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FEATURE

What is the carbon market: Is there a final answer?

Jeffery R. Williams, Siân Mooney, and Jeffrey M. Peterson

The potential for sequestering carbon in agricultural and forestry sinks to generate carbon credits has received increased attention by legislative bodies, government and nongovernment organizations, private firms, farm managers, and universities over the last few years. This increased interest is primarily due to international regulation of greenhouse gas (GHG) emissions under the Kyoto Protocol. Although the United States has not ratified the Kyoto Protocol, a voluntary market and many state and regional initiatives have been developed to reduce atmospheric concentrations of GHGs. In addition, recent legislation proposed within the United States promotes a cap-and-trade system for reducing GHGs (Pew Center 2008; RFF 2008). Since our first examination of fledging carbon credit markets and factors affecting them (Williams et al. 2005), many new markets have developed, as well as new opportunities to reduce GHG emissions.

Several countries have developed GHG markets to help meet their mandatory GHG reductions under the Kyoto Protocol or other regulations. In addition, voluntary markets have formed outside the regulatory constraints to serve businesses interested in trading carbon credits, and there are a number of carbon offset providers that sell offsets to consumers and businesses. Table 1 summarizes the main market types that exist at present. The following sections discuss recent developments in credit and offset markets, as well as other programs designed to reduce GHG emissions. First, the concept of GHG and carbon credit trading and the commodity being traded are described. Following that, the major current markets are described, and the potential role for agriculture within these markets is discussed. In some locations (for example, Europe), mandatory trading has occurred since 2005, and the market has matured. In other locations, GHG markets are nascent or still in planning stages. Following the description of current markets, we discuss potential roles for the agricultural sector within these systems. Only a limited number of markets have an explicit role for agriculture.

Jeffery R. Williams is a professor in the Department of Agricultural Economics at Kansas State University, Manhattan, Kansas. **Siân Mooney** is an associate professor in the Department of Economics at Boise State University, Boise, Idaho. **Jeffrey M. Peterson** is an associate professor in the Department of Agricultural Economics at Kansas State University.

BACKGROUND

Cap-and-Trade and Carbon Credit Trading. Most GHG or carbon credit trading currently takes place within a cap-and-trade regulatory framework. Under cap-and-trade, an overall limit (cap) on GHG emissions is set by a regulator, and emissions credits are issued equal in number to the level of the cap. At the end of the regulatory period, regulated entities must hold enough credits to cover their total GHG emissions over that period or face a fine for each credit that they are in deficit. Regulated entities have several options available to comply with required emissions reductions—they can reduce their own emissions and/or purchase credits from others. Those who can reduce GHG emissions below their target can sell the excess credits. A seller will want to sell credits if they can reduce GHG emissions or sequester additional carbon at a cost that is less than the price of the emissions credit. If it is less expensive for an emitter of GHGs to buy an emissions credit rather than controlling additional emissions, they will buy credits. Despite the fact that some regulated entities might not reduce their emissions, overall emissions are reduced (and the cap is met) because there are only a specific number of credits that are allocated. Trading of emissions credits between buyers and sellers establishes the market price per credit. Williams et al. (2005) outline a number of factors that influence credit prices.

What Is Traded in Markets for GHGs? Credits to reduce GHGs are commonly referred to as carbon credits and are generally defined as 1 t carbon dioxide equivalent (CO_2e). All the major GHGs are sold within carbon markets, not just CO_2. The other gases are converted to their CO_2e using their global warming potentials (GWPs), which compare the ability of different greenhouse gases to trap heat in the atmosphere (table 2). For example, using the information from table 2, 1 t of methane emissions would trade for 23 t worth of CO_2e credits.

Credits, Offsets, Permits, and Project Generated Credits. In order to be bought and sold on a formal exchange, carbon credits must be a uniform commodity (table 1). Carbon offsets, on the other hand, are purchased independent of a formal exchange and may be nonuniform in design and specification. Both carbon credits and offsets can serve to offset emissions. In this paper, we use the distinction that carbon credits are a uniform commodity designed to be traded on an exchange, whereas many, but not all, offsets are nonuniform (not traded on an exchange), and buying them is more akin to purchasing a service that you do not resell later.

It is also important to distinguish between two types of credits. One type, which we refer to as "regulatory credits," is auctioned or allocated to GHG emitters based on regulatory formulas. Regulatory credits are also sometimes called permits, allowances, or quotas. The second type, which we call "project-based credits," is generated from projects that sequester carbon or reduce GHG emissions. While both credit types share a common definition in terms of GHG emissions and can be traded with each other in many markets, they are distinct products because they embody different kinds of risks and obligations. For example, buyers of project-based credits may bear at least some risk of default if the seller does not fulfill the contracted practices. Another important distinction is that the number of regulatory credits is fixed, while project-based credits can accumulate over time (subject to certain limits in many markets) as new projects are undertaken.

EXISTING CARBON CREDIT MARKETS

The Kyoto Protocol and Parallel Domestic Markets. The Kyoto Protocol was created

Table 1

Summary of main greenhouse gas markets and products.

Market	Type	Credit type	Uniform commodity
Kyoto			
European Union Emissions Trading Scheme	Mandatory markets—cap-and-trade		
	AAUs	Regulatory	Yes
	ERUs	Project based	Yes
	CERs	Project based	Yes
	RMUs	Project based	Yes
Chicago Climate Exchange	Voluntary market (US)—cap-and-trade		
	Allowances	Regulatory	Yes
	Rules for creation of offsets	Project based	Yes
Contracts/tenders for projects that create offsets that are specific to a buyer's needs	No mandatory rules for credit creation (some developed and being developed) No formal exchange Buying a service	Project based	Not necessarily
Consumer offsets	Variety of sources Buying a service Many not regulated	Project based	No

Notes: AAUs = assigned amount units. ERUs = emission reduction units. CERs = certified emission reduction credits. RMUs = removal units.

in response to climate change challenges presented by the United Nations Framework Convention on Climate Change (UNFCCC). The Kyoto Protocol sets legally binding emissions reduction targets for 37 industrialized countries and the European Union to reduce their GHG emissions by an average of 5% against 1990 levels over the period 2008 to 2012 (UNFCCC 2008a). To date, 180 countries have ratified the accord.

Each year within the compliance period, countries that are assigned emission reduction targets are allocated regulatory credits by the UNFCCC, equal to their individual annual emissions cap listed in annex B of the protocol. These permits are called assigned amount units (AAUs). The Protocol also established three types of project-based credits: emissions reduction units (ERUs), which are created from projects undertaken under the Joint Implementation provision of the Kyoto Protocol; certified emissions reductions (CERs), which are created under the Clean Development Mechanism (CDM) of Kyoto; and removal units (RMUs), which are created from projects that involved land use, land-use change, and forestry.

Forestry and agricultural producers have enjoyed some success in supplying project-based credits into the Kyoto market. Methodologies for afforestation, reforestation, and methane capture from livestock enterprises are approved under the Kyoto Protocol, and to date, 88 forestry or agricultural projects are registered (UNFCCC 2008b).

Project-based credits are only issued after the GHG reductions claimed by the project have been verified to reduce net GHG emissions below a business-as-usual baseline (Von Butler 2003). Projects must create real emissions reductions that are additional to those that would have occurred in the absence of the project.

For compliance purposes, all the credit types in the Kyoto framework are equivalent. By the end of the compliance period, a country's combined holdings of AAUs, ERUs, CERs, and RMUs must be greater than or equal to its cumulative GHG emissions over the five-year period. Many countries have chosen to allocate their AAUs to their major domestic GHG emitters, which are then required by their national governments to hold credits in proportion to their individual emissions. The Protocol allows for trading of credits between authorized entities within or across countries.

Table 2

Global warming potential of major greenhouse gases.

Gas	Global warming potential*
Carbon dioxide	1
Methane	23
Nitrous oxide	296
HFC-23	12,000
HFC-125	3,400
HFC-134a	1,300
HFC-143a	4,300
HFC-152a	120
HFC-227ea	3,500
HFC-236fa	9,400
Perfluoromethane (CF_4)	5,700
Perfluoroethane (C_2F_6)	11,900
Sulfur Hexafluoride (SF_6)	22,200

Source: Intergovernmental Panel on Climate Change (2001).

Note: HFC = hydroflourocarbons.

* See text for explanation.

In principle, any entity authorized by its government in a Kyoto country can buy or sell credits, as each country must create a national registry to track credit ownership and transfer, which in turn must be linked to the International Transactions Log (ITL) held by the UNFCCC (UNFCCC 2008c). All types of Kyoto credits (AAUs, ERUs, RMUs, and CERs) are tracked by the national registries and the ITL (UNFCCC 2008d). Building on this infrastructure, many Kyoto countries have created national or regional carbon credit markets to help meet their Kyoto commitment. In many cases, national exchanges were created where credits can be traded, although not all credits are traded on formal exchanges. Table 3 provides a list of some of these exchanges, and some of the new and established national markets are discussed in the next section.

While carbon credit markets are becoming a popular policy tool, it should be noted that they are not the only avenue to reduce GHG emissions. Indeed, under the Kyoto Protocol, each country is free to implement a mix of policy tools to meet their commitment, which may also include persuasion, regulations, incentives, and taxes, among others.

Region-Specific Markets in Kyoto Countries. Several parties to the Kyoto Protocol have developed national and regional markets to help meet their net emissions targets. Perhaps the best known of these is the European Union Greenhouse Gas Emission Trading Scheme (EU ETS), which predates the Kyoto market. Phase I of the EU ETS spanned from 2005 to 2007. The EU ETS regulates GHG emissions from energy-intensive operations representing some 40% of the EU emissions (Capoor and Ambrosi 2007).

Parallel to the provisions of the Kyoto Protocol, both regulatory and project-based credits can be traded in the EU ETS. Regulatory credits are called European Union allowances (EUAs), which were allocated, both by regulators and by auction, at the beginning of 2005. Since

Table 3

Formalized market exchanges.

	Instruments traded					
Market	**EUAs**	**CERs**	**VERs**	**NGACs**	**CFIs**	**MCXs**
Chicago Climate Exchange (United States) http://www.chicagoclimatex.com/					X	
Blue Next (France) http://www.bluenext.eu/	X	P				
European Climate Exchange (London) http://www.europeanclimateexchange.com/default_flash.asp	X	X				
The London Energy Brokers' Association (London) http://www.leba.org.uk/	X	X				
NordPool (Norway) http://www.nordpool.com/en/asa/Services/Emissions/	X	X				
The NYMEX Green Exchange (United States) http://www.greenfutures.com/markets/	X	X				
European Energy Exchange (Germany) http://www.eex.com/en/Products/Emission%20Allowances	X					
Montreal Climate Exchange (Canada) http://www.mcex.ca/index_en						X
Australian Climate Exchange (Australia) http://www.climateexchange.com.au/		P	X	X		
Climex (The Netherlands) http://www.climex.com/	X	X	X			

Notes: X = currently traded. P = planned for trading. EUAs = European Union allowances. CERs = certified emissions reduction (CER) credits, which can be developed from Clean Development Mechanism projects. VERs = voluntary emissions reductions. NGACs = New South Wales greenhouse abatement certificate. CFIs = carbon financial instruments. MCXs = 100 Canada carbon dioxide equivalent (CO_2e) units.

the beginning of the Kyoto compliance period, EUAs are equivalent to Kyoto AAUs. Project-based credits include CERs and ERUs as defined by the Kyoto Protocol (Hamilton et al. 2007). Trading these credits within the EU ETS works toward fulfilling the EU countries' Kyoto commitment.

During phase I of the EU ETS, market prices reached a high in April 2006 at €31.5 t^{-1} CO_2e but on May 15, 2006, fell dramatically to €8.0 t^{-1} CO_2e (Brahic 2006). Prices fell after the European Commission announced that European industries had emitted more than 60 million t of GHG less than predicted (Brahic 2006). It is generally believed that the fundamental reason prices fell was that EUAs were overallocated to emitters during phase I, creating an excess supply in the market. The allocations in phase I were based to a large degree on individual industry estimates of historical emissions. When credit allocations were made for phase II of trading (covering the period from 2008 to 2012, the first commitment period for Kyoto), the number of EUAs were based on actual emissions data (Brahic 2006). EUA settlement prices on the European Climate Exchange (ECX) ranged from €22.06 to €37.78 for July 2008. CER prices ranged from €17.72 to €26.34. These are much higher than the maximum price of carbon financial instruments (CFIs) traded on the Chicago Climate Exchange (CCX) of \$7.40 t^{-1} CO_2e from January to August 2008. The differences between CFIs and EUAs contributing to this price gap will be discussed in more detail below.

Canada will also be creating a national carbon credit market as one component of the Canadian government's GHG reduction plan. Details of the plan were released on March 10, 2008 (Government of Canada 2008a). Regulated industries will face mandatory emissions reductions of 18% from 2006 levels by 2010, with 2% continuous improvement every year after that. Some additional regulations will apply to specific industries. The plan will allow for in-house reductions, contributions to a capped and time-limited technology fund, domestic emissions trading, offsets, and limited use of the Kyoto Protocol's CDM (Government of Canada 2008b).

While the EU ETS is better known, one of the oldest mandated GHG trading systems is the New South Wales Greenhouse Gas Reduction Scheme, which was legislated by the New South Wales government in Australia and began trading on January 1, 2003 (Government of New South Wales 2008). The permits traded are New South Wales greenhouse gas abatement certificates (NGACs). The Australian Climate Exchange (ACX) now trades NGACs along with its own instrument called voluntary emissions reductions (VERs). VERs are approved as part of the Australian government certification program known as Greenhouse Friendly and are consistent with Kyoto Protocol guidelines (Government of Australia 2008), even though Australia did not ratify the protocol until 2008. Since ratifying the Protocol, Australia is in the process of establishing their GHG inventory and required emissions reductions. As a result, ACX may also be trading CERs in the future (ACX 2008).

Voluntary Credit Markets. Other markets have developed outside the Kyoto framework, relying on voluntary rather than regulatory motives for trading. Perhaps the best known such market is the CCX, currently the only active GHG market in the United States. The CCX has approximately 300 members, including industries from a number of sectors, municipalities, countries, state governments, offset aggregators, offset suppliers, liquidity providers, and others. The CCX is also affiliated with the ECX and Montreal Climate Exchange (MCeX).

CCX is a cap-and-trade system. Phase II of trading on the CCX began in 2007. Membership in the CCX is voluntary, but each member is obligated to reduce GHG emissions by 6% below those in the 1998 to 2001 baseline period by 2010 (Capoor and Ambrossi 2007). The volume of trades on the CCX in 2006 was less than 1% of the volume traded in the EU ETS system over the same period (Capoor and Ambrosi 2007) and reflects the voluntary nature of the market. Prices on the CCX since January 2008 have ranged from approximately \$1.85 to \$7.40 t^{-1} of CO_2e.

The CCX trades CFIs where 1 CFI is equal to 1 t CO_2e. CFIs come in two varieties—allowances and offsets. These terms are equivalent to regulatory credits and project-based credits as defined above. Allowances are issued to emitting members. Offsets are generated from qualified emission reduction projects, including those from agricultural sources (Hamilton et al. 2007). CCX has standardized rules for CFI contracts for agricultural methane, coal mine methane, landfill methane, agricultural soil carbon, rangeland soil carbon, forestry, renewable energy, and ozone depleting substance destruction projects. Other project types are approved on a project-by-project basis (CCX 2008a).

Several opportunities exist to generate credits by changing agricultural practices to encourage cropland and rangeland soil carbon sequestration as well as methane reduction from livestock operations (CCX 2008a). Eligible projects for soil carbon credits include continuous conservation tillage and grass planting. Under the continuous conservation tillage option, projects initiated on or after January 1, 1999, are eligible for credits under a five-year minimum contractual obligation. The number of credits assigned to each acre enrolled depends on the spatial location of the land, ranging between 0.2 and 0.6 t CO_2 ac^{-1}. Rangeland soil carbon management can also be employed to produce credits, yielding from 0.12 to 0.52 t CO_2 ac^{-1} depending upon project type and location (CCX 2007).

The minimum contract size on the CCX is 100 t CO_2e. Individual projects sequestering less than 10,000 t CO_2e must be enrolled through a CCX registered aggregator, so credits can be pooled for sale on the exchange. Once the aggregators sell credits to the CCX, projects must be independently verified. CCX uses independent verification by employing a variety of private and public organizations. In addition, there is an insurance provision for some projects where 20% of all credits created are placed into the CCX carbon reserve pool.

Difference between Kyoto and CCX Credits. The standards that projects must meet to qualify as creating credits are very different between the EU ETS/Kyoto market and the CCX market. Although both markets sell credits denoted as 1 t CO_2e, these credits are not uniform between the markets.

Project-based credits acceptable for offsetting emissions under the provisions

of the Kyoto-related markets have to pass more stringent requirements than credits accepted on the voluntary CCX market. In particular, approved projects in the Kyoto markets must demonstrate a reduction of emissions or increase in removal of CO_2e by sinks that is additional to any that would occur under a "business-as-usual" baseline (Kyoto Protocol Article 6). Credits sold under the CCX do not have this requirement and in some cases do not provide a change from business as usual. Differences in credit definitions, as well as supply and demand conditions and an inability to trade across carbon credit markets within Kyoto and non-Kyoto protocol countries, contributes to the differences in market prices between the EU ETS and the CCX. (Countries that have not ratified the Kyoto protocol are not eligible to sell carbon credits in Kyoto country markets.)

OTHER GREENHOUSE GAS REDUCTION SYSTEMS WITHIN THE UNITED STATES

Although the United States has not ratified the Kyoto protocol, there is significant interest in reducing GHG emissions at the state and regional levels. Some of the proposed initiatives are still in the planning phase, while some initiatives have been implemented for several years.

Oregon CO_2 Emissions Standards. In 1997, the Oregon legislature gave the Energy Siting Council authority to set CO_2 emission standards from new energy facilities (State of Oregon 2008). The net emissions rate allowed for these power plants is 17% below the most efficient base load gas plant operating in the United States. These plants are allowed to use offset projects to meet the required emission reductions. They may implement a project themselves to reduce CO_2 or use what is referred to as the "monetary path" to reduce emissions. Under the monetary path, they pay an organization called the Climate Trust \$1.27 tn^{-1} (\$1.40 t^{-1}) of excess CO_2 generated above the regulation, plus transaction costs, to implement or participate in offset projects (State of Oregon 2008). There are several sequestration projects undertaken by the Climate Trust, including replanting of riparian vegetation and forest preservation. To date, there are no agricultural soil carbon sequestration projects undertaken by the Climate Trust.

Regional Greenhouse Gas Initiative (RGGI). The RGGI is an effort by nine Northeast and Mid-Atlantic states to develop a cap-and-trade program covering GHG emissions. It is initially focusing on plans to reduce CO_2 emissions from power plants by 2.5% per year between 2015 and 2018, after stabilizing them at current levels during 2009 to 2014 period (RGGI 2007). As currently planned, CO_2 emissions from the combustion of eligible biomass, including many produced by agricultural operations, can be deducted from the power plants' CO_2 compliance obligation. Agriculture may be able to provide offsets by using manure management to avoid methane emissions (Branosky 2006). Each allowance traded in the system will be equivalent to 1 tn (0.97 t) of CO_2. It is proposed that most of the initial emission allowances will be sold at auction to regulated entities. A small number of offsets may be purchased from sequestration of carbon due to afforestation and avoided methane emissions from agricultural manure management among other projects.

California Global Warming Solutions Act. The California Global Warming Solutions Act was signed into law on September 27, 2006. The act requires a statewide emission cap for 2020 based on 1990 emissions levels. A plan is to be in place by January 1, 2009, that indicates how reductions in emissions are to be achieved from regulation, market mechanisms, and other actions (State of California 2006). In June 2007, recommendations for designing a GHG cap-and-trade system were published (State of California 2007). Among the key recommendations are that the initial regulatory credits will be both allocated and auctioned, project-based credits both within and outside the state's border will be recognized, and the state should encourage linkages with other mandatory greenhouse cap-and-trade systems. The report also states that "some activities that reduce emissions from agriculture and forestry might be appropriate for consideration" as project-based credits (State of California 2007). CDM and joint implementation (JI) credits under Kyoto may also qualify to offset emissions.

The Western Climate Initiative (WCI). The WCI, whose members are Arizona, British Columbia, California, Manitoba, New Mexico, Oregon, Utah, and Washington, has a goal to reduce GHGs by 15% below 2005 levels by 2020 (WCI 2007). A cap-and-trade system with an aggregate regional cap is proposed to start in 2010, with the first three-year compliance period spanning from 2010 to 2012 and trading proposed to start January 1, 2012 (WCI 2008). Three-year compliance periods will continue until 2020. Credits will be allocated three years in advance, but the mechanism for allocation is not defined as yet. Both regulatory and project-based credits from other government-approved GHG trading systems will be allowed in the WCI but in limited proportions. At present, the limit discussed is no more than 10% of an individual entity's compliance obligation (WCI 2008). Credit banking will be permitted without limitation. Many emissions reductions and sequestration projects are eligible under the WCI. Agricultural soil carbon sequestration and forestry projects are specifically included. If at the end of the compliance period an entity does not have enough credits to cover emissions, it will be required to surrender three credits for every ton not covered (plus other potential penalties) (WCI 2008).

VOLUNTARY OFFSET MARKETS

A variety of other voluntary trading is taking place. These trades are not always associated with a cap-and-trade system or other form of regulation. Offsets within the voluntary market are commonly generated from projects that generate emission reductions. They generally do not operate through formal trading markets or exchanges and are referred to as over-the-counter (OTC) trades. These include markets where individuals purchase GHG offsets to cover all or some of their annual CO_2 emission from their autos, plane trips, and/or household energy consumption (among other emissions). The firm that issues the offsets invests a portion of the money in GHG reduction projects that may include, but are not limited to, renewable energy industry projects, such as wind power and solar power. Other projects include methane captured from landfills

and coal mines. Agricultural projects may include methane captured from manures and carbon sequestration in forests, cropland, and rangeland. Firms that issue offsets to consumers may also purchase verified credits through the CCX.

Hamilton et al. (2007) reports that suppliers of offsets include developers of GHG offset projects, aggregators that have ownership of a portfolio of credits from offsets, retailers selling directly to individuals or organizations that may have purchased offsets from aggregators, or project developers and brokers that facilitate transactions between buyers and sellers. Buyers could be individual consumers, groups, firms, other organizations, or government entities. Their motivation may be an interest in improving the environment, marketing or public relation advantages, philanthropy, profitability from resale, or gaining experience for expected regulation. The voluntary market in 2006 was 23.7 million t CO_2 and approximately 43% of the transactions were through the CCX (Hamilton et al. 2007). The remainder of the trades were not through formal exchanges.

Consumer carbon offsets do not necessarily result in emissions reductions or sequestration that is additional from business-as-usual. There are some standards in place and being developed to ensure projects result in real GHG reductions. A Voluntary Carbon Standard (VCS) was developed jointly by the Climate Group, the International Emission Trading Association, and the World Business Council for Sustainable Development and published in November 2007 to standardize what a certified voluntary carbon offset is. The United Nations Framework Convention on Climate Change (UNFCCC) CDM and JI project standards are also approved under the VCS (2008). Methods used by the California Climate Action Registry are under review as part of the VCS. The VCS includes standards for agriculture, forestry, and other land use projects (VCS 2007). Projects include afforestation, reforestation, revegetation, agricultural land management, improved forest management, and reducing emissions from deforestation. Agricultural land management projects include projects to increase soil carbon and reduce emissions of soil nitrous oxide and methane.

Carbon Market Glossary

Assigned amount units (AAUs). AAUs are allowances issued to countries under the Kyoto Protocol. AAUs are the unit of measure for a country's assigned amount under the Kyoto Protocol and are the five-year budget for emissions over the period from 2008 to 2012. AAUs are placed in a country's specific national registry. For compliance purposes with Kyoto, AAUs are equivalent to certified emission reductions, emissions reduction units, and removal units (Von Butler 2003).

Carbon allowance. A carbon credit that has been distributed to the holders up to their permitted level of CO_2e emissions. These are called assigned amount units under the Kyoto Protocol. The European Union Emissions Trading Scheme, which follows the Kyoto framework, calls their allowances European Union allowances.

Carbon credit. A permit that allows the holder to emit 1 t CO_2e.

Carbon financial instruments (CFIs). Carbon credits traded on the Chicago Climate Exchange equivalent to 1 t CO_2e.

Carbon offset. A carbon credit that has been generated from CO_2e emissions reduction projects. Offsets are also called certified emission reductions (CERs) when issued for Clean Development Mechanism projects, emission reduction units when issued for joint implementation projects, and removal units when issued for sequestration projects involving land use, land use change, and forestry under the Kyoto Protocol framework. For those trading on the Chicago Climate Exchange, they are called carbon financial instruments.

Certified emissions reduction (CERs) credits. Credits developed from Clean Development Mechanism projects.

Clean Development Mechanism (CDM). Allows industrialized (annex I) countries participating in Kyoto to invest in projects that reduce GHGs in developing countries to create project-based credits.

Carbon dioxide equivalent (CO_2e) units. Carbon dioxide equivalent measure used to indicate the global warming potential of each of the six GHGs.

Emissions reduction units (ERUs). Credits created from joint implementation projects established in countries classified as Economies in Transition. ERUs are converted assigned amount units or removal units as a result of joint implementation projects.

European Union allowances (EUAs). EUAs are emissions allowances traded in the European Union Emissions Trading Scheme equal to 1 t CO_2e.

European Union Emissions Trading Scheme (EU ETS). A cap-and-trade system that regulates CO_2e emissions from energy-intensive operations in the European Union.

Joint implementation (JI). Allows industrialized (annex I) countries participating in Kyoto to invest in projects that reduce GHGs in countries classified as Economies in Transition to create offsets.

Removal Units (RMUs). RMUs are issued to industrialized (annex I) countries for land use, land use change, and forestry projects. RMUs are traded at the country level. These credits are issued after the GHG reductions claimed by the project have been verified (Von Butler 2003).

United Nations Framework Convention on Climate Change (UNFCCC). The international legal framework that commits the parties to the UNFCCC to stabilize human-induced GHG emissions. The UNFCCC and the Kyoto Protocol are serviced by the Climate Change Secretariat. Some of the main functions of the secretariat are to monitor implementation of the commitments, assist in implementing commitments, provide analysis, maintain registries for the issuance of emission credits and for the assigned amounts of emissions of that are traded under emission trading schemes, provide support for compliance with the Kyoto Protocol, and coordinate with the secretariats of other relevant international bodies and other relevant conventions.

Another certification standard is the Green-e Standard for Greenhouse Gas Emission Reduction Products (Green-e 2007). The Center for Resource Solutions (CRS) is the Green-e program administrator. Another is called the Gold Standard. This is a Swiss-based nonprofit foundation supported by nongovernmental organizations to certify CDM, JI, and voluntary offset credits (The Gold Standard 2008). However, in the voluntary offset market, there are currently no requirements that all projects comply with a standard. There are also no requirements that third-party monitoring of voluntary projects occurs to verify reductions. Gillenwater et al. (2007) report that legal mechanisms to define ownership of offsets and prevent more than one firm from selling the same offset, or for one seller to sell a single offset to more than one buyer, do not exist. In the United States, the Federal Trade Commission (FTC) has begun a regulatory review of its environmental marketing guidelines. As part of this review, it is addressing the marketing of carbon offsets (FTC 2007).

US POLICY

As of January 2008, there were 11 market-based GHG bills introduced in Congress, plus another in draft form. Seven of these proposed an economy-wide cap, two an electricity sector cap, and three an economywide tax. Nine of them provide incentives for at least some limited form of sequestration. A summary of these bills is provided by Resources for the Future (2008) and Pew Center on Global Climate Change (2008).

The size of the emissions cap differs between each piece of proposed cap-and-trade legislation. Most proposals favor a reduction in the cap over time, very similar to the system that was put in place for the successful sulfur dioxide (SO_2) trading market (Environmental Defense 2000; USEPA 2002). The caps proposed for the year 2050 range from 71% below 2005 emissions levels to 80% below 1990 emissions levels (Pew Center 2008). The size of the cap, as well as the industries affected, will influence the price of carbon credits (Williams et al. 2005). Each of the proposals includes provisions that seek to reward firms that are engaged in early action to reduce emissions or are engaged in offset projects. Although it is unclear what final US legislation may include, it is possible that early action such as emissions reductions through the CCX may be rewarded in future periods (Pew Center 2008).

The Lieberman-Warner Climate Security Act died in the Senate June 6, 2008, after a vote of 48 to 36, short of the 60 votes needed to invoke cloture. The law proposed a cap-and-trade system to reduce emissions from sources of about 80% of US emissions. The caps under Lieberman-Warner would have reduced emissions to 4% below 2005 emissions levels by 2012, 19% by 2020, and 71% by 2050. Although the legislation failed, it is expected that a similar bill will be proposed again this year.

The Lieberman-Warner bill specifically acknowledged a role for agriculture. Up to 15% of the mandated GHG reductions could have been met by domestic offsets, including those from agricultural sources. The Secretary of Agriculture would have been given 10% of the carbon credit allocations as a reward for the industry's carbon reduction and sequestration efforts, with half the allocations going to agricultural sector and half for national forests and grasslands (Raymond and Shively 2008). One of the goals related to this allocation is to promote the use of native species for sequestration. However, emissions from agriculture were not regulated specifically. Explicit opportunities for agricultural producers were not identified in Lieberman-Warner but would become more transparent after any legislation passes.

Is Agriculture Going to be Regulated? Agriculture accounts for approximately 6% of US GHG emissions (USEPA 2008). Methane and nitrous oxide are the primary greenhouse gases emitted by agricultural activities, with beef and dairy cattle accounting for most of the methane emissions. Enteric fermentation and manure management account for approximately 30% of total US methane emissions (USEPA 2008). Nitrous oxide emissions from fertilizer applications and other cropping practices account for 72% of US nitrous oxide emissions (USEPA 2008).

Because of the transactions costs associated with regulating small emitters, it is unlikely that there will be many individual farms and ranches subject to regulation. For example, under the Warner-Lieberman bill and the Western Climate Initiative, only entities with more than 10,000 t of CO_2e emissions annually are targeted. Many individual farms and ranches would fall below this limit. However, intensive and confined animal operations could emit enough GHGs to exceed this figure. For example, the CCX currently uses baseline annual emissions for dairy cattle within a liquid slurry/pit storage system that range between 4.83 t CO_2e per head in Hawaii to 1.12 t CO_2e per head in Alaska (CCX 2008c). On the basis of these conversions factors, dairy operations within between 2,070 and 8,928 head of dairy cows could emit 10,000 t of CO_2e annually. For dairy operations with an anaerobic lagoon, CO_2e emissions per dairy cow range from a high of 6.24 t CO_2e annually in Hawaii to a low of 3.91 t of CO_2e in Alaska. This means that dairy operations with lagoons ranging in size between 1,603 and 2,557 head could be regulated depending on the state (CCX 2008c).

Industrial processes related to the agriculture industry, such as fertilizer production, are also possible targets for regulation because of the energy-intensive production process and their direct emissions of GHGs, such as nitrous oxide. Food processing and other food-related manufacturing could also be subject to regulation if the emissions at specific plants were large enough.

Opportunities for Agriculture to Participate. Current opportunities for US agricultural producers to participate in the GHG market were discussed previously in the Chicago Climate Exchange section. These opportunities may change in the future if new climate policies are adopted. As noted above, several bills under consideration propose to allow some sequestration offsets. Possible means for agricultural producers and forest managers to generate credits are soil carbon sequestration (storage), afforestation and reforestation, methane capture, reduction of methane and nitrous oxide, energy reductions, and energy production from biomass as a substitute for fossil fuels.

Increases in soil carbon can be achieved through the adoption of various land use and management practices (Lal et al. 1998; CAST 1992). Such practices include removing highly erodible land from pro-

duction and restoring it to conserving uses, such as grassland or wetland. Planting trees for windbreaks or riparian forest buffers is another option (USDA 2006a). Management practices that facilitate soil carbon sequestration include conservation tillage, management of crop residue, cover crops, and improved water management (Lal et al. 1998). If the producer subsequently reverts to conventional management practices, however, the stored carbon is lost. The effectiveness of these production changes in sequestering carbon depends on both cropping intensity and tillage practice. A single land use or management practice will not be effective at sequestering carbon in all regions. It is estimated that 49% of agricultural carbon sequestration can be achieved by adopting conservation tillage and residue management, 25% by changing cropping practices, 13% by land restoration efforts, 7% through land use change, and 6% by better water management (Lal et al. 1998). (While many previous studies have documented soil carbon sequestration from these practices, the reader should note that two recent studies [Baker et al. 2006; Blanco-Canqui and Lal 2008] found limited evidence of increased soil carbon from conservation tillage at their experimental sites.) Nitrous oxide emission can be reduced by increasing efficiency of fertilizer use by including soil tests to determine the appropriate application rates and properly timing applications.

Carbon credits created through soil carbon sequestration can also generate a number of additional public co-benefits that could be of special interest to some buyers. The primary public benefits are related to the ability of improved soil carbon management to reduce wind and water erosion, as well as leaching of nutrients and pesticides. Erosion and leaching can have significant effects on nutrient loading, sedimentation, wildlife habitat, water quality, human health, and many other factors (Feng et al. 2004; McCarl and Schneider 1999; Sparling et al. 2006). Unfortunately, our ability to make good estimates concerning the value of these ecosystem services is significantly hampered by the lack of data, but the benefits are unequivocally positive (Mooney and Williams 2007); for example, erosion reduction is estimated to be worth billions of dollars annually across the United States (Ribaudo 1986; Tegtmeier and Duffy 2004; Clark et al. 1985). Afforestation and reforestation have similar co-benefits.

Livestock producers also have opportunities to produce carbon credits. Improving the nutrient balance and quality of livestock feed to reduce methane emissions produced by animal digestion may be an option for managers. Using methane recovery systems for liquid manure not only reduces GHG emissions but also provides a substitute for energy obtained from the national grid. The practice of composting to reduce methane from livestock operations may be another option to create credits and reduce GHGs. Additional discussion of opportunities for agriculture can be found in studies by Branosky (2006), Branosky and Greenhalgh (2007), and USDA (2000).

The US Department of Energy announced revised guidelines in April of 2006 for the Voluntary Greenhouse Gas Reporting Program, known as 1605(b), that will enable farmers and landowners to estimate, report, and register greenhouse gas reductions and carbon sequestration. Actions that farmers and landowners can consider reporting include using no-till agriculture, installing a waste digester, improving nutrient management, and managing forestland (USDA 2006b). The US Department of Energy's Energy Information Administration will administer this voluntary reporting program. The guidelines offer farmers and ranchers a new online tool called COMET-VR for estimating soil carbon sequestration.

For industries linked to production agriculture, opportunities will be dependent on their specific production technologies and resource constraints. Firms that can reduce their GHG emissions at lower cost than the market price of carbon credit will supply credits into the market, while those firms that have difficulty reducing their GHG emissions for less than the market price of a carbon credit will demand credits within the market. Of course, any policies that may be enacted may limit the role that agriculture plays in greenhouse gas reduction. These polices could affect both the demand and supply of offsets from agricultural enterprises.

CONCLUSIONS

The most significant factors constraining demand in the US carbon credit market at present are the lack of binding emission reduction targets and a lack of clear GHG reduction policy (Young 2003). Market prices will be affected by the design of the regulatory policy. Some critical components of the regulations include the GHG reduction goals, the use of banking, the technology allowed for reduction and sequestration, and the type of project-based credits allowed. The size of the emissions cap relative to the amount of actual GHGs emitted will have a significant impact on demand and price of the allowances or credits. This was true in the EU market when it was discovered there were fewer emissions than expected relative to the cap. This resulted in a price decline. The carryover of unused allowances or offset credits from one compliance period to the next could impact the supply and demand for credits in each period and, therefore, price. Banking may increase the incentive to control emissions in the short run and, therefore, the market price.

Credit prices will also be affected by the rules for generating credits from projects that sequester carbon in managed ecosystems, such as agriculture and forestry. Any set of rules would likely grant credits to projects that sequester carbon for longer periods. Because of the uncertainty surrounding the nonpermanent sequestration of carbon in soils, a policy requiring more than 1 t CO_2 be sequestered for every single credit certified for sale would also reduce the supply of credits and raise price. De facto, a similar scheme is in place at the CCX, where 20% of credits are held back as self-insurance. If such a policy is not used, and credits from reductions or sequestration are viewed as being more risky or less permanent than those from other source, reducing this uncertainty will likely lead to lower market prices for this product if "grades" of credits appear on the market. Development of improved technologies and processes that reduce the cost of sequestering each ton of carbon or GHG emissions will increase the supply of credits and tend to lower price.

In sum, global markets for GHG credit trading are developing at a rapid pace. At present, there are several differ-

ent markets, with nonuniform rules for credit creation and differing degrees of oversight. Although market harmonization is encouraged, it is likely that several different markets will exist for the foreseeable future. The agricultural sector is not explicitly regulated in any market to date. However, large individual emitters may face regulation as a result of the size of their emissions. The GHG markets, both present and future, are likely to generate many positive opportunities for agriculture, although many features of these opportunities have yet to take shape.

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