective roles and (2) the terms and conditions of the agreement to buy and sell CO_2 emissions credits, including the definition of the commodity to be bought and sold.

Stakeholders and Their Roles

There four general classes of stakeholders (See Table 1). Two different groups of forestland owners, private and public, have been identified as possible sellers of carbon credits. The intermediaries are the private and public entities who sell carbon credits on behalf of their clients and who may aggregate the holdings of a group of small forestland owners. Three types of buyers are identified—large corporate buyers, brokers and traders, and the exchanges. Carbon sequestration project development and emission credit sales are assisted by a variety of consulting and advisory firms as well as a variety of government agencies that provide incentives to sellers or that regulate transactions.

Sellers. The sellers of CO_2 emission credits are those public and private entities who own forestland where the CO_2 is taken up and sequestered in forest biomass. In New Jersey, some 88,700 private owners, including individual and joint ownerships, partnerships, corporations, and clubs and other types of associa-

022 anon. 2003. GHG Emissions Credit Trading. Energy Info Source, Inc. Lakewood, Colorado. p. 4.
023 *ibid.* p. 5.

tions, own more than sixty percent of all the forestland in New Jersey, about 1,288,200 acres.[24] The remaining forty percent, about 587,900 acres, are owned by federal, state, county, and municipal government.

Table 1. Principal Stakeholders

Stakeholder	Possible Parties
Sellers	Private landowners Federal, state, county, and municipal government
Intermediaries	For-profit commercial enterprises Non-profit organizations
Buyers and Other Points of Sale	Large corporations Brokers and traders, including project developers Exchanges
Others	Federal and state governments Consultants and advisors

At the outset of this investigation, private landowners were divided into two groups, corporate and noncorporate owners. There is an old business cliché that contracts and other forms of binding legal agreements work best between equals. It was supposed that corporate landowners might have the financial and legal resources and the business savvy to represent themselves in a sophisticated market for buying and selling CO_2 emission credits where noncorporate private landowners might not. It was envisioned that the noncorporate private landowners might come into the market by way of intermediaries who would have the resources and business savvy and who would act on the behalf of the several landowners who are their clients. It also was supposed that noncorporate private landowners were, by and large, a large group of owners with small holdings and that corporate landowners were fewer in number with larger holdings. This latter distinction turns out, strictly speaking, to be true, but the statistics for New Jersey for 1989 (the most recent survey statistics available) show this to be a distinction without much of a difference.[25]

The supposition made about corporate landowners representing themselves is still likely true, but only for the few largest landowners, some fifty or fewer corporations[26] each with holdings of one thousand acres or more.[27] Taken together these large holdings total about 154,000 acres. At the other end of the spectrum, nearly ninety percent of all corporate landowners in New Jersey own holdings smaller than 100 acres.[28] Therefore, the decision was made that all private landowners, corporate and noncorporate, would be aggregated together to comprise a single group.

"In New Jersey, sixty-eight percent of the private forest landowners hold fewer than ten acres of forest. Collectively this group owns about ten percent of the forestland, which is mostly used for homesites.

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024 Richard Widmann. 2002. Trends in New Jersey Forests. NE-INF-148-02. USDA, Forest Service, Northeastern Research Station. Newtown Square, Pennsylvania. p. 2.
025 Thomas W. Birch. 1996. Private Forest-land Owners of the Northern United States, 1994. Resource Bulletin NE-136. USDA, Forest Service, Northeastern Forest Experimental Station. Table 122, p. 150.
026 the precise number is unavailable in public statistics due to privacy concerns
027 Thomas W. Birch. *op. cit.* Table 122, p. 150.
028 *ibid.* Table 122, p. 150.

Since 1972, the estimated number of these owners with fewer than ten acres of forest has increased by seventy-five percent. Unlike owners of large tracts, these owners are less likely to manage their forests...."[29] This group of small private landowners, together holding approximately 129,000 acres of forestland in New Jersey, will likely not opt into the carbon sequestration program envisioned in this research. Their participation likely will be further inhibited by the disproportionally large transactions costs that will be associated with selling the emission offsets from such small holdings.

While it is true that the large number of small forestland owners cited above is more likely to never harvest timber, the converse is not so readily apparent among those with larger holdings.[30] This may be true because the dominant two reasons for owning forestland in New Jersey are (1) profiting from appreciating land values and (2) aesthetic enjoyment.[31] This generalization may also be true, in part, because no forestland in New Jersey is owned by the forest industry.[32] However, these facts bode neither particularly ill nor particularly well for the carbon sequestration program envisioned here. For those wishing to profit from their forestland holdings, the sale of CO_2 emission credits may be seen as an additional source of income and, with the proper buy-out clause in the sale of credits, those landowners will be able to make properly informed financial decisions in the future if and when they decide either to sell the timber on their forestland holdings or to sell their holdings altogether. Those owning forestland for its aesthetic appeal may want to maintain the forest on their holding for the long term, which would be entirely consistent with terms of sale of CO_2 emission credits.

The amount of land held by this latter class of neither very small nor very large private landowners may be calculated as the difference between the total forestland held by private owners [33] and the sum of the other two categories. On this basis, the midsized private landowners hold about 1,005,000 acres of forestland in New Jersey.

In summary, various private forestland owners own 1,288,000 acres of forestland in New Jersey. The smallest private forestland owners, together holding about 129,000 acres likely will not participate in the carbon sequestration program envisioned here. The largest private (corporate) forestland owners, together holding about 154,000 acres may sell their own CO_2 emission credits or they may choose to sell their credits through intermediaries. Of the remaining private forestland owners, together holding about 1,005,000 acres, those wishing to sell CO_2 emission credits likely will do so only through intermediaries.

There are 587,900 acres of publicly-held forest in New Jersey. Nearly 81 percent of this total is owned by the State of New Jersey: 194,900 acres in State Forests and an additional 280,100 acres not in State Forests. Of the remainder, the Federal Government owns 54,200 acres and county and municipal governments own 58,700 acres of forestland.

Revenues received from the sale of CO_2 emission credits might be welcome in these times of declining tax revenues and shrinking government budgets, although the sale of CO_2 emissions credits would likely require the approval among the constituency of whatever level of government contemplated such a sale. Carbon sequestration for the sale of CO_2 emission credits, possibly bundled together with other forest-based environmental services,[34] might well be attractive to an informed electorate so long as these

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029 Richard Widmann. *op. cit.* p. 2.
030 Thomas Birch. *op. cit.* Table 131, p. 159.
031 *ibid.* Table 130, p. 158.
032 Griffith, Douglas M., and Richard H. Widmann. *op. cit.* Table 4, p. 28.
033 Griffith, Douglas M., and Richard H. Widmann. *op. cit.* Table 4, p. 28.
034 watershed protection, aesthetics, and biodiversity

uses of public forestland did not conflict with other uses enjoyed by the public. Moreover, sales agreements could be written so not to preclude the expressed will of the voters at some future date. In addition, the long-term management of public forests for carbon sequestration need not conflict with pre-existing long-term stewardship goals.

Intermediaries. For the purposes of this research, the key characteristic of an intermediary is a public or private entity that will represent the forestland owner as seller of CO_2 emission credits at the point of sale. As such, intermediaries will advise their clients and represent their client's best interests in negotiating the terms and conditions of sales and obtaining the best sales price. Essential to forestland owners in New Jersey, intermediaries will also perform the necessary functions of (1) aggregator, bringing together several smaller forestland owners into groups to create larger transactions, and (2) project developer, structuring overall transactions. In summary, aggregators will provide to their forestland owner clients a concentration of "financial resources, managerial and coordination skills, technical knowledge, and political connections,"[35] reduced transaction costs, greater market power and leverage, and aggregated individual holdings (all on different growth regimes) into a pool with an even flow of credits.

The National Carbon Offset Coalition is an example of a non-profit corporation supported by eight resource and conservation districts. Originally named the Montana Carbon Offset Coalition, NCOC now manages a portfolio of eight carbon sequestration projects located in Idaho, Montana, and Texas. Environmental Financial Products, LLC, assists NCOC in the sale of the credits generated in these projects. The coalition also provides project development assistance to its clients and participates in pilot carbon sequestration projects funded by the U. S. Environmental Protection Agency.

American EnviroTech, LLC, is a private company recently formed by Mr. Thad Miller of Greenwood and Dr. Phil Combs of Edwards, Mississippi. American EnviroTech assists landowners with selling emissions credits generated through carbon sequestration in their forestlands. The company works with forestland owners to "maximize the financial return to the landowner for their environmental assets.... American EnviroTech is working with several firms brokering these credits to buyers."[36]

Currently, there is no organization in New Jersey that offers to serve as an intermediary for forestland owners wishing to sell CO_2 emission credits. However, partnerships of public and private entities have been formed from time to time to develop other environmental assets, such as the partnership of Southern Jersey Quail Unlimited, the South Jersey RC&D Council, and Land Dimensions Engineering which developed the Buckshutem Wildlife Management Area Habitat Restoration Project. There is no reason to believe that organizations like these cannot or will not come together in the future to act as an intermediary for carbon sequestration projects in New Jersey.

Buyers and Other Points of Sale. The first group of buyers are the large corporations, in particular electric utilities, petrochemical, and timber companies. Their purchases to date have been made through brokers, which are described separately below.

The electric utilities that already are buyers include American Electric Power, Illinova Generating, and Utilitree Carbon Company, a subsidiary of the Edison Electric Institute, the latter being a nonprofit corporation supported by electric utilities across the United States. American Electric Power Company has

035 Landell-Mills, Natasha, and Ina T. Porras. *op. cit.* p. v.

036 Ken Wilbanks. 2003. New Company Helps Environment, Provides Opportunity. Delta Business Journal. June 2003 issue. (www.deltabusinessjournal.com/2003_Archives/June/June-newcompany.php)

supported a project to reforest more than eighteen thousand acres of bottomland hardwood forest in central Louisiana.[37] Illinova Generating Company has supported the reforestation of more than one hundred thousand acres in the Lower Mississippi River Valley.[38] The Utilitree Carbon Company has supported reforestation projects in Arkansas, Louisiana, Mississippi, and Oregon.[39]

The second group of buyers are the various brokers and traders, including both carbon sequestration project developers acting as suppliers of CO_2 emission credits as well as financial companies. One essential difference between the intermediaries previously discussed and the carbon sequestration project developers acting as brokers and, for that matter, all other brokers and traders is important. The intermediary is paid by the landowner and thus represents the interest of the landowner. The broker is paid by the buyer of emission credits and thus represents the interest of the buyer.

One of the project-developers-cum-brokers, Environmental Synergy, Incorporated, describes itself as "a service organization providing reforestation and carbon quantification services to corporate clients as a means to offset carbon dioxide (CO_2) emissions and promote sustainable forestry."[40] Environmental Synergy's clients include electric utilities and petrochemical companies. Likewise, Forest Securities, Incorporated, describes its core business as including forest resource management and evaluation and sequestration of forest carbon, but its principal business is procuring "the highest performing and most secure carbon assets worldwide."[41] Forest Securities clients include, among others, timber companies in the Pacific Northwest, both the United States and Canada.

Canter Environmental Brokerage, CO2e.com, Environmental Financial Products, Evolution Markets, and Natsource are all financial companies acting as brokers and traders of CO_2 emission credits. All these companies broker transactions between willing sellers and buyers. Canter Environmental Brokerage, CO2e.com, Environmental Financial Products, and Evolution Markets specialize in CO_2 emission credits; Natsource is an energy broker (natural gas, electricity, and coal) as well as an environmental broker (nitrous oxides, sulfur dioxide, and greenhouse gases). Further, all advertise themselves to be "full-service companies," providing consulting as well as brokerage services. Consulting services include project development, valuation, and verification. Brokerage services include market and policy development guidance, price discovery, matching buyers and sellers, and structuring trade deals.[42]

The only exchange for greenhouse gas emissions credits in the United States is the Chicago Climate Exchange. "The Chicago Climate Exchange is a greenhouse gas (GHG) emission reduction and trading pilot program for emission sources and offset projects in the United States and for offset projects undertaken in Brazil."[43] Sources and projects in Canada and Mexico are to added sometime in 2003. Trading is to begin in October 2003 and will apply to trades for the years of 2003 through 2006. Carbon Financial Instruments, each representing one hundred metric tons of carbon dioxide or its equivalent, will be traded on the exchange. Among the emission offsets recognized is the carbon sequestered in soil and forests.

Others—Governments. Markets rarely operate outside the oversight and influences of government. Governments protect the interest of their citizens and, in turn, provide certainty to markets. Governments

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037 www.environmental-synergy.com
038 *ibid.*
039 anon. 2001. Global Climate Change—Utilitree Carbon Company.
040 www.environmental-synergy.com
041 www.forestsecurities.com
042 www.natsource.com/markets/index.asp?s=22
043 www.chicagoclimatex.com/about

can act to stimulate and shape markets by setting and enforcing regulation, providing information and educational resources, providing technical and financial assistance (including loan guarantees or insurance), inventorying and monitoring forest resources, and defining stakeholders' rights and responsibilities. Government would play a no less important role in a market-based carbon sequestration and CO_2 emissions credits program in New Jersey.

Governments can act to set policy, oversee, regulate, and provide incentives only with a clear understanding of the underlying science and technology, the market, the commodities bought and sold, and the various stakeholders. This understanding is the product of considerable applied and basic research which, at the level of the Federal Government, is coordinated by the U.S. Global Change Research Program. Participants in the USGCRP include the Departments of Agriculture, Commerce, Defense, Energy, Health and Human Services, Interior, State, and Transportation; the U.S. Environmental Protection Agency; the National Aeronautics and Space Administration; the National Science Foundation; and the Smithsonian Institution. Each of these agencies and their relevant programs is described in the appendix that follows.

In June of 2003, Agriculture Secretary Ann M. Veneman announced that henceforth the U. S. Department of Agriculture would factor in carbon as a consideration in all its programs.[44] Of particular interest to this research is the technical and financial assistance that could become available for carbon sequestration projects in New Jersey from several units of the U. S. Department of Agriculture, including the Cooperative State Research, Education, and Extension Service; the Farm Service Agency; the Forest Service; and the Natural Resources Conservation Service. Each of these units and their relevant programs is described in the appendix.

The New Jersey Sustainability Greenhouse Gas Action Plan was created in 1999 as part of an aggressive program to promote sustainability and to reduce greenhouse gas emissions. Today that plan is managed by the Division of Science, Research, and Technology in the New Jersey Department of Environmental Protection (NJDEP). The goal of this plan is the reduction of greenhouse gases—namely, a three-and-one-half percent reduction below 1990 levels by the year 2005. Also part of the NJDEP, the New Jersey Forest Service recently has supported investigations into carbon sequestration.

When this research was first proposed, it was anticipated that another NJDEP program, the Open Market Emissions Trading Program, would figure into this work reported here. This program was started in the DEP in 1996 to provide incentives for voluntarily reducing air emissions. In 2000, the program was modified, in part, to add new provisions for generating and banking greenhouse gas credits. In 2002, however, when a new governor was elected and a new administrator appointed to the NJDEP, problems with the OMET program surfaced that caused the program finally to be scrapped.[45]

One regional program and the programs in four states should be mentioned, if only in passing. The Northeast Regional Biomass Program is administered by a coalition of Northeastern States, including New Jersey, and has sponsored an investigation of the potential role of carbon sequestration in forests and in the forest products industry in the northeastern United States. In Minnesota, the *Releaf Program* promotes and funds the planting, maintenance, and improvement of trees in the state to reduce atmospheric CO_2 levels. Nebraska has created a *Carbon Sequestration Advisory Committee* to investigate the possibility of sequestering carbon in the state through modified agricultural methods. In New Mexico, the

044 Personal communication with Dr. Greg Ruark, Director of the National Agroforestry Center in Lincoln, Nebraska. 9 October 2003.

045 anon. 2003. GHG Emissions Credit Trading. Energy Info Source, Inc. Lakewood, Colorado. p. 42.

Forest Re-Leaf program provides grants to public entities such as schools, cities, counties, and rural communities for the purpose of planting trees. In Oregon, the *Forest Resource Trust* program helps landowners establish and manage healthy forests through private agreements with the state. Each of these programs is referenced in the appendix at the end of the report.

Others—Consultants and Advisors. A number of firms act as advisors and consultants helping to develop and implement carbon sequestration projects. EcoSecurities and Trexler and Associates are financial consultants; CarbonVentures International is the subsidiary of ENVIRON Holdings, Inc., an environmental and public health consulting firm; and Ecological Solutions, the Sampson Group, and Woodrising Consulting are forestry consultants. All these companies are described in the appendix at the end of this report.

Terms and Conditions of Agreements to Buy and Sell CO_2 Emission Credits

Sales contracts for emission credits from a carbon sequestration project will identify (1) the parties entering into the contract, names of responsible persons, and contact information; (2) date of sales contract; (3) the amount of emission credits, the source of the credits, a description of the forestland and its management; (4) the methodology and responsibility for verification of standing forest biomass; (5) description and warranties of the seller's claim to ownership of the credits; (6) description of the structure of the transaction, including schedule of delivery and payment for emission credits; and (7) a discussion of the warranties and risks and their remedies. In addition, "[f]orest projects developed under the rules of the Kyoto Protocol will need to produce greenhouse gas (GHG) mitigation benefits that are real, measurable, additional, verifiable, and consistent with sustainable development."[46]

The Commodity. The commodity is a CO_2 emission credit or offset. Recalling basic chemistry, for every unit of carbon sequestered, there are 3.67 units of CO_2 removed from the atmosphere. Thus 0.27 tons of carbon in woody biomass is the equivalent of one ton of CO_2 emission credits.

The National Carbon Offset Coalition has coined the term "Carbon Sequestration Unit" which it defines as the "amount of organic carbon sequestered in wood or soil that is equivalent to the removal of one tonne of carbon dioxide (CO_2) from the atmosphere."[47] This definition, like the definition used in this report and elsewhere includes the carbon in the trees and the understory, the carbon in the coarse debris and fine organic litter found on the forest floor, and the carbon in the organic matter entrained in the soil beneath the forest.[48, 49] Please note, the units of measurement for CSU's are tonnes or metric tons, which are defined as 1,000 kilograms, the equivalent of 2,204.6 pounds.

CO_2 emission credits as a commodity also may be defined by restrictions on their supply, as articulated by State or Federal rules or regulations or by international agreements. According to the Kyoto Protocol, for example, to qualify as a credit, carbon must be withdrawn from the atmosphere for at least one hundred years (for related discussion, see later subsection on project duration and carbon accounting).

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046 Cottle, Phil, and Charles Crosthwaite-Eyre. Insuring Forest Sinks. from Stefan Pagiola, Joshua Bishop, and Natasha Landell-Mills. 2002. Selling Forest Environmental Services—Market-based Mechanisms for Conservation and Development. Earthscann Publications Limited. London. p 247.

047 Neil Sampson 2002. Project Planning Handbook: Forestry Projects to Create Carbon Sequestration Units (CSU's). Prepared for the National Carbon Offset Coalition by The Sampson Group. Alexandria, Virginia. p. 1.

048 cf. R. A. Birdsey. 1992. Carbon Storage and Accumulation in the United States Forest Ecosystems. General Technical Report WO-59. USDA Forest Service, Northeastern Forest Experiment Station. Radnor, Pennsylvania. pp. 20 – 23.

049 K. G. MacDicken. 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry projects. Winrock International Institute for Agricultural Development. Washington, D. C. p. 8.

The Protocol defines four potential carbon commodities—Assigned Amount Units, Emission Reduction Units, Certified Emission Reductions, and Removal Units—each with its own uses and restrictions.[50]

There are two general approaches for assessing the amount of carbon sequestered in a forested tract. Sequestered carbon can be estimated using the methodology and conversion factors described by Hoover et al. for the purposes of planning and modeling.[51] Sequestered carbon can be measured using the field and laboratory procedures enumerated by MacDicken for structuring transactions.[52]

The estimation procedure for small forested tracts begins with an inventory of the volume of standing trees determined using standard survey methods. The merchantable volume thus determined is then converted first to total volume and then to pounds of carbon using conversion factors specific to tree type, forest type, and/or region. The carbon in the understory, on the forest floor, and in the soil is estimated by interpolating information representative of a particular region and state. The total carbon is then calculated as the sum of the amounts of carbon in each of the four carbon pools—trees, understory vegetation, litter, and organic carbon in the soil.

Measurement begins with the design of inventorying procedures—specifying the sampling design (stratified random sampling produces the most accurate results[53]), selecting sample size, locating a sufficient number of permanent sampling plots, and then mapping plots. A specific time of the year should be chosen for inventorying so that subsequent surveys can be made at the same point in the seasonal cycle of the forest for comparable results and also so that inventory crews can have access to the survey plots. The specific protocols for taking and analyzing samples each of the four carbon pools and measuring and reporting carbon content likewise need to be specified, observed in practice, and documented.

Project Term and Carbon Accounting. The term of the sale of emission credits can be linked to the operating term of the facility generating the emissions. The operating term, in turn, can be determined using a financial valuation to establish a project's useful economic life. "The CARE/Guatemala project, for example, was linked to the thirty-five-year lifetime of the AES power plant it was offsetting."[54] In this case, carbon was sequestered only during the period of time when plant operated, without any apparent concern for the long-term fate of carbon dioxide in the atmosphere.

Alternatively, the term of the sale of emission credits can be linked to the long-term fate of carbon dioxide in the atmosphere. Scientists estimate that carbon dioxide released into the atmosphere will persist for a period of from fifty to two hundred years.[55] Using this approach, projects should have a term of at least fifty years. In fact, some of the earlier carbon sequestration projects undertaken by the National Carbon Offset Coalition required landowners to commit to terms of from 70 to 100 years.[56] Also, the Pacific Forest Trust has set up the Forests Forever Fund to acquire permanent conservation easements on forestland in the Pacific Northwest that will allow carbon to be sequestered in perpetuity.[57]

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050 Landell-Mills, Natasha, and Ina T. Porras. *op. cit.* p. 75.
051 Hoover, Coeli M., Richard A. Birdsey, Linda S. Heath, and Susan L. Stout. 2000. How to Estimate Carbon Sequestration on Small Forest Tracts. Journal of Forestry. 98(9): 13 – 19.
052 K. G. MacDicken. *op. cit.* pp. 12 – 15.
053 *ibid.* p. 9.
054 Brown, Paige, Bruce Cabarle, and Robert Livernash. 1997. Carbon Counts: Estimating Climate Change Mitigation in Forestry Projects. World Resources Institute. Washington, D. C. p. 9.
055 *ibid.* p. 9.
056 Personal Communication with Mr. Larry Van Rinsum, National Carbon Offset Coalition, July 2003.
057 www.pacificforest.org/services/forever.html

If, during the course of the aforementioned long-term projects, timber is to be harvested and forests subsequently regenerated, then proper carbon accounting may require averaging the amount of carbon sequestered over the project term. Where there is no harvesting, the total carbon sequestered is merely the carbon sequestered at the end of the project less any carbon sequestered at the beginning of the project.

The Kyoto Protocol sets one hundred years as a reference timeframe, which may be used to calculate the "Absolute Global Warming Potential" of carbon dioxide.[58] Analysis shows that "removing one ton of CO_2 from the atmosphere and storing it for 55 years counteracts the radiative forcing effect, integrated over a one-hundred-year time horizon, of a one ton CO_2 pulse emission."[59] From this, Moura Costa and Wilson have calculated that one ton of carbon sequestered for one year is equivalent to 0.0182 tons of carbon dioxide emissions avoided over the long term.[60] Using this equivalence factor, the amount of CO_2 emissions credits, hence their value, can be calculated for projects with terms shorter than fifty-five years.

Trading Mechanisms. There are three broad categories of trading mechanisms, bilateral agreements, brokered sales, and exchange trades:

- Bilateral agreements, sometimes referred to as voluntary contractual arrangements[61] or self-organized private deals, are the sales/purchase agreements that typically are made between two parties, one seller and one buyer of CO_2 emission credits.[62] Essential to this type of transaction are clear property rights and enforceable terms. This type of transaction often "lacks price transparency and liquidity that would otherwise be present in an open exchange environment with many buyers and sellers."[63]

- Brokers act as middlemen and bring sellers and buyers together. Brokers typically organize the terms of the transaction between sellers and buyers, whether the sale is through a bilateral agreement, by auction, or on an exchange. The sale/purchase terms may be somewhat more flexible in a transaction brokered between buyer(s) and seller than those typically required by exchanges.

- Exchanges typically offer the greatest price transparency and bring together the largest number of buyers and sellers. "Transactions range from simple purchases and sales to structured options transactions."[64] Structured transactions include immediate settlement trades, forward settlement trades, and option trades.

Each type of transaction offers terms that meet the specific needs of different sellers and buyers. One might expect to see transactions, in general, shift from a preponderance of bilateral agreements initially to more exchange trading as the market matures, but all three types of transactions likely will continue to be used for the foreseeable future.

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058 Moura Costa, Pedro and Charlie Wilson. 2000. An Equivalence Factor between CO2 Avoided Emissions and Sequestration – Description and Applications in Forestry. EcoSecurities Limited. Oxford, England. p. 2.
059 *ibid.* p. 3.
060 *ibid.* p. 4.
061 www.forest-trends.org/keytrends/pdf/tech_briefs/7forestservices.pdf
062 Powel, Ian, Andy White,, and Natasha Landell-Mills. 2002. Developing Markets for the Ecosystem Services of Forests. Forest Trends. Washington, D. C. p. 7.
063 anon. 2003. GHG Emissions Credit Trading. Energy Info Source, Inc. Lakewood, Colorado. p. 34.
064 *ibid.* p. 35.

Payments for Emission Credits. Payments for emission credits may be made by the buyer to the seller (1) in advance, (2) incrementally through time, or (3) after carbon has been sequestered, depending on buyers and sellers requirements.

- Payment may be made *ex ante*—that is to say, in advance of carbon being sequestered. This pays the landowner in advance, perhaps providing funds to undertake forest management practices. Such up-front payment likely will require contract terms that address the risk of nonperformance or underperformance.
- Payment may be made *ex post*—that is to say, only after carbon has been sequestered. This reduces the risk of nonperformance or underperformance and thus allows for much simpler sales contracts and reduced transaction costs. However, this approach may be unacceptable to landowners, who either require up-front payment, perhaps to cover operating costs, or sequential payments through time, comparable to an ongoing income from the sale of emission offsets.
- Payments may be made incrementally on a pay-as-you-go basis. This allows the buyer to pay for the credits over time, perhaps only as carbon actually is sequestered. This approach will lower performance risk, but may raise the transaction costs associated with periodically reverifying actual carbon sequestration.

Risk Management. There are a number of risks that can be associated with the selling and buying of CO_2 emission credits. In all cases, liability first must be assigned before risks may be managed.

- Performance risk usually is associated with nondelivery of emission credits, which may be due to the seller's insolvency (for example, trees don't get planted or future forest management practices are not carried out) or nonperformance or failure (for example, forest growth over time fails to sequester the amount of carbon required to generate the proper amount of credits). The seller is usually liable for performance risks. The buyer may require the seller to obtain project insurance or provide performance guarantees, perhaps with either forestland or financial set-asides.
- Opt-Out risk is a concern for both seller and buyer. Sellers may decide unilaterally to change either forest management regimes (for example, harvesting and selling timber) or forestland uses (for example, clearing forestland for nonforest uses). Buyers may find less expensive alternatives for controlling their greenhouse gas emissions or purchasing offsets. Whoever prematurely terminates the agreement is liable. The remedy for opt-out risk usually is buy-out terms included as part of the sales agreement.
- Natural disaster risk is associated with all the natural perils that may befall a forest, including fire, wind, prolonged flood, insect infestation, and disease epidemics. Typically, neither seller nor buyer is held liable in cases of natural disasters and remedy is usually to be found in the *force majure* clause included in the sales agreement.
- Political/Institutional risk is associated with governments creating new or altering existing laws and regulations that define or otherwise regulate the market for selling and buying CO_2 emission credits. Neither seller nor buyer can be held liable for governmental action. The remedy for such risks may be a "reg-out" clause that defines when and how the sales agreement may be terminated.

Certification. The buyer of emission credits may require certification of the measurement of the amount of carbon sequestered in forest biomass or the use of sustainable forest management practices as a con-

dition of sale of emission credits. The Forest Stewardship Council, for example, provides accreditation of organizations who then are required to evaluate all forests aiming for certification according to the FSC Principles and Criteria for Forest Stewardship.[65]

Market Development

Powell, White, and Landell-Mills describe the developing market for forest services (including the market for CO_2 emission credits based on carbon sequestered) in three broad phases.

- In the early or emerging phase, knowledge is amassed and a consensus is generated concerning potential problems or opportunities. Entrepreneurs and other early adopters lead the way.
- In the middle or defining phase, process and government policy begin to emerge. Government policy is expressed in regulations and incentives. "The regulations define service, settle the particular rights and obligations of stakeholders, and provide a platform for negotiating payments."[66] Incentives may come in the form of technical or financial support or public instruments, such as loan guarantees or insurance.
- In the late or "live" phase, "[t]ransactions take place and money changes hands. Service contracts and agreements are established, along with supporting institutions, such as accounting standards, monitoring, and certification mechanisms."[67]

The ultimate measure of a market's development will be its robustness, transparency, and transactional cost certainty. The market for selling CO_2 emissions offsets, however, is far from mature. While there is a broad consensus that reducing greenhouse gas emissions is a prudent action, that consensus is yet to be officially acknowledged by the government of the United States. Government policy has yet to emerge that strictly defines service or stakeholders' rights or obligations, although some technical and financial assistance may be found. Entrepreneurs do lead the way and, in a few cases, money has changed hands, but the market is not robust in terms of a large number of buyers and sellers, prices are murky rather than transparent, and, without accounting standards, monitoring, and certification mechanisms, transaction costs remain uncertain.

Despite this lack of maturity, a market for selling CO_2 emission credits from carbon sequestration projects could emerge in New Jersey. Government support of research has allowed advances in market definition. This report, for example, describes the role for an intermediary who will act on the behalf of forestland owners and who will aggregate multiple owners together to generate carbon emission credits in sizes and amounts attractive to potential buyers. Moreover, buyers do exist and have entered into agreements underwriting carbon sequestration projects in Arkansas, Idaho, Louisiana, Mississippi, Montana, Oregon, and Texas to produce CO_2 emission credits. All that remains doing is an entrepreneur stepping forward in New Jersey.

065 www.fscoax.org/principal.htm
066 Powell, Ian, Andy White, and Natasha Landell-Mills. *op. cit.* p. 9.
067 *ibid.* p. 9.

Task 3. Program Assessment

In the first task, six generic opportunities for carbon sequestration projects were identified and the total acreage available for five of the six opportunities was estimated. In the second task, different groups of forestland owners as possible sellers of emissions credits were identified and the amount of land held by each group estimated. In this third task, information is developed describing the distribution of forestland in New Jersey by forest type and the amount of carbon sequestered per acre in each forest type. All this information, plus the percentage of tree cover in the urban counties chosen as a surrogate for urban forestry in New Jersey, is then used first to calculate the amount of land in New Jersey in each of the forest types and carbon sequestration opportunities and second to calculate the amount of carbon sequestered in each of the forest types and carbon sequestration opportunities. These totals are reviewed in light of recent CO_2 emission credit prices to assess the possible economic value of such a program in New Jersey.

The first element of this analysis is reviewing the amount of land identified in the first and second tasks for each of the generic carbon sequestration opportunities and landowners:

- In the first task, data retrieved from the latest survey of New Jersey forests was used to calculate that 86.1 percent of timberland in private and public ownership was categorized as either moderately or fully stocked. In the second task, information from that survey and other work was used to determine that 1,159,380 acres of forestland in private ownership might become available for carbon sequestration projects where good forest management practices are applied to existing forestlands. The net amount of land in private ownerships that is both available and can be characterized as either moderately or fully stocked is thus 998,100 acres.
- In the second task, forestland owned by the State was selected as possibly available for carbon sequestration projects on public land where good forest management practices are applied to existing forestlands. Applying the same factor for land either moderately or fully stocked, there are 408,975 acres of such land available.
- From the first task, if eighty percent of nonstocked timberland, twenty percent of pastureland, and five percent of cropland is arbitrarily selected as available for afforestation, reforestation, or short-rotation woody crop projects, then there are 58,655 acres of land available for carbon sequestration.
- From the first task, if half of the 85,000 acres of Atlantic white-cedar forests lost to date were selected for restoration and carbon sequestration, then there are 42,500 acres available.
- In the first task, the six most densely populated counties in the State were chosen as a surrogate representing 643,475 acres available for carbon sequestration through urban forestry projects.

All this is summarized in Table 2.

Table 2. Land in Each of the Carbon Sequestration Opportunities (acres)

Opportunity Type	Acreage
good forest management practices/private land	998,100
good forest management practices/public land	408,975
afforestation/reforestation/short-rotation woody crops	58,655
Atlantic white-cedar restoration	42,500
urban forestry	643,475

The forests in New Jersey may be categorized by-and-large according to one of seven forest types—loblolly/shortleaf pine, oak/pine, oak/hickory, oak/gum/cypress, elm/ash/red maple, northern hardwoods, and aspen/birch. The distribution of forestland in New Jersey according forest type is shown in Table 3.

Table 3. Distribution of Forestland by Forest Type in New Jersey

Forest Type	Acres	Percentage
loblolly/shortleaf pine	415,000	22.1
oak/pine	207,600	11.1
oak/hickory	847,300	45.2
oak/gum/cypress	64,500	3.4
elm/ash/red maple	152,600	8.1
northern hardwoods	187,500	10.0
aspen/birch	1,600	0.1

For the purposes of this analysis the assumption has been made that the forestland in the three categories of good forest management practices/private land, good forest management practices/public land, and afforestation/reforestation/short-rotation woody crops are all evenly distributed throughout all forest types in proportion to those forest type's distribution across New Jersey. Atlantic white-cedar restoration is assumed to take place only on land in the oak/gum/cypress type, the swamp or bottomland hardwoods that displace or succeed Atlantic white-cedar. Comparing the distribution of forest type by county, then essentially all the urban forestry in the counties chosen in the first task will occur in the oak/hickory, elm/ash/red maple and northern hardwoods forest types.[68] Table 4 shows the distribution of acreage in forestland by forest type and by type of carbon sequestration opportunity.

068 Griffith, Douglas M., and Richard H. Widmann. *op. cit.* Table 39, p. 60.

Table 4. Land for Carbon Sequestration by Forest Type and by Type of Opportunity for Carbon Sequestration (acres)

Forest Type	good mgt. /private land	good mgt./public land	afforest/reforest/SRWC	Atl. white-cedar rest.	urban forestry
loblolly/shortleaf pine	220,783	90,467	12,975	0	0
oak/pine	110,445	45,255	6,490	0	0
oak/hickory	450,770	184,705	26,490	0	459,168
oak/gum/cypress	34,315	14,060	2,017	42,500	0
elm/ash/red maple	81,184	33,266	4,771	0	82,697
northern hardwoods	99,751	40,874	5,862	0	101,610
aspen/birch	851	349	50	0	0
total	998,100	408,975	58,655	42,500	643,475

Using data and methodology provided by Richard Birdsey, the amount of carbon sequestered in an acre of forest in New Jersey is calculated by forest type and by forest component and shown in Table 5.[69]

Table 5. Carbon Stored Forests In New Jersey by Forest Type (tons per acre)

Forest type	Trees	Understory	Litter	Soil	Total
loblolly/shortleaf pine	17.6	0.4	11.5	72.4	101.8
oak/pine	26.8	0.5	9.9	72.4	109.6
oak/hickory	28.0	0.6	8.3	72.4	109.2
oak/gum/cypress	25.2	0.5	8.3	72.4	106.4
elm/ash/red maple	16.3	0.3	8.3	72.4	97.3
northern hardwoods	25.5	0.5	8.3	72.4	106.7
aspen/birch	14.9	0.3	8.3	72.4	95.9

The information in Table 5 is based on inventory data for New Jersey representing the standing forest on forestland in New Jersey at the time of the inventory. This information is assumed here to be what is now growing or will grow after natural regeneration. Given the number of acres of land in Table 4 and the amount of carbon sequestered per acre in Table 5, the tonnage of carbon sequestered in New Jersey can

069 Richard A. Birdsey. Carbon Storage and Accumulation in United States Forest Ecosystems. Gen. Tech. Rpt. WO-59. USDA, Forest Service, Northeastern Forest Experiment Station. Newtown Square, Pennsylvania.

be calculated for all but the urban forestry carbon sequestration opportunity. In the case of urban forestry, tonnage was calculated by adjusting the results derived above by a factor representing the percentage of tree cover in each of the six counties identified in the first task.[70] The composite factor for the six counties was calculated to be 34.9 percent. Total tonnage estimated by forest type and by type of opportunity for carbon sequestration is shown in Table 6.

Table 6. Amount of Carbon Sequestration by Forest Type and by Type of Opportunity for Carbon Sequestration (tons)

Forest Type	good mgt. /private land	good mgt./public land	afforest/reforest/SRWC	Atl. white-cedar rest.	urban forestry
loblolly/shortleaf pine	22,477,952	9,210,420	1,320,954	0	0
oak/pine	12,101,728	4,958,726	711,178	0	0
oak/hickory	49,230,394	20,172,328	2,893,106	0	17,494,793
oak/gum/cypress	3,651,,615	1,496,262	214,593	4,522,683	0
elm/ash/red maple	7,898,317	3,236,363	464,158	0	2,806,791
northern hardwoods	10,641,309	4,360,314	625,354	0	3,781,556
aspen/birch	81,621	33,445	4,797	0	0
total	106,082,937	43,467,858	6,234,140	4,522,683	24,083,141

The total amount of carbon that could be sequestered in all types of opportunities in Table 6 exceeds 184 million tons. This total represents the equivalent of nearly 677 million tons of CO_2 emission credits. Recent estimates of the market value of CO_2 emission credits range from two to five dollars per ton.[71] At two dollars per ton, the total value of all these CO_2 emission credits is greater than 1.35 billion dollars.

As reported for the second task, CO_2 emission credits are defined by restrictions on their supply as articulated by State or Federal rules or regulations or by international agreement. Likewise, the market for selling CO_2 emission credits is far from mature; State and Federal policy has not been made that unambiguously defines the commodity. For these reasons, the potential for carbon sequestration opportunities identified above currently remains largely unrealizable at this time. However, under the current rules reflecting the Kyoto Protocol and subsequent Conferences of Parties, the afforestation/reforestation/short-rotation woody crop, the Atlantic white-cedar restoration, and the urban forestry opportunities where forests may qualify for carbon sequestration projects generating saleable CO_2 emission credits.

070 Dwyer, John F., David J. Nowak, Mary Heather Noble, and Susan M. Sisinni. 2000. Connecting People with Ecosystems in the 21st Century: An Assessment of Our Nation's Urban Forests. USDA, Forest Service. Table 42, p. 175.

071 Personal communication with Dr. Greg Ruark, Director of the National Agroforestry Center in Lincoln, Nebraska. 9 October 2003.

The near-term potential for carbon sequestration projects generating saleable CO_2 emission credits is still considerable. Urban forestry projects on could sequester 24,083,141 tons of carbon generating 88,385,126 tons of emission offsets worth as much as $176,770,252. This figure does not include the benefit of the other environmental services, such as cleaner air resulting in lower health costs or cooler temperatures resulting in reduced power bills. Afforestation/reforestation/short-rotation woody crop projects on 58,655 acres could sequester 6,234,140 tons of carbon generating 22,879,292 tons of emission offsets worth as much as $45,758,584. Atlantic white-cedar restoration projects on 42,500 acres could sequester 4,522,683 tons of carbon generating 16,598,247 tons of emission offsets worth as much as $33,196,493.

This translates into revenues of nearly $800 per acre for afforestation/reforestation/short-rotation woody crop projects and for Atlantic white-cedar restoration projects. Please note this is a gross amount not discounted for the cost of doing business or for the timing of payment(s). On the other hand, the cost of replanting a moderately large tract of mostly flat and mostly open land (existing vegetation may include grasses, forbs, and woody shrubs) in New Jersey may total as much as $350 per acre, including the costs of chemical and mechanical site preparation, tree seedlings, and planting.[72] Thus, the revenues from the sale of CO_2 emission credits are as much as twice the cost of re-establishing forest on forestland, more so if the cost of replanting is reduced through the Forest Land Enhancement Program or other conservation programs.

The carbon sequestration programs discussed in this report can help promote sustainable rural development in New Jersey. The revenues forecast here from sale of CO_2 emission credits will encourage forestland owners to restore and manage healthy sustainable forest ecosystems by providing both additional options for good forest management and substantial economic benefits. Secondarily, this program also can help (1) anticipate and respond to societal changes resulting from the increasing perception of the looming threat posed by global warming and (2) influence the public's perception of the increased value of utilizing natural resources without compromising forest ecosystem health and sustainability.

072 Personal communication with Mr. John Benton, New Jersey Forest Service, 20 October 2003.

Appendix — Annotated Bibliography of Sources and Citations

The sources of information and specific literature citations, where appropriate, are listed by organization in what follows. The description of each of the following organizations is excerpted, in whole or in part, from source material provided by that organization, either printed materials or internet content. The author of this report gratefully recognizes and acknowledges the sources of this material.

U. S. Department of Agriculture

Cooperative State Research, Education, and Extension Service – *Sustainable Agriculture Research and Education Program* is a U. S. Department of Agriculture-funded initiative that sponsors competitive grants for sustainable agriculture research and education in a regional process nationwide. SARE works to increase knowledge about—and help farmers and ranchers adopt—practices that are economically viable, environmentally sound and socially responsible. To advance such knowledge nationwide, SARE administers a competitive grants program first funded by Congress in 1988.[73]

Farm Service Agency – *Conservation Reserve Program* provides annual rental payments and cost-share assistance for planting permanent vegetation on your idle, highly erodible farmland. (www.fsa.usda.gov/dafp/cepd/crp.htm) *Continuous Conservation Reserve Program* focuses on protecting environmental sensitive land, including wetlands and riparian areas. *Conservation Reserve Enhancement Program* provides incentive payments for installing specific conservation practices. Through the CREP, farmers can receive annual rental payments and cost-share assistance to establish long-term, resource conserving covers on eligible land.[74]

Forest Service – *The Forest Land Enhancement Program* (FLEP) was part of Title VIII of the 2002 Farm Bill. FLEP replaces the Stewardship Incentives Program and the Forestry Incentives Program. FLEP is optional in each State and is a voluntary program for non-industrial private forest landowners. It provides for technical, educational, and cost-share assistance to promote sustainability of the NIPF forests. Specific targeted activities include: (1) the establishment, management, maintenance, and restoration of forests for shelterbelts, windbreaks, aesthetic quality, and other conservation services; (2) the restoration, use, and enhancement of forest wetland and riparian areas and the protection of water quality and watersheds through, among other practices, planting of trees in riparian areas; and (3) the establishment, management, maintenance, and restoration of forests for energy conservation and carbon sequestration.[75]

National Agroforestry Center – The USDA National Agroforestry Center (www.unl.edu/nac) conducts research on how to design and install forested buffers to protect water quality and develops and delivers technology on a broad suite of agroforestry practices to natural resource professionals who directly assist landowners and communities. In this capacity, the NAC promotes agroforestry practices many of which may include carbon sequestration.[76]

Stuhr, Kimberly (ed.). 2003. *Incentives for Agroforestry—2002 Farm Bill.* Inside Agroforestry. Winter 2003 Edition. Lincoln, Nebraska.

073 www.sare.org/htdocs/docs/SANandSARE.html
074 www.fsa.usda.gov/dafp/cepd/crep.htm
075 Stuhr, Kimberly (ed.). 2003. FLEP Overview—New Program Gives NIPF Owners Boost. from *Inside Agroforestry*. Quarterly published by the USDA National Agroforestry Center. Winter 2003. p. 1.
076 www.unl.edu/nac/aboutnacreshtml

Natural Resources Conservation Service – *Environmental Quality Incentives Program* provides a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement structural and management practices on eligible agricultural land.[77]

Wetland Reserve Program assists landowners in protecting, restoring, and enhancing wetlands on their property. The NRCS provides technical and financial support to help landowners with their wetland restoration efforts. The NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection.[78]

Conservation Security Program, established in the 2002 Farm Bill, is designed to provide payments to producers for adopting or maintaining a wide range of management, vegetative, and land-based structural practices that address one or more resources of concem, such as soil, water, or wildlife habitat. Cropland, grazing land, and forestland that is an incidental part of agricultural operation is eligible for the CSP program.[79]

anon. undated. Growing Carbon: A New Crop that Helps Agricultural Producers and the Climate Too. USDA Natural Resources Conservation Service. Washington, D. C.

U. S. Global Change Research Center

The U.S. Global Change Research Program (USGCRP) supports research on the interactions of natural and human-induced changes in the global environment and their implications for society. The USGCRP began as a presidential initiative in 1989 and was codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), which mandates development of a coordinated interagency research program. Participants in the USGCRP include the Departments of Agriculture, Commerce (National Oceanic and Atmospheric Administration), Defense, Energy, Health and Human Services, Interior (U.S. Geological Survey), State, and Transportation; the U.S. Environmental Protection Agency; the National Aeronautics and Space Administration; the National Science Foundation; and the Smithsonian Institution.[80]

The **Department of Agriculture** sponsored research continues to support long-term studies to improve our understanding of the roles that terrestrial systems play in influencing climate change and the potential effects of global change (including water balance, atmospheric deposition, vegetative quality, and UV-B radiation) on food, fiber, and forestry production in agricultural, forest, and range ecosystems. Research currently is being undertaken by the Agricultural Research Service, the Cooperative State Research, Education, and Extension Service, the Economic Research Service, the Forest Service, and the Natural Resources Conservation Service.[81]

Northern Global Change Research Program – The objectives of the Northern Global Change Program (www.fs.fed.us/ne/global/index.html) are to understand: (1) what processes in forest ecosystems are sensitive to physical and chemical changes in the atmosphere, (2) how future physical and chemical climate changes will influence the structure, function, and productivity of forest and related ecosystems, and to what extent forest ecosystems will change in response to atmospheric changes, and (3) what are the im-

077 www.nrcs.usda.gov/programs/eqip
078 www.nrcs.usda.gov/programs/wrp
079 Stuhr, Kimberly (ed.). 2003. *op. cit.* p. 7.
080 www.usgcrp.gov/usgcrp/about/default.htm
081 www.usgcrp.gov/usgcrp/agencies/usda.htm

plications for forest management and how must forest management activities be altered to sustain forest productivity, health, and diversity.[82]

Birdsey, R. A., and L. S. Heath. 2001. Forest Inventory Data, Models, and Assumptions for Monitoring Carbon Flux. USDA Forest Service. Newtown Square, Pennsylvania.

Hoover, Coeli M.; Richard A. Birdsey; Linda S. Heath; and Susan L. Stout. 2000. How to Estimate Carbon Sequestration on Small Forest Tracks. Journal of Forestry, September 2000, pp. 13 – 19.

Alig, Ralph J.; Karen J. Lee; and Robert J. Moulton. 1990. Likelihood of Timber Management on Nonindustrial Private Forests: Evidence from Research Sites. General Technical ReportSE-60. Southeastern Forest Experiment Station. Asheville, North Carolina.

The **Department of Commerce,** National Oceanographic and Atmospheric Administration's long-term global change efforts are designed to develop a predictive understanding of the variability and change of the global climate system, and to advance the application of this information in climate-sensitive sectors through a suite of process research, observations and modeling, and application and assessment activities.[83]

The **Department of Defense** does not support dedicated global change research, but continues a history of participation in the USGCRP through sponsored research that concurrently satisfies National Security requirements and stated Goals of the USGCRP.[84]

Research supported by the Office of Biological and Environmental Research, **Department of Energy,** is focused on the effects of energy production and use on the global Earth system, primarily through studies of climate response. Research includes climate modeling, atmospheric transport and chemistry, atmospheric properties and processes affecting the Earth's radiation balance, and sources and sinks of energy-related greenhouse gases (primarily CO_2). It also includes research on consequences of climatic and atmospheric changes on ecological systems and resources, and the development of improved methods and models for conducting integrated economic and environmental assessments of climate change and of options for mitigating climate change, and education and training of scientists for climate change research.[85]

The four National Institutes of Health, **Department of Health and Human Services,** institutes support research on the health effects of UV and near-UV radiation.[86]

Research at the U. S. Geological Survey, **Department of the Interior,** examines terrestrial and marine processes and the natural history of global change, including the interactions between climate and the hydrologic system. Studies seek to understand the character of past and present environments and the geological, biological, hydrological, and geochemical processes involved in environmental change.[87]

The Global Change Research Program, **Environmental Protection Agency,** is an assessment-oriented program with primary emphasis on understanding the potential consequences of climate variability and change on human health, ecosystems, and socioeconomic systems in the United States. This entails (1) improving the scientific basis for evaluating effects of global change in the context of other stressors and human dimensions (as humans are catalysts of and respond to global change); (2) conducting as-

082 www.fs.fed.us/ne/global/fsgcrp/index.html
083 www.usgcrp.gov/usgcrp/agencies/noaa.htm
084 www.usgcrp.gov/usgcrp/agencies/defense.htm
085 www.usgcrp.gov/usgcrp/agencies/doe.htm
086 www.usgcrp.gov/usgcrp/agencies/nih.htm
087 www.usgcrp.gov/usgcrp/agencies/interior.htm

sessments of the risks and opportunities presented by global change; and (3) assessing adaptation options to increase resiliency to change and improve society's ability to effectively respond to the risks and opportunities presented by global change.[88]

The mission of Earth Science Enterprise, **National Aeronautics and Space Administration,** is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.[89]

National Science Foundation programs address global change issues through investments in challenging ideas, creative people, and effective tools. In particular, NSF global change research programs support research and related activities to advance the fundamental understanding of physical, chemical, biological, and human systems and the interactions among them.[90]

Within the **Smithsonian Institution,** global change research is organized around themes of atmospheric processes, ecosystem dynamics, observing natural and anthropogenic environmental change on daily to decadal time scales, and defining longer-term climate proxies present in the historical artifacts and records of the museums as well as in the geologic record at field sites.[91]

New Jersey

Department of Agriculture/NJ Division of Taxation – The Farmland Assessment Act of 1964 was amended in 1986, requiring some forestland owners to develop and implement a state-approved forest management plan to qualify for reduced property taxation. Under the amended act, forestland owners must fulfill special requirements concerning property used exclusively for the production and sale of forest products, excluding Christmas trees. Some forestland owners are eligible for reduced property taxes if they follow a state approved forestry plan.[92]

anon. 2001. New Jersey's Farmland Assessment Act – A Primer on Basic Requirements. New Jersey Department of Agriculture. Trenton, New Jersey.

Department of Environmental Projection (DEP), Forest Service – The Forest Service supports the New Jersey Sustainability Greenhouse Gas Action Plan and research, such as the Carbon Sequestration Demonstration Project underway at the Forest Resource Education Center located near Jackson, New Jersey, and this project.[93]

DEP, Office of Innovative Technology and Market Development – Greenhouse Gas Action Plan – The New Jersey Sustainability Greenhouse Gas Action Plan identifies the major sources of GHGs by source and sector in 1990 and it identifies "no regrets" strategies that will achieve the State's 3.5% reduction in New Jersey's GHG emissions below 1990 levels by 2005.[94]

DEP, Division of Watershed Management – The goals of the Watershed Management Program are comprehensive water resource management on a watershed basis to ensure "clean and plentiful water"...and the protection and restoration of the integrity of New Jersey's water resources by preventing,

088 www.usgcrp.gov/usgcrp/agencies/epa.htm
089 www.usgcrp.gov/usgcrp/agencies/nasa.htm
090 www.usgcrp.gov/usgcrp/agencies/nsf.htm
091 www.usgcrp.gov/usgcrp/agencies/smithsonian.htm
092 www.state.nj.us/dep/parksandforests/forest/njfs_farm_assess.html
093 www.state.nj.us/dep/parksandforests/forest/index.html
094 www.state.nj.us/dep/dsr/oitmd/OITMD.htm

abating and controlling water pollution....[95] These goals explicitly include restoration , which includes funding for restoring or re-establishing riparian buffers.

Other State Governments

Northeast Regional Biomass Program is managed through a cooperative agreement between the U. S. Department of Energy, Boston Regional Office, and the Coalition of Northeastern Governors Policy Research Center.[96]

Irland, Lloyd C., and Mike Cline. 1998. Role of Northeastern Forests and Wood Products in Carbon Sequestration. CONEG Policy Research Center, Incorporated. Washington D. C.

Minnesota – The *Releaf Program* promotes and funds the planting, maintenance, and improvement of trees in the state to reduce atmospheric CO_2 levels.[97]

Nebraska – Nebraska has created a *Carbon Sequestration Advisory Committee* to investigate the possibility of sequestering carbon in the state through modified agricultural methods.[98]

New Mexico – *Forest Re-Leaf* provides grants to public entities such as schools, cities, counties, and rural communities for the purpose of planting trees.[99]

Oregon – The *Forest Resource Trust* program helps landowners establish and manage healthy forests through private agreements with the state.[100]

Nonprofit Organizations

Forest Trends is a coalition of individuals from private, public, and non-profit institutions established to maintain and restore forest ecosystems by promoting incentives that diversify trade in the forest sector, moving beyond exclusive focus on lumber and fiber to a broader range of products and services.[101]

Powell, Ian; Andy White; and Natasha Landell-Mills. 2002. Developing Markets for the Ecosystem Services of Forests. Forest Trends. Washington, D. C.

International Institute for Environment and Development is an independent, non-profit organization promoting sustainable patterns of world development through collaborative research, policy studies, networking and knowledge dissemination.[102]

Landell-Mills, Natasha and Ina T. Porras. March 2002. Silver Bullet or Fools' Gold? – A Global Review of Markets for Forest Environmental Services and Their Impacts on the Poor. Instruments for sustainable private sector forestry series. International Institute for Environment and Development, London.

095 www.state.nj.us/dep/watershedmgt/index.html
096 www.nrbp.org
097 www.dnr.state.mn.us/fad/forestmgmt/releaf.html
098 www.carbon.unl.edu
099 www.emnrd.state.nm.us/forestry/releaf/releaf.cfm
100 www.odf.state.or.us/DIVISIONS/management/forestry_assistance/trust
101 www.forest-trends.org
102 www.iied.org

Pew Center on Global Climate Change is a non-profit, non-partisan and independent organization dedicated to providing credible information, straight answers and innovative solutions in the effort to address global climate change.[103]

Ellerman, A. Denny and David Harrison, Jr. 2003. Emissions Trading in the U. S. – Experience, lessons, and considerations for Greenhouse Gases. Pew Center on Global Climate Change, Arlington, Virginia.

Rabe, Barry C. 2002. Greenhouse & Statehouse: The Evolving State Government Role in Climate Change. Pew Center on Global Climate Change, Arlington, Virginia.

Searchable Database: State and Local Net Greenhouse Gas Emissions Reduction Programs.

Winrock International Institute is a global team dedicated to increasing long-term productivity, equity, and responsible resource management.[104]

Brown, Sandra. 2001. Measuring Carbon in Forests: current status and future challenges. Winrock International Institute, Arlington, Virginia.

MacDicken, K. G. 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Forest Carbon Monitoring Program, Winrock International Institute, Morrilton, Arkansas.

Rombold, John. 1996. A bibliography on Carbon Sequestration and Biomass Estimation. Working Paper 96/03. Forest Carbon Monitoring Program, Winrock International Institute, Morrilton, Arkansas.

The Utilitree Carbon Company is a nonprofit company administered by the Edison Electric Institute at the behest of forty utility companies throughout the United States. Utilitree Carbon Company "sponsors a portfolio of forestry projects that manage greenhouse gases, particularly carbon dioxide (CO_2)."[105]

World Resources Institute is a is an environmental think tank that goes beyond research to find practical ways to protect the earth and improve people's lives.[106]

Brown, Paige; Bruce Cabarle; and Robert Livernash. 1997. Carbon Counts: Estimating Climate Change Mitigation in Forestry Projects. World Resources Institute, Washington, D. C.

Totten, Michael. 1999. Getting It Right: Emerging Markets for Storing Carbon in Forests. World Resources Institute, Washington, D. C. (published jointly by WRI and Forest Trends)

Trexler, Mack C. 1991. Minding the Carbon Store: Weighing U. S. Forestry Strategies to Slow Global Warming. World Resources Institute, Washington, D. C.

Private Industry – Companies Specializing in Carbon Sequestration Projects

American EnviroTech, Incorporated, of Edward, Mississippi, assists landowners with managing environmental assets of their land, particularly pursuing the sale of carbon sequestration credits.[107]

National Carbon Offset Coalition an expansion of the Montana Carbon Coalition, seeks to identify and develop forestry projects to generate a portfolio carbon dioxide emission credits. Until recently most of

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103 www.pewclimate.org
104 www.winrock.org
105 www.eei.org/issues/enviro/g_climate/utilitree.pdf
106 www.wri.org
107 www.deltabusinessjournal.com/2003_Archives/June/June-newcompany.php

this organization's projects were located in Montana, although recently NCOC has been developing projects in Idaho and Texas.[108]

Sampson, Neil. 2002. Project Planning Handbook: Forestry Projects to create Carbon Sequestration Units (CSU's). The Sampson Group. Alexandria, Virginia.

Private Industry – Carbon Sequestration Project Development Companies

C*Trade is an international developer of Carbon Trade Credits for renewable energy projects that offset the use of fossil fuels, such as solar, wind turbines, energy efficiency, forest carbon sequestration and waste-to-energy power plants. C*TRADE provides design, monitoring, verification and third party certification services for marketable carbon emission offsets that can be potentially traded like a commodity or banked for future sale or trade pursuant to CDM policies and procedures developed under the Kyoto Protocol.[109]

Environmental Synergy Incorporated of Atlanta, Georgia, is an ecology based consultancy providing reforestation, to date principally bottomland hardwoods in the southeastern United States, and carbon quantification services to corporate clients as a means to offset carbon dioxide (CO2) emissions and promote sustainable forestry.[110]

Forest Securities, Incorporated's core business operations involve forest resource management, evaluation and sequestration of forest carbon, and distribution channel strategies for banking and marketing of environmental assets. FSI has the ability to package the biophysical characteristics of a forest into secured and negotiable products through measurement, verification, and contractual procedures, thus structuring the forest as an environmental capital asset.[111]

Private Industry – Carbon Emissions Offset Brokers and Traders

Canter Environmental Brokerage of Houston, Texas, is a subsidiary of Cantor Fitzgerald that is a brokerage that offers consulting and environmental credit trading services.[112]

CO2e.com of Toronto, Canada, delivers market-based solutions to help companies address climate change issues: (1) brokerage services related to greenhouse gases, renewable energy and other environmental products; (2) the sourcing and delivery of emission offsets with strong sustainability attributes for retirement against today's emissions; (3) financial structuring of wholesale and retail instruments for tax effectiveness and improved risk management; (4) marketplace development, trading and risk management software, delivered together with eSpeed, Incorporated; and (5) helping clients to deal with carbon commerce through appropriate strategy development, analysis, verification, legal, accounting, insurance and other professional services delivered by $CO2e^{SM}$ Associate partners.[113]

Environmental Financial Products of Chicago, Illinois, specializes in developing and trading in new environmental, financial, and commodity markets, including those for carbon dioxide emission offsets.[114]

Evolution Markets of White Plains, New York, is a brokerage firm that has been at the forefront of global greenhouse gas emissions market development, facilitating trades that have met some of the market's

108 www.nationalcarbonoffsetcoalition.org
109 www.ctrade.org
110 www.environmental-synergy.com
111 www.forestsecurities.com
112 www.emissionstrading.com
113 www.co2e.com
114 www.envifi.com

most important milestones - including the first trade of Assigned Amount Units under the Kyoto Protocol's "International Emissions Trading" program.[115]

Natsource, located in New York City and none other cities across the world, provides brokerage and advisory services for natural gas, coal, and electricity, as well as weather hedging and environmental issues, including greenhouse gases.[116]

Private Industry – Exchanges

Chicago Climate Exchange is a self-regulatory exchange that administers the world's first multi-national and multi-sector marketplace for reducing and trading greenhouse gas emissions. and multi-sector marketplace for reducing and trading greenhouse gas emissions.[117]

Private Industry – Consultants, Advisors, and Other Providers of Ancillary Services

CarbonVentures International, a subsidiary of ENVIRON Holdings, Inc., delivers clients a full range of services related to climate change and greenhouse gas emissions management.[118]

EcoSecurities Limited is an established environmental finance company which specializes in advising on strategy regarding global warming issues. EcoSecurities offers unique expertise in the emerging market of greenhouse gases, renewable energy and sustainable forestry.[119]

Costa, Pedro Moura. 2000. Carbon Accounting Methods. EcoSecurities Limited. Oxford, England.

Costa, Pedro Moura. 2000. Carbon Accounting Versus Project Financing. EcoSecurities Limited. Oxford, England.

Costa, Pedro Moura. 2000. Project Duration and Accounting Methods. Unpublished Manuscript. EcoSecurities Limited. Oxford, England.

Costa, Pedro Moura. undated. Carbon Accounting, Trading and the Temporary Nature of Carbon Storage. EcoSecurities Limited. Oxford, England.

Ecological Solutions Incorporated of Sherwood Park, Alberta, Canada, provides forestry-based services for both buyers and sellers of carbon emission offsets. Develops carbon sequestration projects, including GHG transaction agreements.[120]

The Sampson Group of Alexandria, Virginia, are forestry consultants that specialize, among other areas, in carbon sequestration. Available reports include: Carbon Sequestration—What's the Best Approach (2000); Agroforestry as a Carbon Sink (2001); Forestry and Carbon Sequestration (2002); and Monitoring and Measuring Wood Carbon (2002).[121]

Trexler and Associates, Incorporated is a consultancy and an internationally recognized leader in the emerging field of climate change risk management and in identifying and implementing greenhouse gas emissions reduction and offset strategies.[122]

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115 www.evomarkets.com
116 www.natsource.com
117 www.chicagoclimatex.com
118 www.carbonventures.com
119 www.ecosecurities.com
120 www.compusmart.ab.ca/ecosync
121 www.sampsongroup.com
122 www.climateservices.com

Woodrising Consulting Incorporated of Belfountain, Ontario, Canada , specializes in Greenhouse Gas Emission Management. They have developed expertise specifically in the areas of carbon sequestration from land use, land-use change and forestry activities, and landfill gas generation and capture.[123]

anon. 2001. The Woodlot Manager's Guide to Carbon Sequestration and Greenhouse Gas Benefits. Published by Ontario Ministry of Environment and Ministry of Natural Resources. Toronto, Canada.

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Adams, Darius M.; Ralph J. Alig; Bruce A. McCarl; J. M. Callaway; and Steven M. Winnett. 1999. Minimum Cost Strategies for Sequestering Carbon in Forests. (ageco.tamu.edu/faculty/mccarl/)

Bonnie, Robert. 2001. Carbon Sequestration and Emission Trading: Confronting Climate Change While Creating Incentives for Improved Land Management. Testimony before United States Senate Subcommittee on Science Technology, and Space of the Senate Committee on Commerce, Science, and Transportation.

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