EM Feature

Carbon Trading and Sequestration Projects Offer Global Warming Solutions

Nations respond to global warming with successful carbon sequestration projects and international carbon trading programs designed to reduce greenhouse gas emissions. **by Prabhu Dayal**

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Scientists predict the earth's climate is changing because human activities are altering the chemical composition of the atmosphere. In particular, the buildup of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) is changing the radiation balance of the planet. The greenhouse effect occurs when concentrations of GHGs in the earth's atmosphere prevent energy generated by the sun from escaping back into space. Heat is trapped close to the earth's surface, contributing to the rise in global temperature (Figure 1). According to temperature records, the past decade has been the warmest this past century (Figure 2). These trends may be evidence of global warming, which, in addition to temperature changes, can trigger destructive changes in precipitation, soil moisture, and sea level.

OVERVIEW OF THE KYOTO PROTOCOL

In December 1997, the United States and more than 160 countries participating in the Framework Convention on Climate Change adopted the Kyoto Protocol for reducing GHG emissions. The agreement requires each industrialized country ratifying the treaty to reduce its emissions of six GHGs by the period 2008–2012 to a specified level relative to 1990 emissions. The agreement covers CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. If the Kyoto Protocol is ratified by the Senate, the United States will be committed to reduce GHG emissions to a level that is 7% below 1990 emissions by the period 2008–2012. Japan and Canada each pledged a 6% reduction by this period. The agreement will become binding following ratification by at least 55 countries, accounting for at least 55% of the 1990 CO_2 emissions of industrialized countries.

PROJECTION OF U.S. CARBON EMISSIONS

The combustion of fossil fuels such as coal, natural gas, oil, and gasoline emits large quantities of CO_2 (Figure 3). The House Committee on Science has

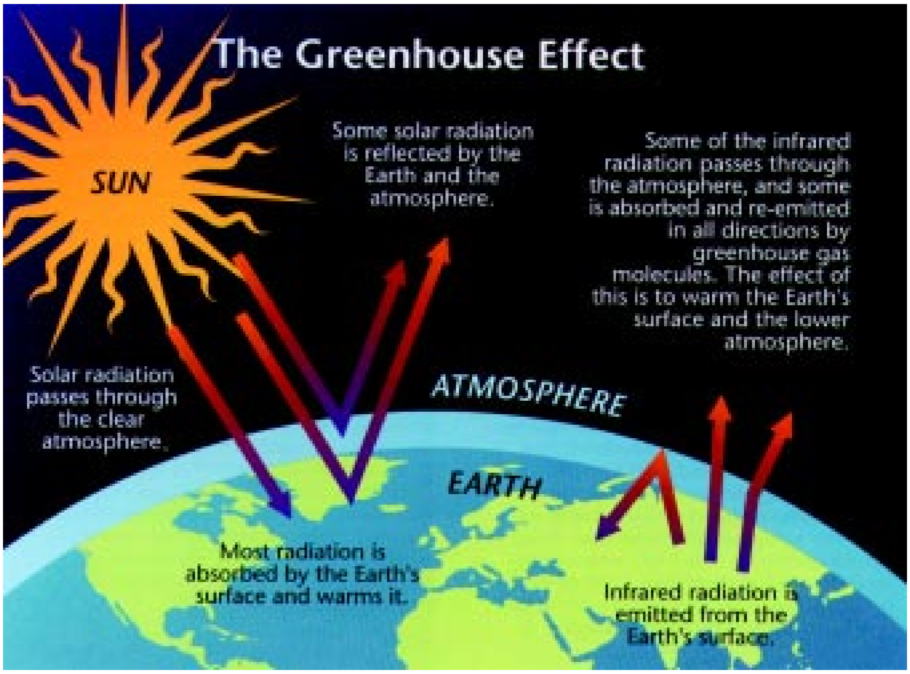

Figure 1. The greenhouse effect naturally warms the earth's surface. Without it, the earth would be 60 °F cooler than it is today—uninhabitable for life as we know it. *Source:* Office of Science and Technology Policy.

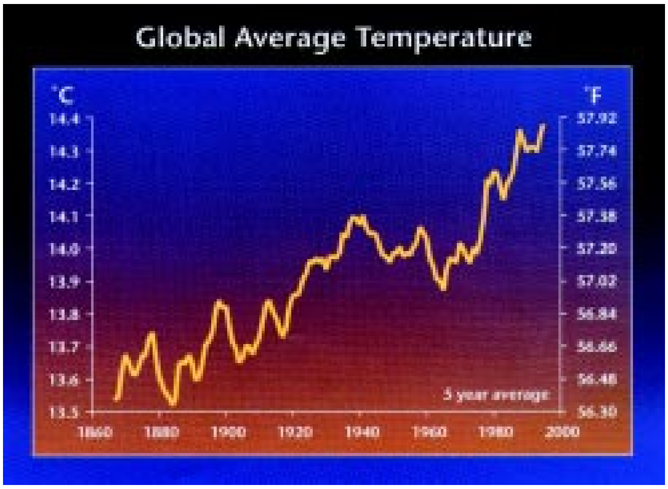

Figure 2. The global average temperature has risen by about 1 °F over the last century. *Source:* Office of Science and Technology Policy.

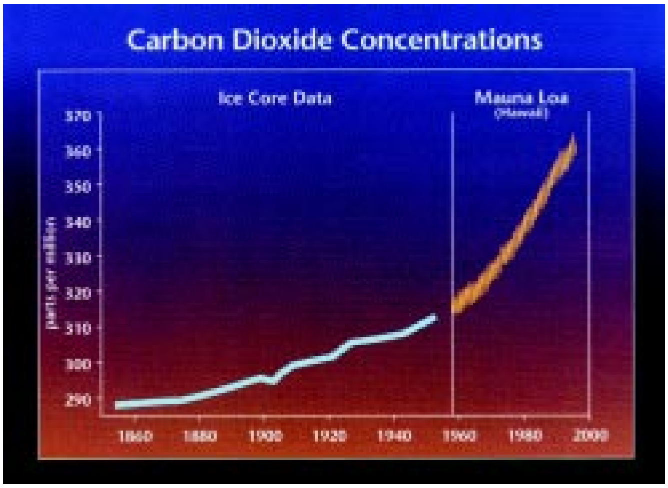

Figure 3. Since the beginning of the Industrial Revolution in the middle of the 19th century, the concentration of CO_2 in the atmosphere has steadily increased. Beginning in 1957, continual measurements of atmospheric CO_2 concentrations have been made by scientists at an observatory in Mauna Loa, HI. The seasonal cycle of vegetation in northern latitudes can be seen in this record: each spring the vegetation "inhales" and absorbs CO_2, and each autumn most of that CO_2 is released into the atmosphere. *Source:* Office of Science and Technology Policy.

charged the Energy Information Administration (EIA) with analyzing the Kyoto Protocol, "focusing on U.S. energy use and prices and the economy in the 2008–2012 time frame." Mary Hutzler of the U.S. Department of Energy summarized the findings of this report at the 1999 EUEC. EIA forecast a 22% increase in carbon emissions, or about 328 million metric tons, in the United States between now and 2010. During the same period, the energy efficiency of new equipment is expected to improve in all sectors of the United States. Between 1996 and 2020, energy efficiency—as measured by the amount of energy consumed per dollar of gross national product in the U.S. economy—is projected to improve by 21%.

In addition to reflecting efficiency improvements in all sectors of the energy economy, this trend will demonstrate the projected continuing shift toward less energy-intensive industries in the United States. In the transportation sector, the average miles per gallon for new cars is expected to improve by 12%, while aircraft and rail efficiency are projected to improve by 17% and 13%, respectively. In the power generation sector, the average fossil fuel heat rate is expected to decrease by 13%, from roughly 10,400 to 9060 Btu per kilowatt-hour. While these improvements in energy efficiency will help reduce some of the expected increases in carbon emissions, economic growth combined with increased dependence on fossil fuels more than offsets the efficiency improvement. The net result of these conflicting trends is that U.S. carbon emissions are projected to increase 33%, or 445 million metric tons above the 1990 level, in 2010. The Kyoto Protocol, if ratified, would require the United States to reduce its GHG emissions approximately 43%, or 539 million metric tons per year, to meet the target of 7% below 1990 levels by 2010.[1]

IMPACTS OF THE KYOTO PROTOCOL ON A TYPICAL ELECTRIC UTILITY

Consider a hypothetical 15,000-MW capacity electric utility with a fuel mix for generation of 80% coal, 5% oil/natural gas, 5% renewables, 5% purchased power, and 5% nuclear. The electricity demand growth rate is assumed to be 2% per year. The impacts of CO_2 emission reductions required under the Kyoto Protocol are illustrated in Figure 4. An average reduction of about 8 million tons of CO_2 per year is projected for this utility between 2008 and 2012.

Switching from coal to natural gas in boilers could reduce CO_2 emissions by more than 40%. This "in-system" option can achieve a quantity of reductions sufficient to return to 1990 levels. However, it is also a relatively expensive option. Approximately 20 MMBtu of gas must be substituted for subbituminous coal to reduce CO_2 emissions by 1 ton. If the natural gas cost is $.40 per MMBtu higher than coal on a delivered basis, then the CO_2 reduction costs about $8 per ton. For some energy companies, higher coal-to-gas price differentials would lead to CO_2 reduction costs of $20 per ton or more. In either case, with a requirement for GHG emission reductions, the higher demand for natural gas would likely drive up market prices, thereby increasing the price per ton of CO_2 reduction cost, compared to current levels.[2]

Sponsoring customer conservation and demand-side management (DSM) programs could offer some relatively low-cost reductions in generation and emissions—many at a cost of less than $10 per ton of CO_2. However, CO_2 reductions from DSM are relatively limited—usually only a few percent of the total load. Some energy companies have used CH_4 emissions from landfills for energy recovery in boilers. The repair or

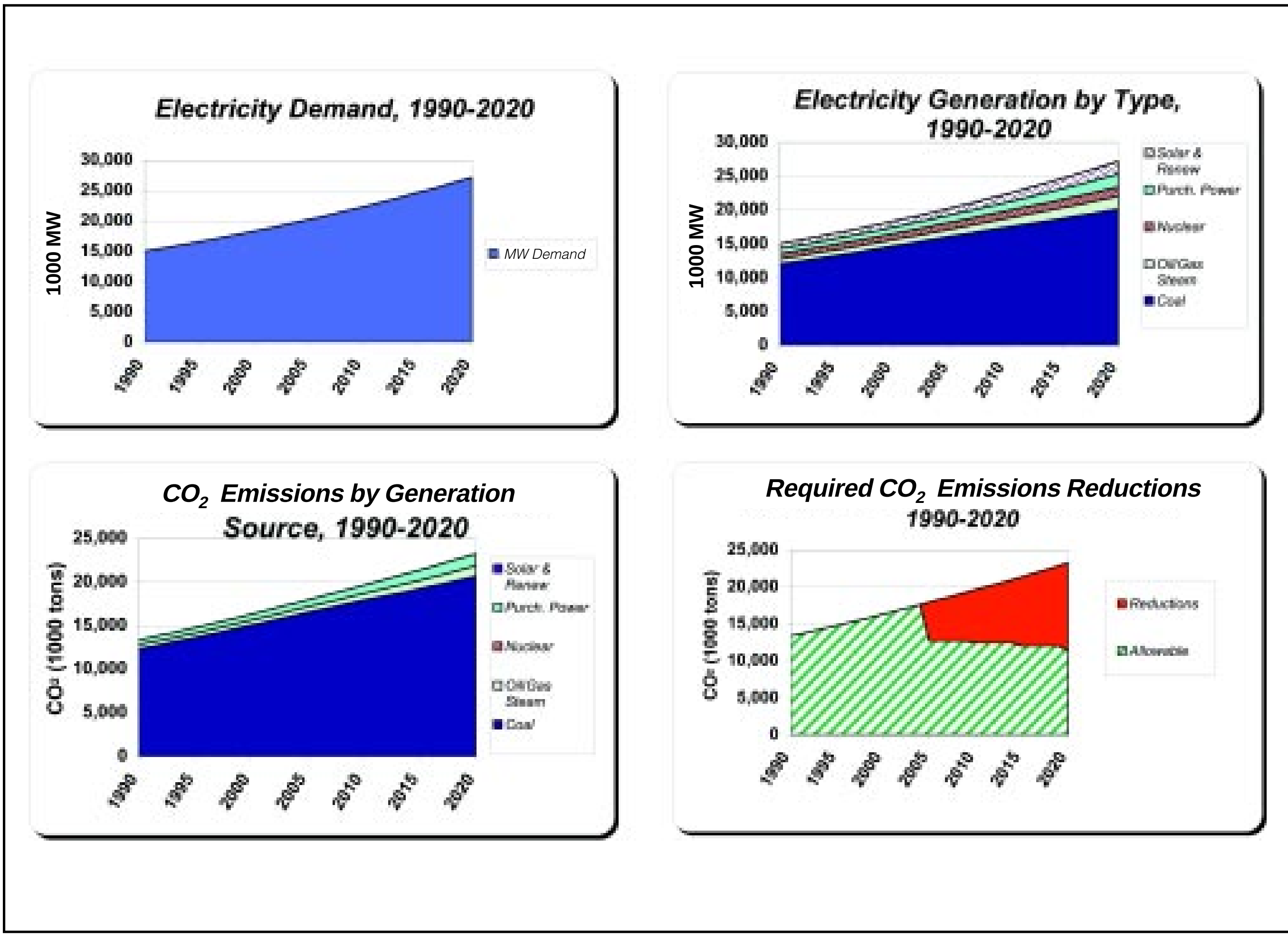

Figure 4. GHG emission trends and implications of the Kyoto Protocol for a 15,000-MW electric utility, 1990–2020.

replacement of leaky equipment containing SF_6 can provide GHG reductions as well.[2] Hence, in the absence of other technological options, this hypothetical utility may be forced to rely on potentially expensive approaches to achieve the 8 million tons of CO_2 reductions per year for the years 2008–2012 proposed by the Kyoto Protocol.

OPTIONS TO REDUCE GHGs

Typical fossil fuel-dependent electric utilities that could be affected by the Kyoto Protocol have various options to reduce GHG emissions. Direct reduction of emissions from domestic sources can be accomplished via fuel switching, reducing off-system sales, reducing native load, and improving efficiency. Alternatively, utilities could reduce emissions using offsets, or engage in international trading.

Offsets to reduce GHGs include carbon sequestration; reducing CH_4 emissions from landfills, coal mines, and feedlots; and cogeneration. Carbon sequestration via forestry activities is one method of using offsets to achieve CO_2 reductions. International offsets include low-cost opportunities to reduce CO_2 in other countries. However, there are risks with any of these offset projects: the need for certification, credible monitoring, verification, and meeting future regulatory requirements.

Acting early to reduce GHG emissions has potential benefits and risks. Some analyses of future national impacts of GHG limits indicate an implied CO_2 price that exceeds $20 per ton in 2010. Because of time discounting, policy uncertainty, and limited current demand for offsets, CO_2 offsets can be acquired today for roughly $1 per ton. If viewed either as an insurance policy or an investment in future commodity prices, acting early to secure GHG reductions may be lucrative. Of course, the downside is the risk inherent in the uncertain outcome of ongoing development of the international GHG reduction requirements and trading processes.

MANAGING CO_2 VIA FORESTRY/CARBON SEQUESTRATION

Kinsman and Smith defined "sequestration" as the natural biogenic process where atmospheric CO_2 is removed and stored by trees or other plants, which are referred to as "carbon sinks."[3] About one-half of the dry weight of a tree is carbon. When an emissions source manages its emissions indirectly by effecting a reduction at another source, or enhancing a sink, it is "offsetting" its emissions. CO_2 is long-lived in the atmosphere, mixes globally, and can be offset anywhere in the world. Many different options can provide cost-effective management for GHG reductions, including trading as "offsets."[3]

The potential for managing carbon levels through forestry is significant. The Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report found that during the period 1995–2050, slowing deforestation, promoting natural forest regeneration, and encouraging global reforestation could offset 220–320 billion tons of CO_2 (12–15%) of fossil emissions (Figure 5). Carbon sequestration may be accomplished through forest preservation to reduce deforestation; forest management techniques to enhance existing carbon sinks; creating new carbon sinks by planting on pasture, agricultural land, or degraded forest sites; and storing carbon in wood products.[3]

Kinsman and Smith have detailed the significant benefits of energy company participation in forest carbon management projects.[3] U.S. energy companies have recently initiated various forestry projects specifically designed to conserve energy and offset CO_2 emissions. A single properly managed project can offset millions of tons of carbon emissions. Forestry projects may provide cost-effective options that cost only a few dollars per ton of CO_2 offset, compared to $20 per ton for other options. Forestry carbon management projects add diversification in a portfolio of GHG reduction projects. Forestry options to manage CO_2 are well received by the public and environmental groups. They have positive secondary environmental benefits, such as restoration of degraded lands and protection of biodiversity, as well as social benefits, such as employing indigenous people through tree planting programs.

EXAMPLES OF CARBON SEQUESTRATION PROJECTS

A variety of projects are being developed to sequester carbon and to research the feasibility of such projects. Some examples of domestic and international projects follow.

Smithson and Kaster presented a paper on the accomplishments of the UtiliTree Carbon Company, a nonprofit corporation established in 1995 by 40 utilities to sponsor forest carbon management projects with GHG benefits.[4] The current funded projects represent a diverse mix of rural tree planting, forest preservation, forest management, and research efforts at both domestic and international sites. The UtiliTree Carbon Company has committed slightly more than $2.5 million to fund these projects. Carbon dioxide will be managed at a cost of about $1 per ton. More than 2 million tons of CO_2 reductions will result during the life of the projects. All UtiliTree projects include extensive external verification of benefits. Participants will share reporting of CO_2 benefits on a pro rata basis to the voluntary Energy Policy Act section 1605(b) database.

Figure 5. Deforestation worldwide adds 1–2 billion metric tons of carbon to the atmosphere each year. *Source:* Office of Science and Technology Policy.

Williams described UtiliTree's projects to investigate the feasibility of using bottomland hardwood forest restoration on marginal farmland in the Mississippi River Valley as a means of sequestering atmospheric CO_2.[5] More than 2000 acres are being planted at several sites in Louisiana, Mississippi, and Arkansas in conjunction with the U.S. Fish and Wildlife Service, the Louisiana Department of Wildlife and Fisheries, and the School of Forestry at Louisiana Tech University. Hardwood forests will sequester an estimated 600 tons of CO_2 per acre over 70 years. Restoration of bottomland hardwood forests in the Mississippi River Valley will improve depleted wildlife habitats and provide potential economic stimulus for a depressed region by serving as a sustainable source of raw materials for the forest products industry and as a source of recreation revenues.

Kuhn detailed how the partnership between the Nature Conservancy, Programme for Belize, four U.S. energy companies, and UtiliTree reduced CO_2 emissions and increased storage of carbon in standing timber in Belize.[6] The goals of the Rio Bravo Carbon Sequestration Pilot Project in Belize include addressing protection of ecosystems and biodiversity, improving local environmental quality, and creating economic opportunities for local people. The Rio Bravo Conservation and Management Area comprises 104,892 hectares of mixed lowland and moist sub-tropical broadleaf forest in the biologically and culturally significant Mayan forest region of northwest Belize. Carbon sequestration activities occur on approximately 50% of Rio Bravo lands. Rio Bravo is home to endangered animals, contains forest cover types protected nowhere else in Belize, and is under imminent and demonstrable threat of conversion to agriculture.

Experiences with the techniques of reduced-impact logging (RIL) of natural forests was presented by Jones and Dayal.[7] Uncontrolled and destructive logging practices in natural tropical rain forests emit a large amount of CO_2. RIL techniques reduce CO_2 emissions from uncontrolled logging by as much as 50% through precutting vines, directional felling, and planned extraction of timber on properly constructed and utilized skid trails. UtiliTree has funded a RIL project on 2500 acres in Sabah, Malaysia, that is anticipated to reduce CO_2 emissions by 147,000 tons by 2000 and by 379,000 tons over the project's 40-year life. The project will also yield many secondary environmental benefits related to habitat and watershed protection. New England Power Company; Rakyat Berjaya Sdn. Bhd of Malaysia; Forest Research Institute of Malaysia; Sabah Forestry Department; Center of International Forestry Research in Bogor, Indonesia; and Rainforest Alliance collaborate on the project.

Trexler discusses a UtiliTree project conducted by Trexler & Associates to sequester carbon by planting trees on unforested non-industrial timberland in western Oregon that otherwise would not be replanted.[8] Landowners will sign a contract obligating them to plant and maintain various native species for a minimum of 65 years. The project brings a notable sustainable forest management program to a region that contains some of the most productive timberland in the United States. Slightly more than 300 acres of new trees are projected to sequester approximately 200,000 tons of CO_2. The project will yield environmental benefits beyond carbon sequestration, including expanded wildlife habitat, improved water quality through watershed protection, and reduced soil erosion and soil compaction.

Boyd and Chastain presented a paper on forest sequestration through cooperative tree planting.[9] Southern Company has launched a $4.5 million forestry program through which each of its system operating companies developed its own specific program. To date, the overall program has resulted in the planting of more than 16 million trees on almost 20,000 acres of previously open land. Almost 6 million metric tons of CO_2 are projected to be sequestered by 2030. Other benefits of the program include the production of valuable forest products for state industries, the creation of wildlife habitat, and soil stabilization.

Coakley discusses Florida Power & Light Company's (FPL) analysis of vegetative options to sequester CO_2, assessing 18 tree types of upland and fresh water wetland species native to peninsular Florida.[10] The results indicated that FPL could convert 16,957 acres to either pine forests or lowland hardwoods that would cumulatively capture 9.2 million tons of CO_2 in 100 years at a cost of $0.34–$0.68 per ton of CO_2.

Atkin and Dayal have presented a paper discussing techniques of sustainable tropical forestry management in South American countries such as Paraguay and Bolivia.[11] Tropical climates provide fast growth rates and economical land values for the development of sustainable forestry management techniques. High-quality fiber production has the longest shelf life, unlike eucalyptus for paper. The carbon in high-value wood products (e.g., tables, chairs, flooring) does not return to the atmosphere for decades.

Another carbon sequestration forestry project in the Asia-Pacific region is a 600-hectare, RIL project in Indonesia that has the potential to sequester about 50,000 tons of carbon during a 40-year period. More than 25,000 hectares are planned for tropical forest rehabilitation in Sabah, Malaysia. Similar forestry projects that sequester carbon are in various stages of development in Fiji, the Solomon Islands, Papua New Guinea, India, and Vanuatu.[12]

LANDFILL GAS-TO-ENERGY PROJECTS

Methane is a potent GHG with about 21 times the global warming potential of CO_2. Landfills are the largest human-made CH_4 source in the United States. Landfill gas-to-energy (LFGTE) programs are a cost-effective option for reducing GHG emissions, which helps to offset the cost of compliance with certain landfill rules. Other benefits include improved landfill management and economic development in the community. McGuigan presented the benefits of GHG emission reductions from LFGTE projects that have the participation of agencies such as the U.S. Environmental Protection Agency, the Landfill Methane Outreach Program, the U.S.-Asia Environmental Partnership, and the U.S. Agency for International Development.[13]

More than 300 LFGTE projects are currently online in the United States, with the average project producing more than 200,000 tons per year of CO_2 benefit.

More than 300 LFGTE projects are currently online in the United States, with the average project producing more than 200,000 tons per year of CO_2 benefit. For example, a landfill in Pen Argyl, PA, serves as a local energy source, generating approximately 10 MW—equivalent to planting 118,270 acres of trees. Benefits include improved environmental conditions at and around the landfill, more responsible community planning, and community economic development.[13] Counterpart International has established an office in Jakarta, Indonesia, for the development of similar carbon sequestration projects in the countries of eastern Asia. At the Los Reales Landfill in Tucson, AZ, landfill gas that was previously flared is transported by a 3.5-mile pipeline to Tucson Electric Power Company's Irvington Station, displacing 20,000 tons of coal per year. Zahren Alternative Power Corp. owns and operates the project, with an investment of $4 million. The project will result in the sequestration of 9400 tons of CH_4. The city of Tucson owns the 347-acre landfill.[14]

OTHER CARBON OFFSET PROJECTS

Oregon passed a law in 1996 that established CO_2 emission limits for new electricity generators. PacifiCorp is constructing a 500-MW cogeneration facility that will be owned by the city of Klamath Falls, OR. PacifiCorp will manage and operate the plant at 62% efficiency, which is nearly double the efficiency of a typical coal-fired unit. In addition, PacifiCorp has created a $5.5 million CO_2 offset portfolio to provide funds for projects that reduce or sequester GHG emissions. This portfolio will help the facility reduce its CO_2 emissions by more than 30%. More than $1 million of the portfolio will be dedicated to forestation efforts with the Oregon Department of Forestry, including a project to plant 600,000 acres of Douglas fir on under-forested land. PacifiCorp will also join with Oregon-based Northwest Fuels to recover CH_4 from coal mines.[15] Several international energy efficiency and biomass projects have been identified for development in Honduras, Argentina, Belize, Bolivia, Czech Republic, Guatemala, Nicaragua, and the Philippines by the International Utility Efficiency Partnership, an affiliate of the Edison Electric Institute. These projects offer carbon offsets for trade, after the project has been certified by the U.S. Initiative on Joint Implementation (USIJI).[16]

CARBON TRADING

Overview

The Kyoto Protocol provides the following three mechanisms that would allow transfers or crediting of emissions reductions achieved in other countries:

- Developed countries may share emissions credits resulting from joint implementation (JI) of projects that result in net reductions of GHG emissions;
- A clean development mechanism (CDM) establishes funding

of approved projects in developing countries to promote sustainable development and also generate emissions credits. Unlike JI, CDM credits accrue from 2000 to 2007 rather than just over the 2008–2012 period; and

- Credits or allowances may be transferred through international emissions trading. For example, one industrialized country can purchase emission reduction credits from another country.

Mondshine covers CDM in more detail.[17] Created by Article 12 of the Kyoto Protocol, the CDM is defined as an "emission reduction project between a developing country and a developed country, with the former acting as a project host and the latter providing financing and technology in exchange for certified emission reductions (CER)." The developed country's CER can be applied to emission reduction commitments under the Kyoto Protocol. In November 1998 in Buenos Aires, the parties pointed out that primary CDM implementation would be through private investments and bilateral agreements. Because the CER can be accrued beginning in 2000, a country or firm could demonstrate significant progress toward its commitments before the 2008–2012 compliance period.

Constraints: Competition for Carbon Trading with the U.S.

The United States faces a challenge in competing with other nations for carbon offsets. Other countries will be willing to pay more than the United States for excess emissions because the U.S. marginal cost of control is lower than the marginal control cost in other countries. The United States will compete with Canada, Japan, and Australia for the excess reductions available from the former Soviet Union countries. Wooten points out that most analysts assume that the European Union (EU) will trade between its member countries (creating the "EU bubble"). At one point, the United States was assumed to be able to secure at least 40% of the available excess emissions from the former Soviet Union countries, which are equivalent to 15% of its required reduction. However, these countries now predict that they will need these emissions credits for future expansion.[18] Reinstein expects demand for carbon credits to exceed the likely supply of credits by a factor of 2 to as high as 10 or more.[19]

Restrictions on Flexibility Mechanisms

Although the Clinton administration is promoting the unlimited use of flexibility mechanisms, the treaty and other parties are positioned to limit their applicability. For example, the treaty stipulates that reductions from emissions trading (ET), JI, and CDM should be supplemental to domestic reductions. The EU has indicated that it favors a ceiling on the use of ET, JI, and CDM to achieve a party's emission reductions. At the same time, developing countries have reinforced their support for the treaty's language, which stipulates that ET, JI, and CDM should be supplemental to domestic actions.

To enable carbon trading, international agreement is needed in areas such as rules, guidelines, modalities, procedures governing flexibility mechanisms, monitoring and verification of results, and other aspects of these mechanisms. Reinstein estimates that these international agreements may not be completed for at least the next five years.[19]

Benefits of Carbon Trading

In a system of carbon trading, resources are allocated in the most efficient manner possible. GHG emission reductions are attained at the lowest possible cost, with equal benefit to the environment. Developing countries can benefit from the investment of funds available for project development, gain new emissions reduction technology, and earn a profit by selling their emissions reductions. It has been recognized that countries with lower emission reduction costs and higher emission limits will generally be in a better position to sell offsets. Developing countries will have the opportunity to sell emission reductions to developed countries and generate badly needed investment capital, which is good for development and global economic efficiency.[20]

Biodiversity and environmental protection are some of the secondary benefits gained from projects that protect or develop natural habitats for endangered species (e.g., orangutans in Indonesia and Malaysia [see Figure 6], and jaguars in Paraguay). Carbon trading could help save the rain forests by establishing funds for reforestation or RIL in rainforests that are being harvested. Of course, the system benefits industrialized countries by providing economical and cost-effective carbon credits, compared to more expensive alternatives (e.g., refueling, carbon taxes, curtailment).

The Need to Establish Market Rules

The development of clear guidelines and market rules will help increase business participation in emission trading. It is important for carbon sequestration projects to accurately define the quantities of GHGs sequestered by vintage year to enable monitoring and verification of projects that are used in offset trades. Clarification of the design of the trading system is crucial for successful trades. Design issues include determining the party responsible for the integrity of emission reduction credits, an allowance of forward banking of credits, and a mechanism for borrowing credits from future compliance periods to meet temporary compliance shortfalls. Further, Cohn et al. call for a system that can track emissions monitoring results and emissions trading activity.[20] Other key implementation issues include data transparency, standardization of emission reduction credits, and establishment of a way to address "bad trades."

Examples of International Carbon Trades

Initial pilot-scale trades demonstrate the feasibility of international CO_2 emissions trading involving all stakeholders, including national governments and certification bodies. These trades promote the need for inclusion of GHG emissions reduction trading and credits in the United Nations Framework Convention on Climate Change of the Kyoto Protocol. Some examples are described below.

In December 1997, Ontario Hydro agreed to purchase 10,000 tons of excess CO_2 emission reduction credits (ERCs) from Southern California Edison Company. Edison generated the CO_2 ERCs via a heat rate improvement program at its Mohave Power Project. The emission reduction trade helped Ontario Hydro meet its voluntary commitment with the Canadian government to stabilize CO_2 emissions at 1990 levels by 2000. Edison made the trade because it exceeded its commitment to reduce its GHG emissions by 2 million tons in the year 2000 from 1990 levels and plans to reduce emissions by an additional 10% by 2005.[21]

Figure 6. Carbon trading could help save the rainforests, and the habitat of native orangutans, by establishing funds for reforestation or reduced-impact logging in rainforests that are being harvested. Here, an orangutan visits a feeding site in Indonesia's tropical rainforest of North Sumatra. Photo by Prabhu Dayal.

In early 1998, the Canadian firm Suncor Energy, Inc. purchased 100,000 tons of CO_2 credits, with an option to purchase an additional 10 million tons of GHG reductions, potentially valued at $6 million over a 10-year period, from Niagara Mohawk Power Corp. Niagara Mohawk reduced GHG emissions below 1990 levels through performance, fuel switching, and energy efficiency improvements. The deal helps Suncor achieve voluntary emission targets, while Niagara Mohawk obtains funding for new GHG project investments.[22]

Ontario Power Generation bought the rights to 119,000 tons of CH_4 in exchange for 2.5 million tons of CO_2 from Zahren Alternative Power, an LFGTE company. The total value of the emissions trade is about $25 million.[23]

Royal Dutch Shell began a carbon trading system to reduce its emissions by 10% from 1990 levels by 2002. The company established its Shell Tradable Emission Permit System to cut emissions in its chemicals, refining, and exploration and production businesses in North America, Europe, and Australia.[24]

The World Bank recently launched its own "carbon fund" to which governments and private companies can contribute by investing in projects to reduce GHG emissions in developing countries.[25] The bank can issue emissions reduction certificates to contributors after verifying the reductions. The World Bank is acting as a broker in this arrangement by setting a price for emissions reductions that satisfies both the buyer and the seller.[25] To date, contributions from several Scandinavian countries, Japan, and Belgium total $85 million. The fund's cap of $150 million is expected to be available later this year.[25]

Price of Carbon

Several researchers have determined estimates of the price of carbon using different models and assumptions in their calculations. If the Kyoto Protocol is implemented and enforced with the proposed mandatory carbon targets in the 2008–2012 time frame, the price of carbon is projected to increase to more than $30 per ton. The carbon price is estimated at more than $300 per ton if "flexibility" mechanisms such as carbon sequestration and trading are restricted or not given credit. Although the protocol has yet to be ratified by the U.S. Congress, several GHG emission trades, have taken place on a voluntary basis. Based on these recent trades, a rough base price for the present value of carbon for international emission trading, CDM, and JI projects is less than $3 per ton. However, it should be recognized that the price of these trades is very low because it is purely voluntary with no mandated emission caps for carbon.

Brokerage Services

Brokers will undoubtedly play a key role in devising market solutions that allow businesses to comply with the proposed new requirements or regulations, matching buyers and sellers. They need to develop innovative transaction structures, serving as a source of price information and advice on the changing regulatory environment to implement cost-effective trades. Brokers are in a good position to develop portfolios of various GHG instruments (e.g., interpollutant swaps, credit sharing, immediate and forward settlement, options, and investment opportunities in international emission reduction projects) to diversify holdings.[20]

FOR MORE INFORMATION

Online information services for carbon management can be obtained from Web sites such as *www.Ctrade.org*. Companies such as Charles River Associates and law firms such as Troutman Sanders, LLP analyze and evaluate options and develop corporate strategies on behalf of clients to prepare them for uncertain future regulatory constraints. Ctrade.org can provide energy companies with valuable tools to assess the risk impacts of the Kyoto Protocol and information on investing in carbon trading or sequestration. This site also provides online information on the status of carbon sequestration projects. The site classifies risks (e.g., certification status), lists verification protocols, includes the status of host country acceptance, and estimates carbon sequestration costs for each project. The status and the amount of carbon sequestered is provided for projects in the United States and abroad. The site also provides updated information on current carbon trading

Table 1. Samples of carbon sequestration projects from around the world. Visit *www.Ctrade.org* for more information.

Country	Type	Value Added	C-Cost	Description
Fiji	Reforestation	carbon farming	$4/ton	6400 hectares, Fiji pine
Indonesia	Reduced-impact logging	biodiversity	$3/ton	USIJI approved, 1,000,000 tons
India	Sustainable forestry	tree planting	$4/ton	2500 acres, USIJI certification
Malaysia	Reduced-impact logging	biodiversity	$2/ton	Host country certification
Mexico	Sustainable forestry	agro-forestry	$12/ton	2400 hectares, USIJI approved
Paraguay	Sustainable forestry	habitat conservation	$4/ton	50,000 hectares, return on investment

prices in the international market. Table 1 illustrates a sample list of carbon sequestration projects from *www.Ctrade.org*.

CONCLUSION

This article reviews numerous examples of carbon sequestration projects and recent international carbon trades. Several abstracts and excerpts are referenced, including a wealth of information presented by many experts and researchers at the 1999 EUEC. The variety of carbon sequestration projects implemented or in progress, and the number of recent international carbon trades executed, demonstrates the feasibility of a voluntary and flexible approach to reducing GHGs worldwide. The benefits of carbon sequestration on biodiversity are value added to the economic benefits of carbon trading. Carbon sequestration and carbon trading offer a synergistic cost-effective solution to the global warming problem that affects generations the world over.

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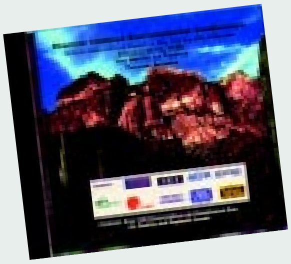

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