THE ROLE OF DOMESTIC OFFSETS IN U.S. CLIMATE POLICY AND THE IMPORTANCE OF PROGRAM DESIGN

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EXECUTIVE SUMMARY

Greenhouse gas (GHG) offsets are likely to be a major feature in the design of a U.S. cap-and-trade program for greenhouse gases, in large part because of their potential to significantly lower the costs of compliance for regulated entities, and thus the overall cost of climate change mitigation programs. The ability of offsets to reduce compliance costs for regulated firms will depend on the pace, volume, and cost at which offsets become available. A number of modeling studies have estimated the technically and economically achievable supply of domestically available greenhouse gas emissions reductions and removals from sectors, such as agriculture and forestry, that are expected to be excluded from an emissions cap (regulation of greenhouse gas emissions) in the U.S. These studies have implicitly assumed such reductions could be available as offsets. However, few of these studies have considered how offset program design eligibility rules, quantification protocols, quality criteria, and other variables -- might affect the quantity, prices, and net emissions impact of offsets under a U.S. cap-and-trade program. This analysis demonstrates how different offset program rules can dramatically impact the potential supply of offset credits, as well as the actual emissions reduction benefits of an offset program.

The World Resources Institute and Stockholm Environment Institute developed a simple model of offset cost and availability, based on recent U.S. Environmental Protection Agency (EPA) offset supply analysis, allowance price estimates from the Congressional Budget Office, and offset program design variables that have been considered in US cap-and-trade legislation, such as quantitative limits, allowance set-aside provisions, and the use of discounts. We then examine a range of existing offset quantification protocols, and develop two illustrative scenarios: one that leans toward more lenient rules and higher generation of offset credits, and another that leans toward more stringent rules and greater net emissions reduction benefits.

Our findings suggest that while more lenient offset protocols and rules may bring several times more credits to the market as compared with more conservative approaches, these gains in offset supply could come at a significant cost to the environmental integrity of the cap-and-trade system. If the risks of reversals, leakage, and crediting business-as-usual (non additional) reductions are not adequately addressed, then offset provisions could result in net emissions exceeding target levels, e.g. by up to 200 MMtCO2e, or 10% of economy-wide emissions reduction, in 2020. More conservative approaches, in contrast, could yield substantially fewer offset credits, thereby potentially increasing allowance prices, but also resulting in net emissions reductions beyond targeted levels. In this scenario, fewer offset credits would be issued than the emissions reductions that were actually realized as a result of the offset program.

To address concerns about the potential variability and uncertainty in both offset supply and emissions reduction benefits, as well as to provide greater certainty to the growing offset market, we propose a number of approaches for designing an offsets program. A scientific offset advisory board should be established to provide expert guidance and advice to the U.S. federal offset program administrator, with sufficient independence and expertise to ensure that offset protocols are rigorous enough to avoid undermining overall emissions reduction objectives. Program administrators and the advisory board should aim to find the optimal balance that increases the efficiency as well as integrity of the offset market, through, for example, the development of accurate, clear, and conservative crediting protocols, as well as transparent and streamlined regulatory review processes. For GHG reductions where uncertainties in quantification remain very large, policy makers should consider other mechanisms to spur mitigation in uncapped sectors, such as allowance set-asides, subsidies and regulations. Other recommendations include consideration of a system-wide offset true-up mechanism, which would allow for a periodic review and adjustment of the cap based on the demonstrated performance of the offset program; the use of system-wide and project type-specific offset discounts where appropriate; and further research and model development in areas that could inform key policy decisions.

1. INTRODUCTION AND CONTEXT

Greenhouse gas offsets ("offsets") are a central feature of most proposed or enacted regional, national, and international cap-and-trade systems. A GHG offset is a reduction in GHG emissions or an increase in carbon sequestration that is achieved to compensate for, or "offset," GHG emissions occurring at another source (Broekhoff and Zyla, 2009; OQI, 2009). Proposed national climate policy in the United States -- from the Lieberman-McCain Climate Stewardship Act of 2003 to the Waxman-Markey American Clean Energy and Security Act of 2009 (ACESA, or HR 2454) – have included offsets to provide cost containment and increase compliance flexibility for entities under the cap. Offsets offer the potential to involve a greater array of entities in emissions reduction activities– namely, those in agriculture, forestry, and other sectors to which binding greenhouse gas limits would not apply.

Analyses to date generally support the inclusion of offsets in a cap-and-trade program for greenhouse gases (GHGs) to significantly lower the cost of compliance for capped entities. For example, modeling by the U.S. Environmental Protection Agency of ACESA has estimated that the inclusion of offsets could reduce the cost of compliance by over 50% (EPA, 2009c).[1] In the EPA's analysis – as well as those by other analysts, such as the Congressional Budget Office (CBO, 2009) – offsets represent a significant fraction of the emissions reductions achieved by a domestic cap-and-trade program. These analyses, however, depend on uncertain assumptions about the sources and quantity of offsets that would be available over the life of the cap-and-trade program.

To provide the cost savings, flexibility, and other benefits envisioned, offsets would need to be available in sufficient quantity, quality and at prices highly competitive with the cost of emissions reductions by regulated entities. Prospective participants in offset projects – such as landowners, financiers, and brokers -- will need to judge that the projected future stream of offset payments will justify the risk of undertaking investments in GHG reductions, such as the conversion of agricultural lands to managed forests or the installation of a manure digester on a dairy farm. Risk and reward for these project developers will depend not only on the costs of land, labor, technology, and other inputs, but also on the offset rules established by program administrators. These rules will also be essential for ensuring that offsets represent real and additional GHG emissions reductions or removals.

A sound understanding of the potential supply of offsets under projected future market and policy conditions is critically important for policymakers as they address major design decisions in crafting climate policy. These decisions include whether and how to place limits on the use or supply of offsets, whether to expedite or favor certain types of offset activities (such as those with co-benefits?), and whether other mechanisms in addition to offsets should be considered to encourage some types of emissions reduction or sequestration activities. Those designing a U.S. offset program will need to balance many, sometimes competing, objectives, particularly the desire to manage costs for capped entities while ensuring that offsets do not impede or undermine the needed reductions in greenhouse gas emissions.

This report provides the results of an analysis of potential domestic offset supply under a U.S. cap-and-trade program on greenhouse gases. Using modeling results from the U.S. EPA and EPA's research partners as a foundation, this study provides new, quantitative analysis of the impacts of various offset program design elements, offset market parameters and constraints, and other factors that could impact the supply and quality of offsets from non-capped sectors. Several studies have used economic models to estimate the supply of offsets available in future years at a range of prices (see Appendix A for a review of approaches and studies). This report is among the few that consider how the design of offset protocols, and their rules for eligibility, measuring, verifying, and crediting offsets, might impact actual offset crediting and thus the realization of GHG mitigation potential.

The results of our analysis provide insights for policymakers and offset program administrators on the effect of various policy design decisions on the supply and availability of GHG offsets from domestic sources. It addresses a number of crucial questions concerning offsets – including the economic, environmental, and equity impacts of various approaches to defining and limiting the use of offsets. The focus throughout is on offsets from the

[1] Offsets are not the only means of cost containment proposed in cap-and-trade programs. Some policymakers, for example, have proposed "safety valve" provisions that restrict allowance prices from rising above a certain level. Another cost containment is a strategic reserve of allowances that can be released to the system in the event of rapid or unexpected allowance price increases. However, if triggered, both safety valves and strategic allowance reserves, would allow emissions to rise above the cap. Unlike offsets, they do not yield corresponding emissions reductions that occur outside the capped system. Thus, the inclusion of offsets is generally seen as a cost-containment mechanism that can maintain environmental benefits relative to other cost containment mechanisms. (These mechanisms can also be combined, e.g. if a strategic reserve could be replenished through the purchase of offsets or retirement of allowances.)

agriculture, forestry, industrial, and waste sectors in the U.S.. After discussing the role of offsets in cap-and-trade programs (Section 2), the paper describes this study's analytical approach and scenarios (Section 3), and presents modeled results of the effect of cap-and-trade design variables on domestic offset supply (Section 4). It closes with conclusions (Section 5), including recommendations for how cap-and-trade program designers and administrators can help ensure program credibility, effectiveness, and market efficiency.[2]

2. THE ROLE OF OFFSETS IN GHG CAP-AND-TRADE SYSTEMS

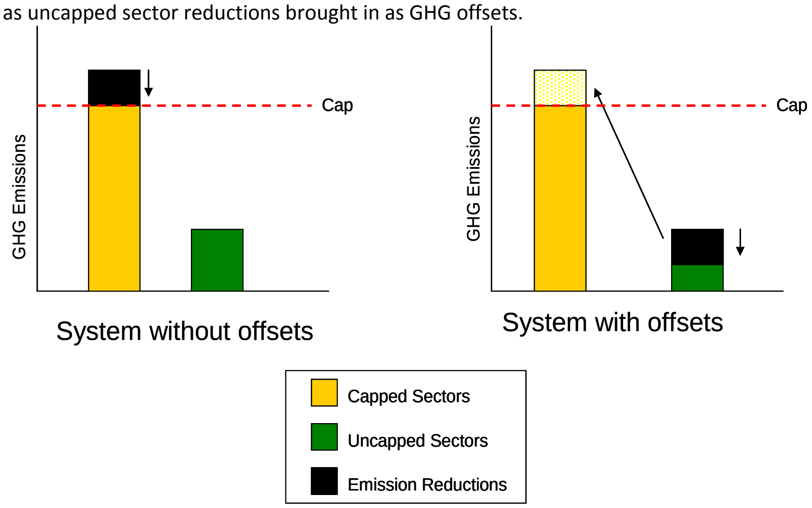
In GHG cap-and-trade systems, offsets provide regulated entities with an alternative mechanism for achieving compliance with emissions reduction requirements. A GHG offset credit represents a metric ton of carbon dioxide equivalent (CO_2e) reduced, avoided or sequestered by a project implemented specifically to compensate for emissions occurring elsewhere (Broekhoff and Zyla, 2008; OQI, 2008).

Under current legislative proposals, such as ACESA, approximately 85% of the U.S. economy would be covered by a "cap" on emissions or other emissions reduction requirements (Larsen and Heilmayr, 2009). The cap will establish a total allowable amount of GHG emissions for the sectors that are subject to an emissions reduction requirement. Emission reduction obligations within those sectors are generally established by an annual emissions threshold for coverage (e.g. 25,000 metric tons per year of carbon dioxide (CO_2), entities that emit at or above this threshold level are required to obtain a combination emissions allowances and offsets equal to their total annual emissions. The most commonly included sectors are the electricity, transportation and industrial sources of GHG emissions. As a result, approximately 15% of the economy in the United States would be "uncapped" or not required to reduce emissions. In general, GHG offsets are sourced from sectors not covered by an emissions cap (see Box 1); in the U.S, agriculture and forestry represent sectors that are both unlikely to be covered as well as likely to offer significant potential for lower-cost emissions reductions and removals.

[2] Appendix C presents results for the American Clean Energy and Security Act (H.R. 2454) and will be updated as the bill is considered and modified in the Senate.

Box 1: Offsets and Allowances in Cap-and-Trade

Offsets provide an additional compliance option to capped entities by allowing them to surrender an offset credit in lieu of an allowance. Allowances represent the right to emit one ton of CO_2e by an entity subject to binding emissions regulation. When an offset is surrendered in place of an allowance, the total number of allowances in the system remains unchanged, rather than being reduced by 1 allowance. This results in a greater number of compliance options available to capped entities than would have otherwise been available in a system without offsets. The figure below illustrates the role of offsets in cap-and-trade programs. This figure is a simplification designed to describe the role of offsets in cap-and-trade programs; in reality emission reductions are likely to be driven by a combination of capped sector reductions as well as uncapped sector reductions brought in as GHG offsets.



Including GHG offsets in a cap-and-trade system has both advantages and disadvantages. Advantages include:

- provide broader access to emissions reduction opportunities throughout the economy. By accessing lower-cost emissions reductions in uncapped sectors of both the developed and developing world, the cost of compliance to regulated entities can be reduced.

- stimulate technology transfer in uncapped sectors and countries.

- provide environmental, economic and social co-benefits in uncapped sectors. For example, the installation of manure digesters on dairy farms can reduce noxious odors, insect populations, and disease transmission and can improve local soil and water quality.

However, offsets can also pose significant disadvantages. These include:

- High volumes of offsets can significantly reduce the extent of emissions reduction activities and investment within capped sectors, potentially "locking-in" high carbon infrastructure and delaying important technology learning and transformation needed to move to a lower carbon economy.

- Offsets can undermine the integrity of GHG caps, if they do not represent additional emissions reductions. Ensuring that, on an aggregate level, emissions reductions from offsets would not have occurred is inherently difficult.

- Offset systems are complex and can be costly to administer. Evaluating, approving and enforcing offset projects requires substantial administrative and enforcement infrastructure that can add significant cost to the offset program, and thus, the total cost of climate policy.

- Offsets provide cost savings to regulated entities, but may not be the most cost-effective means of achieving a given quantity of GHG emissions reductions, thereby potentially resulting in higher overall costs to society as a whole for a given unit of GHG abatement. (Broekhoff and Zyla, 2009)

In sum, the inclusion of GHG offsets in any emissions reduction regime presents both risks and opportunities. Policy makers must weigh a variety of competing interests when deciding whether and how to include offsets in a cap-and-trade system.

3. OFFSET SUPPLY – ANALYTICAL APPROACH

The ability of offsets to deliver reduced-cost compliance for capped entities depends heavily on the quantity and cost of offsets available over time. While a number of modeling studies have been conducted to estimate the supply of greenhouse gas emissions reductions from non-capped sectors in the U.S.?, few have focused on how rules on qualifying, measuring, verifying, and registering these reductions as offsets might affect the quantity and prices of these offsets under a national cap-and-trade program.[3] For example, EPA's economic analysis of ACESA did not explicitly assess what effect such program design factors might have on the quantity and cost of potential offset supply (EPA, 2009b). In contrast, the analysis provided by this report demonstrates how offset protocols, and corresponding assumptions about eligibility and offset cost and pricing, can dramatically impact the quantity and quality of credits and thus the benefits of an offset program.

This analysis builds on experience with existing voluntary and compliance offset markets in the U.S. and international markets, currently available offset protocols from the Regional Greenhouse Gas Initiative (RGGI), the Clean Development Mechanism (CDM), EPA Climate Leaders and others and studies of how such protocols might affect offset crediting of sample projects (e.g., Galik et al, 2008; Lazarus, Lee, and Smith, 2009). Differences in

[3] See Appendix A for a review of existing studies.

protocol design can change the number of emissions credited by a factor of two or more for a given reduction activity (e.g., Galik et al, 2008; Lazarus, Lee, and Smith, 2009). Variables in the protocol design affecting the number of credits generated include: choice of methodologies for quantifying baseline and project emissions, how leakage, and permanence are addressed, and the method used to determine project additionality and eligibility. Below we assess the potential impact of protocol design and other potential rules of offset programs that could affect offset supply and quality. Based on this assessment, we present new analysis of offset supply under a hypothetical cap-and-trade policy design scenario. A version of the analysis specific to ACESA is included as Appendix C.[4]

Key features of this analysis include:

- **Reliance on the EPA's 2009 marginal abatement curves for mitigation potential in agriculture and forestry.** In March, 2009, the EPA released updated marginal abatement curves (MACs) for agriculture and forestry activities (EPA, 2009a) based on improvements and updates to their underlying FASOM-GHG model made since previous (2005) marginal abatement curves (EPA, 2005). The 2009 MACs predict lower overall offset potential, due largely to updated estimates of demand for agricultural commodities, requirements of the Renewable Fuel Standard, and updated economic projections (EPA, 2009c). These revised 2009 MAC curves form the basis of the analysis conducted in this study.
- **Consideration of factors that might affect offset activity, such as how offset protocols might credit projects differently.** Drawing on recent analyses of how the design of offset protocols might credit projects (e.g., Galik et al, 2008; Lazarus. Lee, and Smith, 2009), we derive estimates of how many offsets might be creditable relative to the EPA-generated marginal abatement curves. (For an example of such a calculation, see Box 2). We also consider research by whom? on measurement or scientific uncertainty of emissions benefits, estimates of potential leakage, and treatment of reversal risk (i.e., permanence) through buffers or other means, among other factors.

- **Assumptions regarding future growth in the price of greenhouse gas allowances under a federal cap-and-trade program.** Specifically, we assume an allowance price trajectory of $20 per ton CO2e in 2012 increasing at 5% per year. A 5% increase is the same assumption used in EPA's new MACs (EPA 2009a)[5] and is also the average rate of allowance price growth in EPA's analysis of ACESA (EPA, 2009b)[6]. A $20 starting price is within the range of current and prior legislative analyses.[7] We further assume that the price of offsets is the same as the price of allowances, except when an offset limit constrains their use (in which case the offset price is driven down, as described in Box 2) or when offsets are discounted (in which case the offset price is discounted a corresponding amount).[8]

For a more detailed discussion of the analysis methodology, please see Appendix B.

As discussed above, the manner in which offset programs are designed and implemented, the degree of robustness and stringency of their protocols, and strength and clarity of the price signals sent to offset project developers, remain a major unknown. As a result, the uncertainties in projecting offset supply and cost – and the broader benefits offsets can provide -- are very large.

[4] Based on the version released May 21, 2009 but with consideration of changes made prior to the bill's passing on June 26, 2009.
[5] In addition to this 5%-per-year rising price scenario, EPA also included constant price scenarios in its new set of marginal abatement curves (EPA, 2009a).
[6] The 5% increase in allowance prices in EPA (2009b) is driven by their assumption of the real discount rate, also 5%, given that capped entities are allowed to bank and borrow allowances.
[7] The $20 + 5% per year price trajectory is similar to Scenario 7 in EPA's analysis of ACESA, a no-international-offset case. Using this projected trajectory in our analyses is, effectively, to assume that domestic offsets do not need to compete with international offsets. We evaluate this assumption by using a lower price trajectory (specifically, that from the EPA's Scenario 2), in Figure 9.
[8] The assumption of parity between offset and allowance prices may result in overestimates of offset supply, since buyers may perceive an increased risk in purchasing offsets relative to allowances and thus demand lower prices. This risk may account for the spread between allowance and offset prices observed in the EU carbon markets, which has ranged from $1 to over $10/tCO2 in recent years. At lower prices (higher spreads), project developers would supply fewer offsets to the market.

To develop initial estimates of the degree of potential variability in offset supply and quality, three distinct scenarios were examined. Scenario 1 is a base case that represents offset supply as in the EPA's existing 2009 marginal abatement curves. EPA analysts employed the same approach in their June 2009 analysis of ACESA (EPA, 2009a) and previous economic analyses of climate legislation (e.g., EPA, 2008). Building on this base case, Scenarios 2 and 3 represent alternative, bounding cases for how policymakers might approach the design of offset protocols and, in turn, affect both offset supply and environmental benefits. The three analytical scenarios are as follows.

Scenario 1: Marginal abatement curves used directly as offset supply curves.

This approach -- used by EPA in its economic analyses of proposed cap-and-trade legislation -- assumes that all of the domestic reduction potential in non capped sectors in the underlying marginal abatement curves is available as creditable offsets.[9] Previous EPA authors, however, have explicitly cautioned against this approach: "Caution should be taken not to apply the MAC data directly as offset curves. Offset curves are a supply curve of emissions permits that could potentially be available in the market at a given carbon-price. However, a price signal alone is not likely to bring about all of the mitigation opportunities available along the MACs" (EPA, 2006). Accordingly, some analysts have suggested that MACs should be interpreted as upper bounds of offsets supply and thus mitigation potential due to the underlying models' key assumptions of "perfect foresight" .[10] Despite these caveats, scenario 1 was included here to provide a link to these previously published studies by EPA and other analysts, as well as a point of departure for developing Scenarios 2 and 3, each of which build upon (and modify) this first scenario.

Scenario 2: Offset protocols are designed to maximize the volume of offsets eligible for crediting and thus cost-savings to capped entities.

Under this scenario, the offset program administrator is assumed to select protocols and methodologies that emphasize the generation of high volumes of offset credits over more stringent assessments and safeguards for additionality, permanence, uncertainty, leakage, or other factors. As a result, a greater array and volume of potential offset activities would be allowable, even if some of those credited activities may not result in real reductions (e.g., are not additional and would have occurred regardless of the incentive provided by the offset market or are non permanent or cause increased emissions at other sources (leakage)).We base our characterization of Scenario 2 largely on examination of select existing offset protocols**.**

Scenario 3: Offset protocols emphasize integrity of greenhouse gas reductions.

Under this approach, we assume the offset program administrator makes a concerted effort through the design of the offset crediting protocols to ensure that offset credits represent real, additional emissions reductions or sequestration that would not have happened in the absence of the incentive provided by the offset market, even if some legitimate projects remain un-credited. As with Scenario 2, we base our characterization of Scenario 3 largely on examination of select existing offset protocols.

In reality, neither the lenient protocols of Scenario 2 nor the stringent protocols of Scenario 3 are likely to perfectly reflect the choices made by a future offset program administrator, yet each serves as a representation of a potential regulatory direction.[11] Table 1 describes the general approach of the three hypothetical cases to addressing key design factors in offset protocols. For specific quantitative parameters used, please see Appendix

[9] With one exception: in some cases, the EPA has discounted the natural gas sector marginal abatement curve by 50%.
[10] The FASOM-GHG model, which underlies the estimates of domestic agricultural and forestry sector mitigation, assumes individual landowners and actors have perfect foresight of future price trends and act accordingly, implementing options as soon as the "net present value" of an options becomes positive relative to the assumed discount rate of 4% (EPA, 2005)
[11] Arguably, the goal of the administrator could be to neither over- or under-credit and, in effect, perfectly realize the potential embedded in the EPA's marginal abatement curves. However, other factors beyond the scope of this analysis may affect whether the potential implied in the marginal abatement curves is realistic.).

Table 1. The Relationship Between Offset Protocol Design Factors and the Three Scenarios

Offset Design Factor	Scenario 1: MACs as Offset Supply Curves	Scenario 2: Focus on Maximizing Credits	Scenario 3: Focus on Environmental Integrity
Project Eligibility	Agricultural soil sequestration, animal methane, other agricultural methane and nitrous oxide mitigation projects, forest management, afforestation, landfill methane, coal mine methane, oil sector methane, natural gas sector methane[12]	Same as Scenario 1	Same as Scenario 1
Additionality / Baselines	Assume the EPA's MACs include only additional tons and do not credit any BAU activity	▪ Apply relatively loose tests for additionality that enable crediting of a high percentage of business-as-usual activity, enabling "free riders". ▪ Assume crediting is generous, and estimated project baselines assume low business-as-usual penetration and growth of emission reduction activities.	▪ Apply strict tests for additionality that limit crediting of business-as-usual activity and thus prevent "free riders". ▪ Assume crediting is relatively conservative, and estimated project baselines assume relatively high business-as-usual penetration and growth of emission reduction activities.
Uncertainty (measurement, variation)	No discounts for uncertainty are applied.	Same as scenario 1	Explicit discounts are applied to project types with larger uncertainties (e.g., reductions in agricultural N2O).
Permanence	No buffer requirements or permanence discounts are applied.	Same as scenario 1	Permanence discounts and/or buffer requirements are applied to project types with a risk of reversal (e.g., carbon sequestration projects in agricultural soil or forests).
Leakage	No leakage discounts are applied.	Same as scenario 1	Leakage discounts are applied reflecting the latest academic research.
Transaction / Other Costs	No transaction costs applied.	Basic transaction costs are applied, as a 10% brokerage or middle-man fee for market intermediaries.	Basic transaction costs are applied, as a 10% brokerage or middle-man fee for market intermediaries.

For each of the three scenarios, we calculate both potential offset supply – that is, what quantity of offsets would be credited and sold – as well as the "actual" greenhouse gas mitigation as a result of these offsets. We assume, except where noted, that the EPA's marginal abatement curves accurately assess "actual" greenhouse gas mitigation potential and so, by definition, the offset credits issued equal greenhouse gas mitigation in Scenario 1.[13] For Scenario 2, relatively lenient protocols may issue offset credits in excess of actual emissions mitigation, whereas in Scenario 3, relatively stringent protocols may issue offset credits less than actual emissions mitigation.

Throughout the analysis, estimates of potential offset crediting include nine different groups of offset project types, as detailed in Table 2. Previous researchers have described how different types of offset projects face different intrinsic levels of risk and uncertainty. For example, measuring methane capture from landfills is relatively accurate, whereas quantifying the emissions sequestered on agricultural soils through no-till practices can be highly uncertain, particularly for smaller projects (Broekhoff and Zyla, 2008). In this analysis, we

[12] For a description of each of these project types, see Table 2.
[13] A full assessment of each of the underlying assumptions in EPA's assessments was beyond the scope of this study.

quantitatively assess how key offset protocol design factors (as defined under the three scenarios outlined in Table 1) affect offset supply.[14] For an example of how offset protocols might affect crediting of emissions reductions at landfills, see Box 2.

Table 2. Description of Project Types Included in Mitigation Potential Assessments

Project Type	Description	Potential Relative Supply in 2030[15]
Agricultural soil	Activities include conservation tillage (a way of growing crops from year to year without less disturbance of the soil than under traditional tillage practices), the retirement of marginal lands from protection through programs such as the USDA Conservation Reserve Program, and changes in crop mix or management that increase the standing biomass (McCarl et al, 2005; EPA, 2005).	*Low-High*
Animal methane	Reducing methane emissions from animal manures can be accomplished through technologies such as anaerobic digesters (EPA, 2005).	*Low*
Other agricultural methane and nitrous oxide	These options include reducing fertilization rates through techniques such as "precision farming", reducing acreage in rice cultivation, manipulating enteric fermentation by altering livestock herd size, feed type, and/or feed rate (McCarl et al, 2005; EPA, 2005).	*Low-Medium*
Forest Management	A number of activities can be classified as "forest management", including lengthened timber harvest rotation, increased forest management intensity (through use of fertilization, thinning, and/or prescribed burns, among other practices), reforestation (replanting of trees on existing forest land), the related options of forest preservation and avoided deforestation (both of which remove forest lands from harvesting), and the conversion of harvested wood into longer-lived wood products (McCarl et al, 2005; EPA, 2005).	*Medium-High*
Afforestation	Afforestation refers to growing trees on land that historically was not forested (EPA, 2005)	*Medium-High*
Landfill methane	The EPA's analysis of mitigation of landfill methane includes technologies to capture the methane and either flare it or use it for energy (EPA, 2006)	*Low-Medium*
Coal mine methane	Coal mining releases methane stored in natural pockets within coal seams. Because the high concentrations of methane are a safety hazard, mines generally vent the mine, releasing methane to the atmosphere. Mitigation options include various methods to either capture and destroy the methane or oxidize it to generate heat (EPA, 2006).	*Medium*
Oil sector methane	Methane is released in several stages of oil production, but most methane emissions from this sector occur during oil extraction at oil production fields. Mitigation options included in the EPA's marginal abatement curves include flaring, direct use, and reinjection into oil fields (EPA, 2006)	*Low*
Natural gas sector methane	The primary source of methane from the natural gas sector is leakage from pressurized transmission pipelines. Mitigation options included in the marginal abatement curves are equipment changes and upgrades, changes in operational practices, and increased inspection and maintenance (EPA, 2006).	*Medium*

In summary, this study develops three hypothetical scenarios for how offset protocol designs and markets might affect crediting of nine potential classes of offset projects. We explore implications of each of these scenarios in detail in the next section.

[14] Conducting a full scientific assessment of each factor for each project type was beyond the scope of this project. Instead, we relied on a review of existing studies, as described in Appendix B.

[15] Potential supply is characterized as *Low* if estimates of potential offset supply (as detailed in subsequent sections) are less than 10 MMtCO2e in 2030, *Medium* if between 10 and 100 MMtCO2e, and *High* if greater than 100 MMtCO2e.

Box 2. Example Calculation of Potential Over- or Under-Crediting of Landfill Projects

The EPA's assessment and marginal abatement curves represent methane recovery for energy and flaring (EPA, 2006), which are the sole solid waste management activities currently credited in the offset market. Offset protocols used today in both the voluntary and regulatory offset markets differ in their accounting for emissions reductions associated with methane destruction at landfills. These key accounting differences can lead to significantly variant numbers of offset credits being awarded depending on which protocol is used to quantify the emissions reductions from a project.

One of the key uncertainties in landfill emissions concerns the fraction of methane that is oxidized within the landfill, thereby reducing methane emissions. For example, some protocols (i.e., those from the Regional Greenhouse Gas Initiative, Climate Leaders, and Climate Action Reserve) use the assumption that 10% of methane is oxidized, the same assumption used in the EPA national inventory, while others (Chicago Climate Exchange, CDM) do not. Assuming that 10% is a reasonable estimate for soil oxidation, these latter protocols over-credit actual emissions reductions by just over 10% (1-1/1.1). Existing landfill gas offset protocols also differ in their treatment of combustion efficiency from similar combustion devices, ranging in most cases from 90% combustion of methane (closed flare, CDM) to 100% (all combustion devices, CCX), which can also have a significant impact on the number of offset credits generated from the same activity depending on the quantification methodology used.

Given the impact that these calculation differences can have on the number of offset credits awarded for a given activity, this analysis has attempted to estimate scenarios where both over and under crediting occur. For example, in the case of landfill gas crediting, this analysis assumes that future protocols can follow a test-based approach to combustion efficiency (like Climate Action Reserve) under our Scenario 3, while under a maximized crediting scenario (Scenario 2) a simple 100% combustion rate would be assumed. Assuming that 95% represents a reasonable average combustion rate, we use a 0% potential under-crediting relative to the EPA's marginal abatement curves and a 15% potential over-crediting.

4. EFFECT OF CAP-AND-TRADE DESIGN VARIABLES ON OFFSET SUPPLY

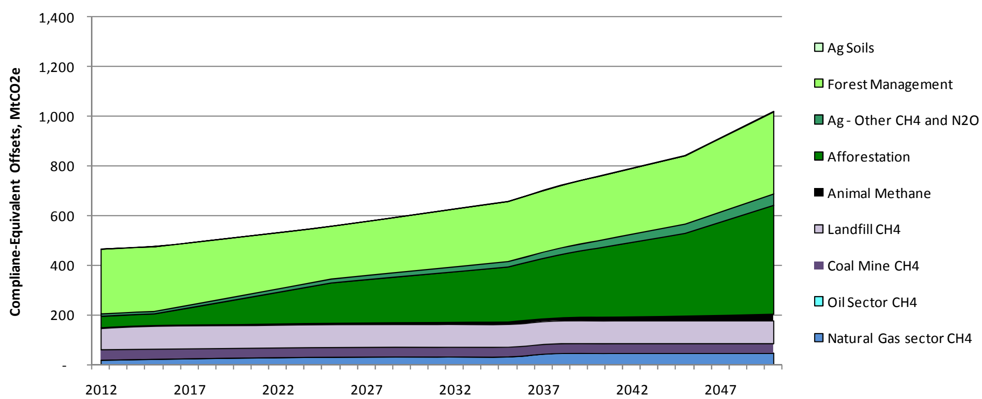
This section presents results of the analysis for several offset program and general climate policy design variables. This includes an assessment of how the following design variables could affect supply of emissions credits:

- **Offset protocols,** which determine how offset projects generate saleable credits;
- **Offset limits**, which restrict the number of offset credits that can be used by capped entities to meet compliance obligations under the cap;
- **Offset discounts**, where each offset credit counts as less than one emissions allowance;
- **Additional policies** applied to the uncapped sectors, such as set-asides or regulations; and
- **Offset program ramp-up,** such as the speed and efficiency with which administrative and technical infrastructure can be put in place, as well as the availability of "early action" offsets.

Each of these factors is discussed below for a hypothetical U.S. cap-and-trade policy for greenhouse gases. For a discussion of how these factors combine to affect offset supply under the American Clean Energy and Security Act of 2009 (ACESA), please see Appendix C..

To begin this discussion, Figure 1 presents a projection of how offset supply might evolve over time without consideration of the design variables listed above, this study's Scenario 1, which assumes that the full potential in the EPA's marginal abatement curves is available as offsets.[16] As seen in the figure, under the assumptions of Scenario 1, domestic offset supply could be greater than 450 MtCO2e in 2012 and rise to approximately 1 billion tons in 2050.

Figure 1. Potential Domestic Offset Supply Over Time (Scenario 1)
(at price of $20/ton in 2012, increasing at 5% per year)



Note the relatively consistent potential in forest management and industrial methane projects over time, with increasing mitigation potential in afforestation as the price of offsets increase over time. Mitigation potential in afforestation rises consistently over time, reflecting both tree growth and the relatively high opportunity costs of converting agricultural land to forest land – a barrier, that, once overcome by rising greenhouse gas prices, results in afforestation having the highest overall potential (EPA, 2005).

Figure 1 displays minimal mitigation potential from soil sequestration projects due to assumptions in the EPA's underlying marginal abatement curves regarding continued "business-as-usual", baseline adoption of conservation tillage practices and changes in land use resulting from higher energy prices and the Renewable Fuel Standard, RFS2 (EPA, 2009a).[17] However, previous estimates by the EPA, using different baseline assumptions, showed substantially more potential in agricultural soil sequestration. The actual amount of over-and-above business-as-usual (i.e, additional) potential for soil sequestration as offsets is likely somewhat greater than represented in the EPA's 2009 marginal abatement curves. (For potential offset supply over time using EPA's previous marginal abatement curves, estimates that included a much greater potential for soil sequestration, see Figure 2.)

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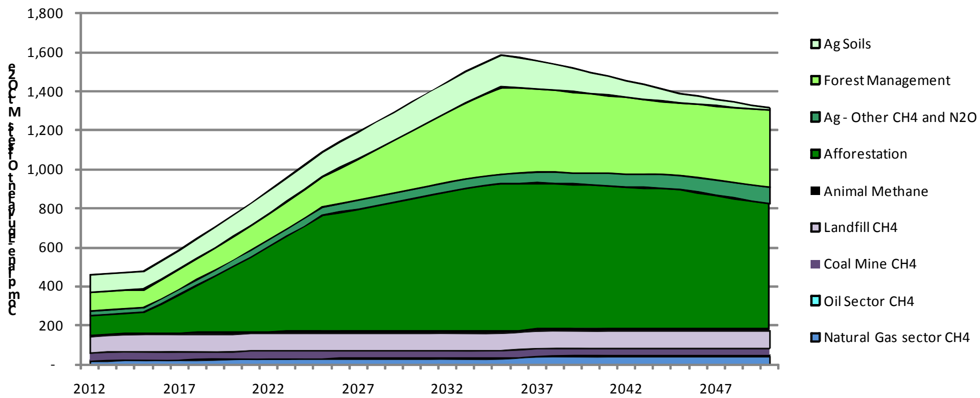
[16] Note that all quantities of emissions and mitigation in this report are reported as metric tons carbon-dioxide equivalent.

[17] In addition, the additional sequestration that is projected to take place is largely "netted out" by other agricultural land being afforested, where FASOM-GHG then assigns the soil carbon to afforestation rather than agricultural soils (EPA, 2009c).

Figure 2. Potential Offset Use Over Time (Scenario 1) Under Lower Energy and Commodity prices and Lower Biofuel production

The EPA's previous marginal abatement curves for forestry and agriculture activities, used for analyses of S.2191 and other bills, estimated greater crediting? potential in many activities. Updates in baseline assumptions regarding energy and agricultural commodity prices, implementation of the new renewable fuels standards, and increased baseline adoption of soil sequestration practices are all factors that contribute to the decline in overall crediting? potential between the 2005 and 2009 marginal abatement curves (EPA, 2009a).



IMPACT OF OFFSET PROTOCOLS

Lenient offset protocols could – in theory – generate even more offset credits in some project types than represented in the marginal abatement curves used in Scenario 1. For example, lenient protocols as modeled in Scenario 2 could offer significant credits to agricultural soil sequestration activities already being practiced or expected to be implemented under "business as usual" conditions. Protocols that favored stricter tests for additionality and other factors, however, would (as modeled in Scenario 3) exclude this business-as-usual soil sequestration and also issue fewer credits for forest management and afforestation activities for which baseline and measurement methodologies, leakage, and permanence could be more conservative. Figure 3, below, displays how these two bounding protocol cases could affect offset supply in 2020 relative to that displayed in Figure 1 for Scenario 1.

Figure 3. Potential Domestic Offset Supply in 2020 (All Three Scenarios)
(At a price of $30/ton CO2e)

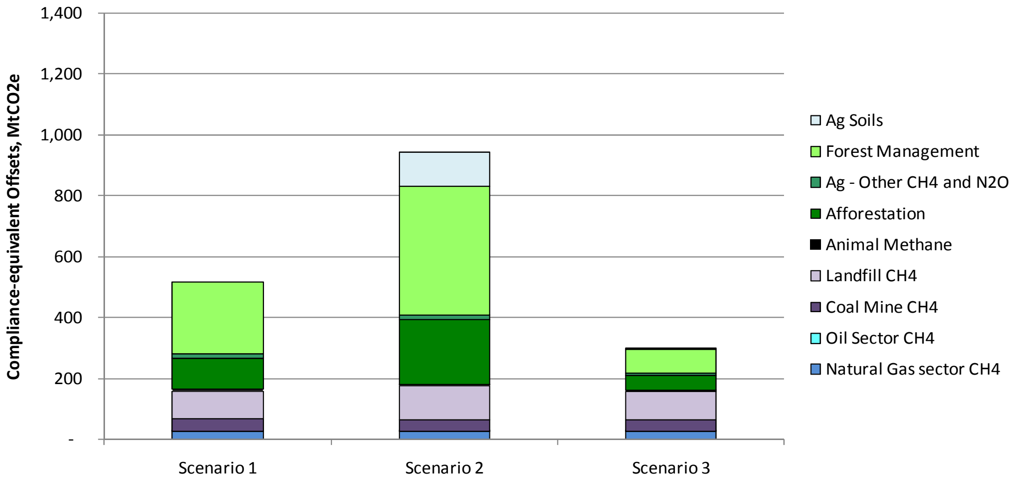
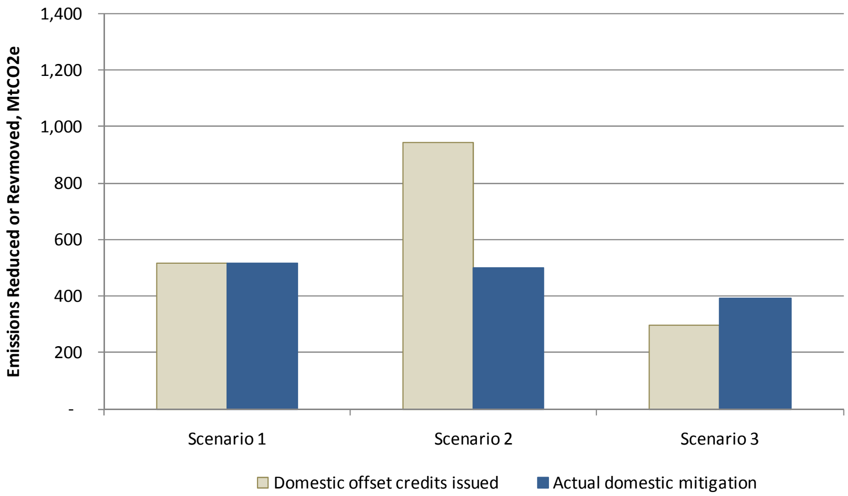


Figure 3 displays a relatively large variation in potential offset supply in 2020 as a result of the varying approaches to crediting offsets in each scenario. The approximately 75% increase in crediting in Scenario 2, however, is not matched by an equal increase in actual greenhouse gas mitigation, as the loose crediting protocols employed issue credits for emissions reductions or removals that would have happened in the absence of the offset program. These credits would also result in an increase in emissions in the capped sectors,[18] resulting in a net increase in emissions over time equivalent to the amount of non-additional tons credited with offsets. Likewise, the 30% decrease in crediting in Scenario 3 is not matched by an equal decrease in actual mitigation, as the relatively stringent protocols do not offer credits for all the emissions abatement actually induced. Thus, there is an additional environmental benefit associated with Scenario 3. Figure 4, below, displays the effects of the hypothetical protocols on both offset crediting and actual emissions reductions. In this example, offset protocols as in Scenario 2 would over-credit actual emissions abatement by nearly 60%, whereas Scenario 3 would under-credit actual abatement by nearly 25%.

[18] See discussion of offsets in cap and trade in section 2 for a more complete discussion of the dynamics of emissions under climate change mitigation policy that allows GHG offsets.

Figure 4. Offset Credits Versus Emissions Reductions – Three Scenarios
(In year 2020 at price of $30/ton)



The relative increase or decrease in offset crediting under the three scenarios has implications for the price of allowances and compliance cost for capped entities. Higher crediting of offsets increases the supply of allowance-equivalent mitigation opportunities, while lower crediting of offsets would tend to increase costs, at least in the near term. However, as noted in the introduction of this report, higher cost to capped entities does not necessarily translate to higher cost to society.

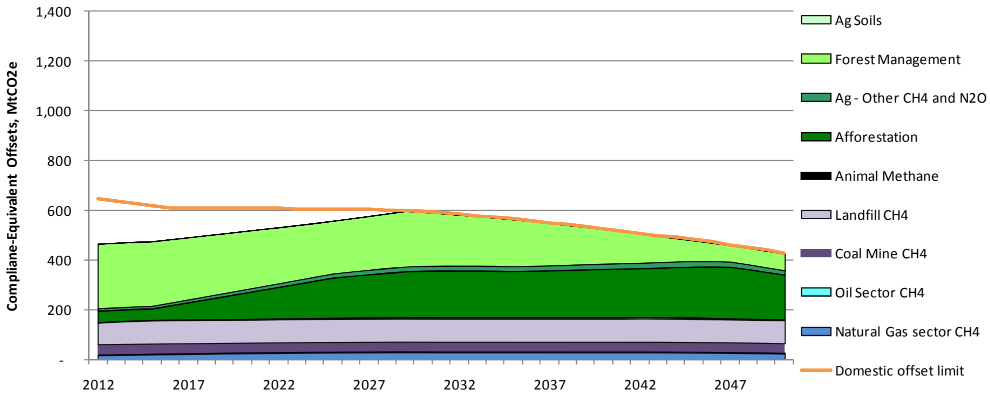
EFFECT OF OFFSET VOLUME LIMITS

Policymakers have generally placed limits on the overall amount of offsets that can be used for compliance. A common rationale for doing so is to ensure that a certain amount of emissions reductions take place within the operations and facilities of capped entities. Proposed offset limits have taken many forms, from a fixed tonnage limit over time (e.g., 1 billion tons of domestic offsets annually as in ACESA) to a fixed percentage of a covered entity's compliance obligation that can be met by offsets (e.g., the 15% limit in S.2191) that is, in effect, a declining tonnage limit.[19]

Figure 5, below, displays the effect of imposing such a declining limit on offset supply under Scenario 1.[20] Note that in this scenario, the limit constrains offset supply beginning in 2029. Note also that, compared to Figure 1, the relative contribution of forest management projects declines much more than industrial methane projects. This differential decline arises because of the declining price of offsets under an offset limit: at decreasing offset prices (e.g., $44 in 2040 in Figure 5 under an offset limit as opposed to $78 in 2040 in Figure 1), the decline in available offsets from forest management activities is greater than the decline in available offsets in industrial methane mitigation.

[19] Note that ACESA translates the fixed tonnage limit (2 billion tons including international offsets) into a percentage limit on the use of offsets by covered entities, which increases from about 30% in early years to over 60% by 2050.
[20] The current proposed offset limit of 1 billion tons of domestic offsets under the Waxman-Markey Discussion Draft ????? is not used in this example because, under Scenario 1, the limit is non-binding for the life of the cap-and-trade program. That is, the amount of abatement potential available through an offset program is never equal to or greater than the limit on the use of offsets for compliance. Thus, in order to illustrate the impact of a binding limit on the supply and price of offsets, the quantitative limit on the use of offsets in S. 2191 was used.

Figure 5. Potential Domestic Offset Supply Over Time Under a Declining Offset Limit (Scenario 1)
(Offset Limit as in S.2191)



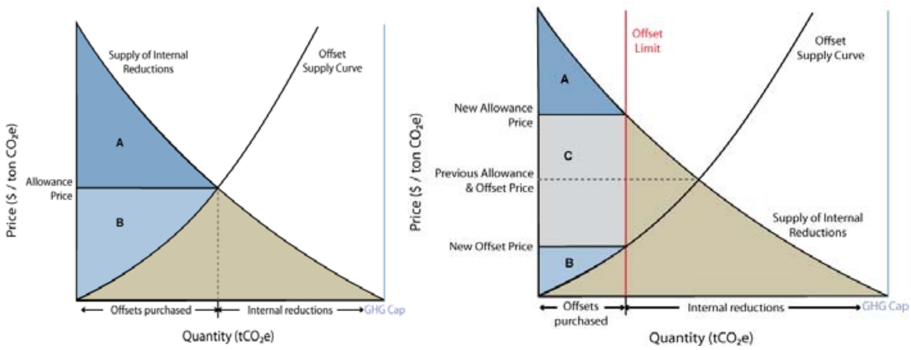
A natural question, however, is why the imposition of an offset limit drives offset prices lower. The presence of an offset limit has an effect on the price of both offsets and allowances, but the effects on the two prices are opposite. Restricting use of offsets below the equilibrium, market-clearing level will increase the market price of allowances, as the overall supply available in the marketplace decreases with declining availability of offsets. The offset price, however, would be expected to decline, as offset providers compete to supply the limited quantity of offsets now able to be sold. In effect, the imposition of an offset limit serves to create separate markets for offsets and allowances, where the quantity of offsets sold is determined only by the offset limit rather than the market-clearing price of offsets in the broader market for compliance credits (i.e., allowances or offsets). (For further explanation of the economic theory of offset prices and limits, see Box 3.)

The overall impact of an offset limit on compliance cost can be substantial. For example, the EPA has estimated

Box 2. Economic Theory of Offsets and Offset Limits

In the absence of an offset limit, the equilibrium, market-clearing price of offsets and allowances is determined by the intersection of the offset supply curve with the curve describing emissions reductions available from capped entities as indicated in the figure at left, below. Under an offset limit, however, the supply of offsets is limited (as indicated by the red line in the figure at right), resulting in a new, lower market-clearing price for offsets, as offset suppliers compete to supply the quantity of offsets able to be sold. The price of allowances, however, increases, as fewer offsets are available in the market.

The introduction of an offset limit also raises questions concerning equity and distribution of economic “rents”, or profit. In particular, the choice of how to implement an offset limit determines to a large extent who will benefit from the cost savings offsets provide. If offsets are not limited, capped entities receive an economic benefit equal to area A in the figure at left below, while offsets providers receive a benefit equal to area B. When offsets are limited, however, the magnitude of these benefits decline – as indicated by the size of areas A and B in the chart at right below. Who receives the benefit associated with area C depends on whether the offset limit is imposed on the overall supply of offsets or instead on the use of offsets by individual capped entities (Dixon et al, 2008; Olander et al, 2008).



that by restricting the use of offsets in ACESA from 2 billion tons of offsets per year (split equally between domestic and international offsets) to 1 billion tons of offsets (e.g. only allowing domestic offsets) would increase compliance cost by 89% (EPA, 2009c). However, imposing the offset limit also has cost benefits, as the offsets that are available would be at lower cost, and the untapped mitigation potential in the uncapped sectors may still be available, potentially even at a lower overall cost to society through other mechanisms.

The introduction of an offset limit may raise questions concerning equity. In particular, the choice of how to implement an offset limit largely determines who will benefit from the cost savings offset provide. If offsets are not limited, economic benefit accrues to both capped entities (area “A” in Box 3, sometimes called consumer surplus) and offset providers (area “B” in Box 3, sometimes called producer surplus). However, when an offset limit is imposed, the choice of whether the limit is imposed on the overall supply of offsets or on a capped entities’ individual compliance obligations determines whether capped entities or offset project developers will receive the greatest economic benefit.[21]

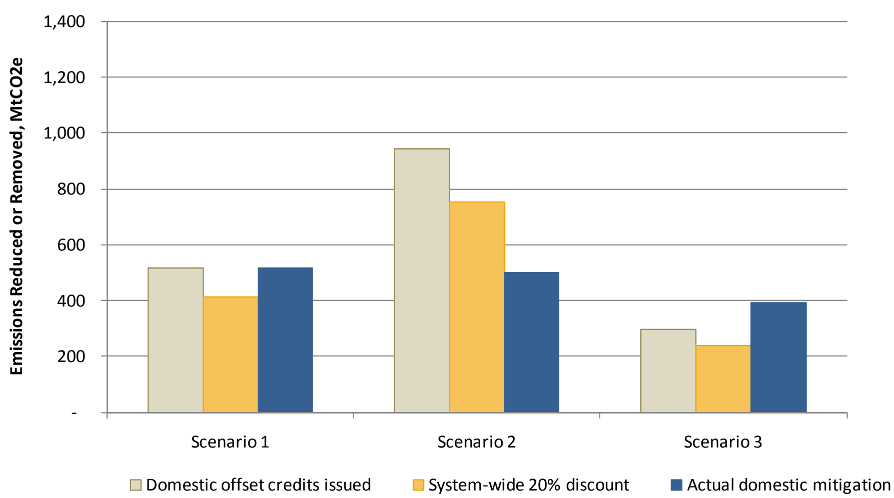
[21] For a helpful discussion on how limits on international offset have similar implications, see Dixon et al, 2008.

DISCOUNTING OFFSETS

To help ensure the environmental integrity of offsets, some stakeholders and policymakers have suggested that discounts be applied to address their inherent uncertainty and risk, or to drive additional emissions reductions in uncapped sectors as part of an economy-wide emissions reduction program. Under a discount, an offset that resulted in one metric ton of GHG reduction would count as less than one metric ton of allowance-equivalent compliance credit. Some groups have suggested discounts that vary by project type (see, for example, Olander et al, 2008) while others (such as ACSE) apply a uniform discount across all project types. Applying a discount can, in theory, increase the overall environmental benefit of using offsets. For example, suppose that a 20% discount is applied to the use of offsets as compliance credits under a cap-and-trade program. If one offset ton does indeed represent one ton of actual emissions reduced or removed, then use of each offset as an allowance-equivalent compliance unit generates an additional, 25% environmental benefit (1 divided by 0.8). On the other hand, if one offset ton represents less then one ton of actual emissions reduced or removed, then the discount protects against underperformance. Discounts (both system-wide and project-specific) are a significant topic of conversation in the international negotiations leading up to a post-2012 Copenhagen agreement (see, for example, Schneider, 2009 and Michaelowa, 2008).

The analysis presented in this report indicates that the potential over-crediting of mitigation by offset protocols is greater than 20%, indicating that a 20%, system-wide discount would not in itself be sufficient to cover the risk of over-crediting due to inaccurate quantification methods. Figure 6, below displays the effect of a system-wide, 20% discount in the three study scenarios compared to both offset credits issued as well as to actual domestic mitigation. Note that under the lenient protocols modeled in Scenario 2, actual domestic mitigation is nearly 40% less than the number of credits issued, or nearly 175 MtCO2e less than the discounted offset quantity.

Figure 6. Offset Credits Versus Emissions Reductions Versus System-Wide Discount – Three Scenarios
(In year 2020 at price of $30/ton)



INTERACTION OF OFFSETS WITH OTHER POLICIES IN UNCAPPED SECTORS

Offsets are, by definition, mitigation or sequestration of greenhouse gas emissions purchased by capped sectors that instead occur in sectors, such as agriculture and forestry, that are outside the emissions cap. Although most national cap-and-trade proposal have not included the agriculture and forestry sectors under the cap, several analysts have articulated reasons to include agriculture and forestry as regulated entities under the emissions cap

(Smith 2008, Pacific Forest Trust, 2009). Offsets are not the only mechanism available for reducing emissions or increasing sequestration in uncapped sectors or regions. Two other means often discussed and included in climate legislation proposed in recent years are set-asides and complementary regulations:

- **Set-asides** are the allocation of allowances or associated revenue to particular emissions mitigation activities in uncapped sectors. Under such a system, a federal program would be set up to pay for targeted mitigation activities. Set-asides are generally best suited for activities with either high uncertainty (e.g., reduction of methane emissions from rice cultivation) or high programmatic needs (Olander et al, 2008; Broekhoff and Zyla, 2008). Since set-asides are funded via allowances, they have the benefit– if successful – of reducing emissions below the level required in the cap. Like set-asides, other forms of incentives proposed – such as subsidies or tax credits – could also help achieve greater emissions reductions at lower overall cost because, unlike offsets, they would not be used to compensate for increased emissions by capped entities, thereby enabling the use of more flexible, and lower cost, measurement and verification mechanisms (Broekhoff and Zyla, 2008).

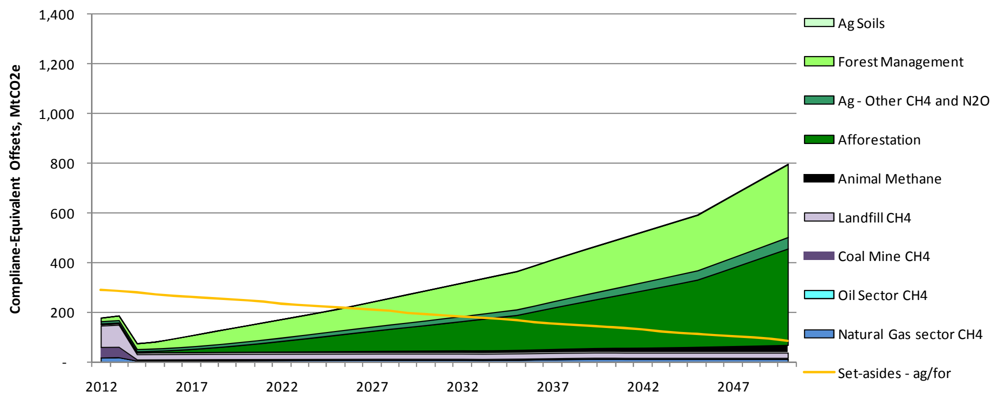
- **Regulations**, such as use of the Clean Air Act to restrict emissions, have also become possible given the Supreme Court's 2007 ruling in Massachusetts v. EPA, 549 U.S. 497 that greenhouse gases are air pollutants covered by the Clean Air Act and the EPA's subsequent proposed ruling that greenhouse gases "endanger the public health and welfare of current and future generations." (EPA, 2009d). For example, Title VIII of ACESA proposes that uncapped stationary sources that comprise "greater than 10,000 tons of carbon dioxide equivalent and that, in the aggregate, were responsible for emitting at least 20 percent of the uncapped greenhouse gas emissions" be regulated under the Clean Air Act. Candidate sources include, for example, landfills and coal mines, which are both projected to be sources of offset credits.

Either of these two strategies, while contributing significantly to overall emissions reductions, would potentially reduce the supply of credits available to capped entities for compliance. For example, if some greenhouse gas sequestration activities from agriculture and forestry were included as set-asides (as they were in S.2191), such projects would not also be eligible for offsets. Similarly, if industrial methane emissions from landfills and coal mines were included under the Clean Air Act (as they are in ACESA), the portion of these emitters that would be covered would not also be eligible for offsets, or would only be eligible for offsets in the event that they were able to reduce emissions below the levels required by the regulation.

Figure 7 below shows the potential implications of these provisions in the absence of an offset limit, assuming set-asides of agricultural and forestry carbon sequestration activities as in S.2191 and coverage of most natural gas sector, coal mine, and landfill methane under the Clean Air Act.[22] Under Scenario 1, this implies at least 200 MtCO2e per year of mitigation potential from the offset market would be moved to these other policy mechanisms. (Compare, for example, Figure 7, below, to Figure 1, which uses the same assumptions except for the introduction of set-asides and alternative regulations.) While reducing the offset supply would increase the cost to capped entities of complying with the cap, the overall cost to society could be reduced by addressing certain mitigation activities through other, potentially more cost-effective policies (Broekhoff and Zyla, 2008).

[22] More specifically, based on analysis of the EPA's national greenhouse gas inventory, we assumed 74% of natural gas sector methane, 85% of coal mine methane, and 77% of landfill methane would be covered by the Clean Air Act, with the remainder eligible for offsets, per Larsen and Heilmayr (2009).

Figure 7. Potential Domestic Offset Supply over Time - Interaction with Other Policies



OFFSET PROGRAM START-UP AND EARLY ACTION OFFSETS

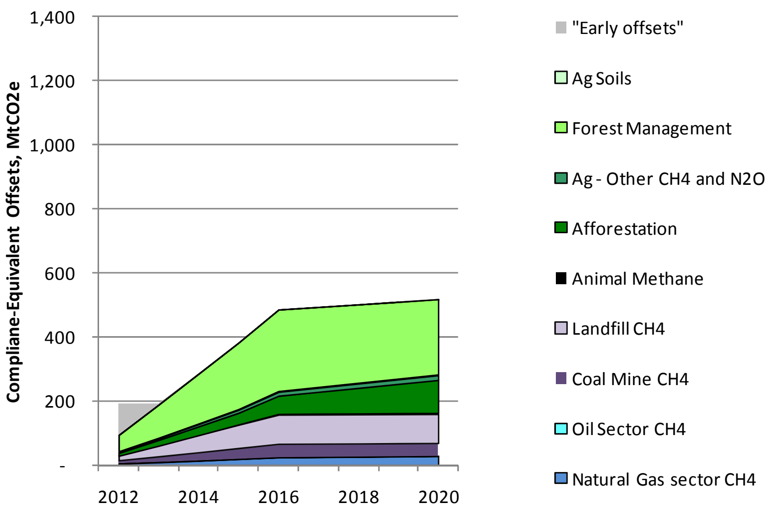
Experience from the Clean Development Mechanism (CDM) of the Kyoto Protocol suggests that lag times exist between enactment of a regulation and the market's capacity to provide offsets. Clearly, most actors – from capped entities to offset project developers to program administrators – would tend to favor an efficient and effective deployment of both technical and administrative infrastructure to encourage and enable offset project activity. Real-world constraints, however – such as limitations in administrative, technical, or market capacity, may limit market uptake in early years.

Assume, for example, a case in which general agreement on offset rules and procedures is established in 2011, enabling offset project developers to begin work on projects even as protocol details are finalized and allowing offset activity to grow from 0% to 100% of its potential over 5 years[23]. Offset supply in early years – while constrained by these realities of program ramp-up, could be partially aided by the availability of "early offsets" from the voluntary and other existing regulatory markets, as proposed in ACESA. Supposing that 100 MtCO2e of "early offset" credits are available from emissions mitigation that occurred prior to 2012[24] the supply of offsets in early years of a program could unfold as in Figure 8, with early offsets helping to provide a bridge between the voluntary and regulated offset markets and offering cost savings to capped entities.

[23] The assumption of this timeline is based on review of the experience of the Clean Development Mechanism, in which general agreement on rules and procedures was reached in late 2001 at the Marrakech accords, protocols were established in 2003, and the first Certified Emissions Reduction (CER) credits were issued in 2005 (for CERs dating back to 2003). The assumption of 100% availability in year 4 is likely at the optimistic end of potential outcomes.

[24] We use the figure of 100 MtCO2e based on analysis of annual offsets issuance in the voluntary market, which suggests that 30+ MtCO2e of offsets may be available annually by 2012. Assuming 30+ MtCO2e of offsets issued in each year 2009, 2010, and 2011 would qualify as "early offsets" available for use in 2012 and early years leads to an estimate of approximately 100 MtCO2e of "early offsets" available.

Figure 8. Potential Ramp-up of Offset Supply and Availability of Early Offsets (Applied to Scenario 1)



Program ramp-up, however, could be significantly more constrained than in this example, in which 100% offset availability is assumed in only 5 years. For example, if offset protocol development continues into 2012, investment by project developers would similarly be delayed, constraining supply and ramp-up of offset availability in early years. Additional, market challenges may also arise: such as the inability of market intermediaries to aggregate thousands of small landowners into marketable projects, or the inability of the carbon price to motivate development of new projects.

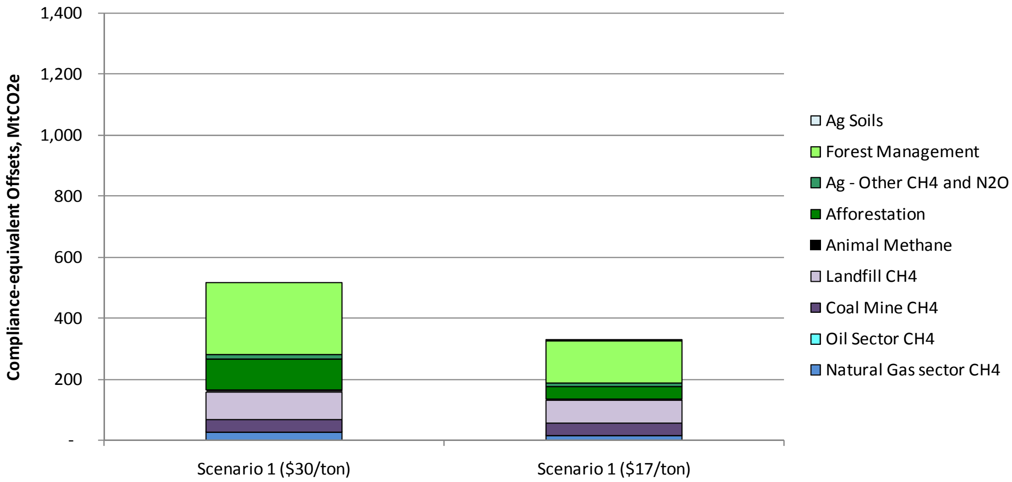
EFFECT OF ALLOWANCE AND OFFSET PRICE LEVELS

We conclude our assessment of individual cap-and-trade policy factors on offset supply by considering the impact of lower allowance price, which, in the absence of a limit on the use of offsets, is also the offset price.[25] Results presented so far have assumed an allowance price trajectory of $20 in 2012 plus 5% per year. If instead allowance prices started in 2012 at $11 and rose at 5% per year – which could be the result of the inclusion of international offsets, more-rapid-than-expected increase in mitigation technology development, a less stringent cap, or other factors[26] -- then offset supply could be diminished.

At a lower allowance price, fewer domestic offsets are supplied. In particular, under this lower price trajectory, with prices 42% to 44% lower over time than previously projected, domestic offset activity is estimated to drop 27% to 30% in Scenario 1. Figure 9, below, displays the difference in projected offset activity under Scenario 1 in 2020 at the two offset price trajectories.

[25] As discussed previously, the imposition of a limit on the use of offsets can create separate markets for allowances than offsets and result in the two products trading at different prices.
[26] The price trajectory we used closely mirrors that in EPA's Scenario 2 analysis of ACESA (EPA, 2009b).

Figure 9. Potential Domestic Offset Supply in 2020
(Scenario 1, at $30 versus $17 per ton CO2e)



LIMITATIONS OF ANALYSIS

Our discussion of individual offset policy questions has focused on a hypothetical national cap-and-trade policy. The analysis has several limitations, including:

- **Use of the EPA's marginal abatement curves for agriculture and forestry sectors likely overestimates the potential in some activities while underestimating the potential in others.** In particular, if carbon price signals prove insufficient to motivate landowners to make long-term changes in the use of their land, offset supply for agricultural and forest carbon sequestration activities could be lower. For example, family farms with generations invested in producing agricultural commodities may be reluctant to plant their farmland in trees (i.e., afforestation) – even if the long-term net present value calculations would support such an action. On the other hand, potential in some practices could be higher. The EPA's underlying FASOM-GHG model outputs *net* potential in each activity type, a practice that is likely to under-count the potential in agricultural soil sequestration since some new, additional sequestration from conservation tillage is, in effect, cancelled out in the underlying FASOM-GHG model when other landowners convert agricultural land to forest (EPA, 2009c).

- **Transaction costs could be significantly higher.** We include basic transaction costs of less than $1/ton plus a 10% brokerage fee (as applied to the market offset price) in both Scenario 2 and Scenario 3. Actual transaction costs under a regulatory offset system could be higher, however, and reduce offset potential, particularly in projects that require significant aggregation of thousands of small landowners into market-size projects, or in project types that have higher monitoring and verification costs (such as biological sequestration projects).

- **We have not included discounts for international leakage.** Little research has been conducted on emissions leakage to other countries as a result of domestic offset activity. Emissions leakage is defined as an increase or decrease in emissions outside of the project's boundary as a result of the project, where it remains uncounted and uncontrolled (OQI, 2008 and Murray et al, 2004). That is, if agricultural land is converted to forest for sequestration purposes and demand for the displaced agricultural product remains unchanged, it is likely that another area could be deforested in order to replace the land that was taken out of production, thereby negating the emissions reduction benefits of the afforestation project. Preliminary research by Gan and McCarl (2007) on leakage of forest output (not, strictly speaking, *emissions* leakage) due to domestic forest conservation policies has suggested international leakage rates to developing countries on the order of 64%, assuming that Canada, Europe, Australia, and New Zealand adopt legislation similar to that assumed in the United States. If these world regions do not have similar policies, international leakage has been estimated to be as high as 77% (Gan and McCarl, 2007).

- **Our assessment of the effect of offset protocols relies on relatively few comparative assessments.** Our assessment of the variability of creditable carbon for certain project types under different protocols builds from limited "road-test" work on a very small number of projects. For example, our assessment that creditable carbon could vary widely for forest management projects that increase rotation age is based on application of several voluntary market offset protocols to a single modeled project in North Carolina (Galik et al, 2008). Very few studies exist that compare how different protocols would generate credits for a consistent project or set of projects.

For further details on this study's methodology, please see Appendix B.

5. CONCLUSIONS AND RECOMMENDATIONS

Recent draft climate legislation in the U.S. Congress expects offsets to play an important cost containment role for capped sectors. This expectation is generally supported by government analyses, but those analyses have made assumptions about the availability of offsets that are uncertain. This study indicates that the design of offset protocols and other cap-and-trade design rules will have a significant impact on the supply of offsets in future years.

While this report provides as assessment of the impact of potential offset protocols and other cap-and-trade design variables on domestic offset supply, it is important to view the specific numerical estimates of potential future offset supply with caution, especially out as far as 2050. The US domestic offset market is still at a very early stage of development, and significant uncertainties remain. Whether and how forest and agricultural landowners respond to offset market opportunities at a large scale, for example, remains an open question.

Experience with the early international offset market under the CDM suggests it is appropriate to expect the unexpected. As illustrated in Figure 10, the current mix of offset project types in the CDM differs substantially from the mix of existing, identified, and predicted just 5 years prior. As one example, most early studies failed to predict the scale of industrial GHG projects that dominated early CDM markets.

As with modeling analyses in general, insights regarding the impact of key policy variables can be more valuable than the precise projections themselves (Peace and Weyant, 2008). With this in mind, our analysis suggests that offset supply will be strongly affected by:

- **The requirements of offset protocols**, which will dictate the quantity of *credited* emissions reduced or sequestered by each future offset project, though not necessarily the *actual* amount reduced or sequestered by a given project. In some cases (e.g., emissions reductions from livestock enteric fermentation), the details of measuring offset credits and ensuring additionality may prove so challenging that offset protocols may not be feasible. Striking a balance between quality and volume is an inherent challenge in designing the offset program. Careful attention will need to be paid to the development of offset protocol requirements in order to ensure that any offset system is achieving its intended purpose of stimulating real, additional emissions reductions while delivering cost-containment for capped entities.

- **The extent and type of other policies**, such as set-asides, other incentives, or regulations that offer the potential to reduce emissions from certain sectors or practices at a lower overall cost to society but would also reduce the supply of offsets to capped entities.

- **Constraints in offset program ramp-up and project deployment,** such as the ability of market structures, equipment and material availability, technical capacity, and landowner awareness (among other factors) to develop to near-full capacity in just a few years.

- **Barriers to offset project implementation**, such as high transaction costs and perceived risk by market participants that could hamper the delivery of offsets to the market.

- **Global economy, energy, commodity, and land prices**, which affect the ability of offset projects to compete economically with alternative practices or land uses.

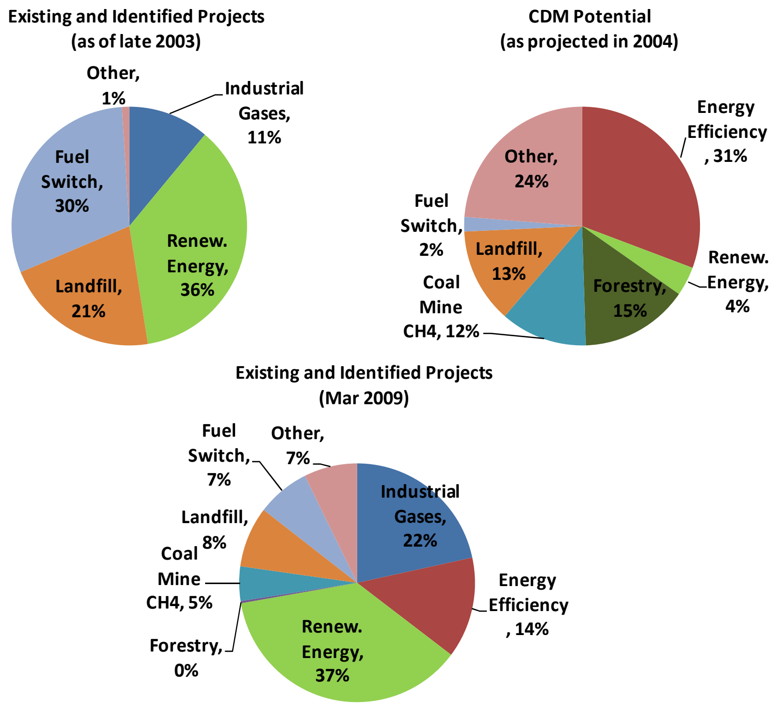
- **The effect of cap-and-trade design parameters on expected allowance prices**, and their relationship to expected offset prices, as future offset availability (especially from projects that involve considerable incremental investment cost) will be highly dependent on the expectations of offset project developers at the time project investments are made.

To address the factors above, we recommend that cap-and-trade program designers and administrators:

1. **Establish as early as possible an independent and scientifically rigorous advisory body to evaluate existing offset protocols, develop a process for new ones, and ensure offset program credibility and effectiveness.** Providing early market signals and clear regulatory guidance to project developers will be particularly important to ensure an adequate supply of offset credits in early years of the program.
2. **Pursue actions to increase both the efficiency and environmental integrity of the market.** Actions that will help to maximize both the volume of offset credits issued and the "real" mitigation benefits of offsets should be an integral part of the offset regulatory structure. These include the development of accurate, clear, and conservative crediting methodologies and clear, transparent and streamlined regulatory review processes, as well as efforts to keep transaction costs low, provide early and opaque market signals, and identify and address barriers.
3. **Tailor policy choices to the specific conditions of each project type**. Research on existing protocols and uncertainties suggests that the variability in potential credit issuance and actual mitigation potential of certain projects is much higher than others. Such projects may be better addressed through other policy approaches (Broekhoff and Zyla, 2008). Such project types may still be offered as offsets in early years to provide cost containment benefits to capped entities as a transitional mechanism while offset methods, monitoring, and infrastructure is developed and deployed.
4. **Consider a system-wide true-up mechanism** to ensure that the collective impact of individual domestic offset project activities has a corresponding impact on national net emissions (Olander and Galik, 2009). Such a mechanism would aim to compare changes in the national emissions inventory to the total offsets credited and then adjust offset methodologies for identifiable differences between offset crediting and actual reductions/removals. In addition to adjusting offset methodologies, this mechanism could take a variety of forms, including tightening or loosening of the cap, drawing down/building up a strategic reserve of allowances, or discounting or awarding bonuses to future crediting of offset projects.
5. **Utilize offset discounts in a selective and staged manner.** System-wide discounts – as included for international offsets in the June 22, 2009 version of ACESA and originally also proposed for domestic offsets in the initial Waxman-Markey discussion draft, as well as in international discussions regarding CDM (Schneider, 2009; Michaelowa, 2008) – help to generate increased emissions mitigation benefits from each offset. Discounts also depress the trading price of offsets, an effect that could lower the supply of projects offering additional reductions, which are more price-sensitive than the projects more likely to happen anyway (i.e. less additional). One option would be to increase offset discounts over time. Lower discounts in early years of the offset programs would tend to shorten payback times and encourage investment by project developers, while increasing discounts in later years would help to maximize overall environmental benefits.
6. **Improve the ability of models to represent offset rules and protocols.** Although our research offers initial, general quantification of the effect of protocols on offset supply, further, detailed "road-tests" of offset

protocols could help improve these estimates. Similarly, further research into actual landowner willingness to engage in offset projects – beyond simplifying economic assumptions that assume "rational" decisions – would be beneficial. Furthermore, inclusion of actual protocol characteristics and effects in underlying modeling of offset potential – such as the models that produce marginal abatement curves – would help develop more integrated, detailed, and "real world" estimates of offset supply.

Figure 10. Percentage of Emissions Reduction/Removals from CDM Projects



Sources: Erik Haites, PCFplus Report 19, June 2004; UNEP-Risoe CDM pipeline analysis, as of March 1, 2009, www.cdmpipeline.org

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APPENDIX A. OFFSET SUPPLY CURVES – DEVELOPMENT AND USE

This appendix discusses the development and use of offset supply curves to date in various analyses. It also explains the methodology developed and used by the authors in this analysis and identifies key differences as compared to other studies conducted to date.

OFFSET SUPPLY AND MARGINAL ABATEMENT COST CURVES

In this paper, we use the term *offset supply curve* to mean a curve that describes what quantity of offsets would be supplied at a range of market prices *after* considering the impact of measurement and quantification protocols and other market factors or barriers. By including the effects of offset protocols, offset supply curves differ from the *marginal abatement cost curves* (MACs) on which they depend. Marginal abatement cost curves instead provide estimates of the economic potential of activities possibly eligible for offsets without directly considering what fraction of the curve (either more or less) might ultimately be creditable as an offset.

Recent efforts to develop marginal abatement cost curves for particular greenhouse gas mitigation options have generally relied on one of two methods: "bottom-up" engineering estimates of the costs of particular practices and technologies, or "top-down" models that solve for a market-clearing equilibrium. Both of these methods are described briefly below.

1. **"Bottom-up" analyses rely on estimates of the costs and benefits of particular practices and technologies.** Under this method, analysts estimate both the costs (e.g., capital and operating costs) and benefits (e.g., value of captured methane for electricity or heat generation, value of greenhouse gas offsets) for the corresponding abatement potential of each option, as measured relative to business-as-usual emissions and practices. Based on these estimates of costs and benefits, analysts then calculate the break-even price, which is the price at which entities are assumed to take action. Individual practices or technologies are then ordered in ascending order of breakeven price and plotted against their greenhouse gas abatement potentials to develop the marginal abatement curve, where abatement potentials are measured relative to baseline, "business-as-usual" emissions and practices. Bottom-up estimates are generally most appropriate for technologic options that are not subject to spatial competition for resources (e.g., land) or significant temporal market feedbacks and dynamics (e.g., commodity prices, technological progress). A bottom-up method was used by the EPA and its partners in the development of its numerous non-CO_2 MACs for the U.S. and other world regions and countries (EPA, 2006), MACs that have served as the basis for nearly all studies of offset supply from coal mines, the oil and natural gas sectors, and landfills since, including analyses in this study as presented in Section 4.

2. **"Top-down" models, by contrast, attempt to capture the dynamics of the larger economy.** Equilibrium models (whether "partial" or "general") solve for market-clearing prices that match the demand for goods and services to supply from producers. Such models solve for equilibrium quantities and prices by assuming that producers and consumers maximize their welfare or profits, making "rational" decisions, usually with full understanding of future prices and trends, i.e., "perfect foresight" (Repetto and Austin, 1997). Examples of such top-down models used to generate marginal abatement curves for potential offset activities include FASOM-GHG and MiniCam, among others. FASOM-GHG, which focuses on forestry and agricultural land and commodities, is an optimization model that solves for equilibrium over both space (e.g., land use) and time.[27] MiniCam is a partial equilibrium, integrated assessment model that balances supply and demand for commodities such energy and agricultural products. In both models,

[27] Marginal abatement cost curves developed using FASOM-GHG also include the concept of *competitive potential*, which reflects the potential for higher greenhouse gas prices to increase profitability of a variety of competing GHG-reducing or sequestering options and therefore divert potential from less profitable to more profitable options (EPA, 2005). Accordingly, by considering competitive potential, increasing prices may actually decrease potential in some options.

the potential greenhouse gas effects of all measures are calculated relative to projections of baseline, business-as-usual conditions.

In general, both the bottom-up and top-down methods estimate the theoretical economic potential of greenhouse gas mitigation options. As the authors of the studies and corresponding models generally point out (e.g., EPA, 2006; EPA, 2005), price signals may not be enough to incent entities to implement emissions reductions, particularly under "real world" market conditions or the additional requirements of an offset crediting framework. For example, barriers such as social acceptance or high transaction costs associated with offset crediting can also constrain adoption.[28] The unique requirements of a national offset crediting protocol, as called for in both S.2191 ("Lieberman-Warner") and HR 2454 ("Waxman-Markey"), among other bills, may further affect offset supply, as program administrators will, perhaps more so than current operators of voluntary offset markets, implement particular requirements for registering and verifying offset credits. In short, as stated by the EPA (2006) authors, "caution should be taken not to apply the MAC data directly as offset curves."

The most common approach to adapting marginal abatement curves to yield offset supply curves is to apply transaction costs and /or adjustment factors to account for protocol or market factors such as achievability, uncertainty, or additionality. However, any such adjustment factors must be made relative to what is already included in the underlying marginal abatement curves. Table 3 describes how protocol and other factors are treated in the EPA's marginal abatement curves.[29]

Table 3. Key Factors in an Offset Protocols and Corresponding Treatment in EPA's Marginal Abatement Curves

Factor	Description	Treatment in Agriculture and Forestry Marginal Abatement Curves (EPA, 2009a) (produced using the FASOM-GHG model)	Treatment in Industrial and Waste Marginal Abatement Curves (EPA, 2008) (produced using engineering estimates)
Eligibility	What specific activities would be eligible as offsets	Included, with caveats. EPA analysts performed a review of what practices could mitigate emissions, but eventual offset protocols may or may not allow the same activities	Included, with caveats. EPA analysts performed a review of what practices could mitigate emissions, but eventual offset protocols may or may not allow the same activities
Additionality	Project activities can only count as offsets if they are departures from baseline practices (e.g., business-as-usual or regional average practices) i.e., the project would not have "happened anyway."	Included implicitly, but not directly. FASOM-GHG implicitly addresses additionality because it only accounts for greenhouse gas mitigation over and above estimated business-as-usual practices (Adams et al, 2005). FASOM-GHG does not, however, "impose additionality as a requirement for GHG payment – in essence all GHG effects are potentially eligible for payment" (EPA, 2005). An offset protocol's requirements for additionality could therefore affect the potential for mitigation as compared to FASOM-GHG estimates	Included, with some caveats. EPA (2006) only accounts for mitigation relative to a projected baseline. However, the authors note that particular caution is warranted for options that depend on energy supply. For example, a carbon price (as a result of a national cap-and-trade program) could result in reduced coal use, which may, in turn, reduce methane emissions from coal mining as a result of economic factors rather than installation of a mitigation technology and should therefore be non-additional.
Baselines	Estimates of "business-as-usual" emissions and adoption of mitigation practices in the absence of a greenhouse gas policy	Included: FASOM only accounts for greenhouse gas mitigation over and above its estimated business-as-usual practices included in the model (McCarl et al, 2005).	Included: EPA only accounts for mitigation over and above estimated business-as-usual practices and also includes advancing market penetration of some mitigation technologies in the baseline (EPA, 2006)
Uncertainty	Many offset projects involve inherent measurement or scientific uncertainty (e.g.,	Not included. While the authors note concerns and potential project-level approaches, they are not included in the FASOM-GHG model	Not explicitly included. The authors do not apply specific uncertainty discounts, but they stress that, in general, their

[28] The discussion here focused on the bottom-up and top-down methods of MAC development. However, a third approach also exists, revealed preferences, which, by contrast, implicitly accounts for some of these factors (Stavins, 1999).

[29] EPA collaborators at the Nicholas Institute for Environmental Policy Solutions and the Electric Power Research Institute (EPRI) are expected to release a joint working paper exploring some of these factors in more detail for the FASOM-GHG model in summer, 2009.

	soil carbon sequestration).	(EPA, 2005; Adams et al, 2005).	approach and emission factors are conservative (EPA, 2006)[30]
Leakage	Occurs when activities to mitigate emissions in one place or time lead to increase emissions or reduced sequestration elsewhere or at a later date.	Includes domestic, but not international, leakage. FASOM-GHG uses a comprehensive accounting method that accounts for domestic leakage. FASOM-GHG does not capture leakage to outside the U.S., however (EPA, 2005).	Not included.
Permanence	The longevity of a greenhouse gas offset, which can be affected by numerous factors, including future actions of the project owner.	Includes accounting for reversal risk (i.e., impermanence) via a comprehensive accounting, rather than project-based, approach (EPA, 2005). This method, while yielding reasonable national averages, does not address the potential treatment of reversal risk in offset protocols such as buffers or ex ante discounting methods.	Included, by definition. Options to avoid or use methane for alternative uses are permanent by definition since they prevent the release of the gas or else destroy it in the service of creating energy
Crediting Period	Period over which greenhouse gas reductions or sequestration are measured and verified as offsets.	Not included.	Not included.
Transaction Costs	Costs needed to bring the offset project to market, including costs to aggregate projects, measure and monitor, and certify projects, among others.	Not included. The EPA (2005) authors note that transaction costs could be "considerable" and suggest that the addition of "data on the size and distribution of transaction costs across mitigation options would be a helpful addition".	Not included.

For example, consider the case of additionality. Since marginal abatement curves estimate abatement quantity and cost relative to a business-as-usual (BAU) projection, by definition, BAU activities cannot generate abatement tons in these analyses. In principle, in these analyses, all additional activities are assumed to be credited; similar, no non-additional activities are credited: there are neither false negatives nor false positives. Unfortunately, it is impossible to design an offset program with the omniscience and determinism of a modeling exercise. Real-world programs utilize additionality rules that inevitably make both false positives and false negatives. In particular:

- To the extent that actual offset protocols err on the side of assessing BAU activities as additional – or overstating baseline emissions or underestimating leakage -- potential offset supply would be higher than projected by EPA/FASOM modeling. As experience with CDM has shown, such errors can be significant; some estimates suggest that over a third of all offsets generated to date might be non-additional. Such (non-additional) tons do not tend to show up in a typical offset supply curves or model analyses, though they do show up in real offset programs.
- Conversely, if actual offset protocols err on the side of conservatism and stringency -- overestimating leakage, assessing additional activities as non-additional, or understating baseline emissions -- potential offset supply would be lower than projected by typical offset supply curves.

Some, but not all, modelers account for these possibilities through discount factors, where the credited greenhouse mitigation is discounted by a percentage. Discounting has clear policy relevance: for example, early versions of the Waxman-Markey discussion drafts, unlike previous proposals, included a specific discount of 20% for all offset projects.[31]

In addition to discount factors, some analysts also use transaction cost estimates, and/or diffusion curves that simulate the adoption of practices over time. The following section summarizes specific approaches taken by analysts to generating offset supply curves from marginal abatement curves.

[30] EPA (2006) authors note their use of conservative emissions factors for several project types, as well as use of a global "average" approach that results in mitigation potential estimates that are more conservative than those reported in the EPA's national greenhouse gas inventory.
[31] "A covered entity may satisfy a percentage of its compliance obligation by holding 1.25 offset credits in lieu of an emission allowance" (p. 372 of the March 31st, 2009 Discussion Draft)). Since 1.0 is 80% of 1.25, this is akin to a 20% discount.

TREATMENT OF OFFSET SUPPLY IN EXISTING POLICY STUDIES

Few policy studies have incorporated the various components of existing offset protocols into quantitative estimates of offset supply. Those that have incorporated protocol factors have generally applied select adjustments to the EPA's underlying marginal abatement curves (MACs). For example, the Energy Information Administration (EIA) used results from its prior research into diffusion of new technologies to dampen the uptake of offsets in early years (EIA, 2008). Charles River and Associates International (CRA), by contrast, has used escalating transaction cost tiers to model the extra effort required to aggregate, register, monitor, and verify greenhouse gas offsets under a regulated system (Montgomery and Smith, 2008). Both approaches have the effect of decreasing projected offset supply in any given year. Neither study, however, considered specific offset protocols already in use to assess how such protocols might over or under credit the supply estimated by the EPA's underlying models.

In contrast to the approach taken by government and academic institutions in offset policy studies, consulting and brokerage businesses to the existing voluntary carbon market generally take a different approach. In particular, these firms (such as Ecosecurities, Natsource, ICF, PointCarbon, and others) tend to pay closer attention to recent market experience with offsets and how the potential rules and methods might determine offset project feasibility and, in turn, the quantity of credits ultimately generated. Such studies can project offset quantities dramatically different than those projected in policy studies. For example, PointCarbon has estimated – based on current trends in the voluntary offset market – that offset supply in 2012 might be on the order of 30 million tons CO2e (PointCarbon, 2009). These types of market analyses tend to use much more detailed analyses of offset supply to guide their business planning, yet their underlying assumptions are rarely made public.

Table 4, below, summarizes how recent studies of cap-and-trade economics have considered key offset protocol factors. Note that in many cases, the studies use the EPA's underlying modeling results of mitigation potential in sectors outside the cap (e.g., agriculture, forestry) and so could – in theory – supply offsets. These modeling results are presented by the EPA and others as marginal abatement curves that relate greenhouse gas (GHG) prices to GHG mitigation potential and – although not intended to strictly represent offset potential, are often used as such.

Table 4. Approaches to Including Offset Protocols in Selected Studies of Domestic Offset Supply[32]

Study	Additionality and Baselines	Uncertainty & Measurement	Permanence	Leakage	Transaction Costs & Other Market Uptake Factors
EPA's analysis of ACESA (EPA, 2009b)	▪ Only counts reductions beyond business-as-usual	▪ Does not address uncertainty	▪ No consideration of permanence other than that embedded in the underlying marginal abatement curves	▪ No consideration of leakage other than that embedded in the underlying marginal abatement curves	▪ No transaction costs applied
Congressional Budget Office (CBO)'s analysis of ACESA (CBO, 2009)	▪ Unspecified	▪ Unspecified	▪ Unspecified	▪ Unspecified	▪ Applied transaction costs and modified EPA's MAC curves to restrain the rate at which offset projects entered the market
EPA's analysis of Lieberman-Warner	▪ Same as above	▪ Does not	▪ Same as	▪ Same as above	▪ No transaction costs

[32] For a definition of additionality, permanence, and other terms in this table, please see Table 3 in Appendix A.

S.2191 (EPA, 2008)		address uncertainty	above		or other market uptake factors applied
EIA's analysis of Lieberman-Warner (EIA, 2008)	▪ Same as above	▪ Unspecified	▪ Same as above	▪ Same as above	▪ Discounts most project types by 25% to account for achievability and transaction hurdles ▪ Applied market penetrate curve based on energy technologies
CRA (Montgomery and Smith, 2008)	▪ Same as above	▪ Does not address uncertainty	▪ Applied cost function to incorporate some quality risks, e.g., due to need to prevent leakage from forest management	▪ Applied cost function and select discounts (e.g., soil sequestration) to incorporate some consideration of permanence.	▪ Applied project-type-specific distribution function of transaction costs ▪ Applied project-specific lag times (especially for afforestation)

In this study, we attempt to include all of the protocol factors included in Table 4 by constructing hypothetical scenarios of how cap-and-trade program administrators might treat offset supply. Details of our assumptions and data sources are included in the Appendix B.

APPENDIX B. – MODELING METHODOLOGY AND ASSUMPTIONS

MODELING METHODOLOGY

Modeling of offset supply for this project was conducted in a spreadsheet model. The foundation of all analyses was the EPA-generated marginal abatement curves (MACs) for agriculture and forestry activities (EPA, 2009a; EPA, 2005) as well as industry and waste activities (EPA, 2006) that relate GHG prices (as the vertical axis) to mitigation potential (the horizontal axis). Offset protocol factors were then applied to those offset supply curves and either shifted the curves left/right (factors that affect quantity of offset credits issued) or up/down (e.g., transaction costs). In addition, offset discounts (whether system-wide or project-type-specific) were also assumed to affect the trading price of offsets. For example, a 20% discount as proposed in the initial Waxman-Markey discussion draft would both decrease the supply of potential offsets by 20% (shifting the supply curve left) as well as decrease the price at which those offsets would be sold (an affect that was implemented in the model by adjusting the price axis). Specific parameters used in each of the study's three main scenarios (plus a fourth scenario described in Box 3 of the main report) are documented in the next section of this appendix.

The EPA's underlying MAC curves represent decadal averages (e.g., the 2010 MAC represents the average mitigation potential for each year in the decade 2010-2019). We "anchored" each decadal MAC in the year ending in "5", (e.g., 2010 MACs shifted to 2015), a practice not used by EPA (2008) but initially suggested to us by the authors of EIA (2008). We then linearly interpolated mitigation potential across these decadal MACs to each year between 2012 and 2050, with the exception of years 2012-2014, for which the 2010 MACs were used to avoid edge effects of projecting back before the first MAC available (the 2010 MAC, reassigned to 2015).

All discounts on quantities (including any system-wide discount) were then applied to adjust the quantities available, as were transaction costs. Discounts were also used to adjust the price axis to reflect "allowance-equivalent" offset credits.

In most cases, the price of compliance-equivalent offsets is assumed to be the same as the price of allowances. Allowance prices therefore are a key input and are either defined by simple, hypothetical scenarios (e.g., $20 in 2012 plus 5% per year) or are taken exogenously from existing policy studies (e.g., EPA 2009b or CBO, 2009). If the offset limit would constrain offset use below the level normally supplied at the allowance price, however, the price of offsets is calculated by calculating the point at which the aggregate (all project type) offset supply curve (after applying any adjustments and transaction costs) intersects the offset limit. If set-asides are included in the policy being modeled, the set-aside level is added to the offset limit for the purpose of calculating the market-clearing offset price.

Once the final price of compliance-equivalent offsets is determined (either as the allowance price, or if the offset limit is binding, the intersection of the aggregate supply curve with the offset limit, as described above), the model then uses the price in each year as the basis for linearly interpolating projected offset quantity across the various price scenarios used in the underlying marginal abatement curves.

If set-asides are called for in the model run, they are removed from the resulting quantity of offsets purchased based on the relative share of (non-zero) project types available as offsets at the market clearing price.

SCENARIO ASSUMPTIONS

A key challenge in determining reasonable offset protocol parameters is that all such factors must be assessed relative to what is already included in the underlying MACs. This involved examining the assumptions of underlying models (e.g., FASOM-GHG) and coordinating with their authors and/or practitioners. While we made the best judgments we could, uncertainty remains, and we find substantial room for further work on this topic. Table 5 documents the specific assumptions used in each Scenario.

Table 5. Assumptions Used in Analytical Cases

	Scenario 1: MACs as Offset Supply Curves	Scenario 2: Focus on Maximizing Credits	Scenario 3: Focus on Environmental Integrity	Scenario 4: Barriers to Implementation
MACs used	▪ EPA (2009) for agriculture and forestry options ▪ EPA (2006) for all other (i.e., industry) options as released in EPA (2008)	▪ Same as Scenario 1	▪ Same as Scenario 1	▪ Same as Scenario 1
Project Type Eligibility	▪ All options included in the MACs (except where noted)[33]	▪ All options included in the MACs (except where noted), as in Scenario 1	▪ All options included in the MACs (except where noted), as in Scenario 1	▪ All options included in the MACs except: o Agricultural N2O (fertilizer, pasture), rice CH4, enteric fermentation CH4 all excluded due to infeasibility of protocols o Natural gas sector, coal mine, and landfill methane emissions would be regulated under the Clean Air Act after 2013. o Avoided deforestation and forest protection excluded due to high uncertainty, risk o Others, where noted[33]
Scale-up	▪ No scale-up factors used in base runs, but scale-up is addressed for specific proposals such as Waxman-Markey (see discussion of program start up and early action offsets in main body	▪ Same as Scenario 1	▪ Same as Scenario 1	▪ Start scale-up at 0% in 2011 for all options and ramp up to "full" implementation (subject to other constraints) at: o 10 years for industrial, waste, and animal CH4 projects

[33] In some analyses included in this report specific to the Waxman-Markey Discussion Draft, we have assumed that most natural gas sector, coal mine, and landfill methane emissions would be regulated under the Clean Air Act. Specifically, we assume that 74% of natural gas sector CH4, 85% of coal mine CH4, and 77% of landfill CH4 assumed to be covered by other mechanisms Waxman-Markey's March 31, 2009 discussion draft proposed inclusion of these sectors under the Clean Air Act. The percentages listed here are taken from Larsen and Heilmayr (2009)

	of report)			o 20 years for afforestation / forest management projects
Overall availability	▪ 100% of MAC technically available except for natural gas sector methane, for which 50% is achievable[34]	▪ 100% of MAC available except for natural gas sector methane, for which 50% is achievable[34]	▪ 100% of MAC available except for natural gas sector methane, for which 50% is achievable[34]	▪ Same as other scenarios except: o 50% [?] of additional soil sequestration, forest management projects denied due to stringency [???]
Additionality / Baselines : Approach to Crediting "Business-as-usual" activity	▪ Assume the EPA's MACs include only additional tons and do not credit any BAU activity	▪ 100% of BAU conservation and no-till activity is eligible for crediting at 0.5 tons per acre (including both pre-existing BAU and BAU growth) for 15 years from either 2012 or beginning of the activity, whichever is later [35] ▪ 100% crediting of existing CRP land at 1.4 tons per acre per year for 15 years from 2012[36] ▪ 100% of existing landfill methane recovery continues to qualify[37] ▪ Minimum crediting of BAU activity for other options. Assume all of the EPA's MACs already exclude this BAU activity.	▪ Assume the EPA's MACs include only additional tons and do not credit any BAU activity	▪ Assume the EPA's MACs include only additional tons and do not credit any BAU activity
Additionality / Baselines: Effect of protocol on supply of offsets	▪ Assume the EPA's MACs include only additional tons and do not credit any BAU activity	▪ 171% of emissions reductions in the extended harvest rotation portion of the FASOM forest management MAC is creditable[41] ▪ 171% of emissions reductions in the increased management intensity portion of FASOM's forest management MAC is creditable. [38] ▪ 115% of emissions reductions in the landfill MAC is creditable[43] ▪ 131% of emissions reductions in the afforestation MAC (and the reforestation portion of the forest management MAC) is creditable[39]	▪ 67% of emissions reductions in the estimated extended harvest rotation portion of the FASOM forest management MAC is creditable[41] ▪ 67% of emissions reductions in the increased management intensity portion of the FASOM forest management MAC is creditable[42] ▪ 100% of emissions reductions in the landfill MAC is creditable[43] ▪ 80% of emissions reductions in the afforestation MAC (and the reforestation portion of the forest management MAC) is creditable[44]	▪ Assume the EPA's MACs include only additional tons and do not credit any BAU activity, as in Scenario 1

[34] Per EPA (2008)

[35] 0.5 tons is the average sequestration rate of transitioning from conventional to conservation tillage across all regions in Lewandrowski et al, 2004, Table 4.2

[36] 1.4 is the average sequestration rate of transitioning from continuous annual cropping to grassland across all regions in Lewandrowski et al, 2004, Table 4.2. We assume the stock of CRP land of 33 million acres remains constant over time.

[37] According to the EPA's Landfill Methane Outreach Program, an estimated 5.2 MtCO2e is currently reduced through capture of landfill gas.

[38] We assume that the creditable portion of increased management intensity would be the same as for longer rotation ages. See footnote 41 for discussion of estimate for longer rotation ages based on supporting data from Galik et al (2008).

[39] We assume that a maximum crediting case would reflect inclusion of wood products, which to first order are assumed to produce no added sequestration in FASOM-GHG (since to first order the amount of wood products in use is not significantly increased relative to the amount produced.) See also Figure 3-3 of EPA (2005), which suggests even if forest products are considered as a benefit for afforestation products they amount to a de minimis (<5%) contribution to carbon accumulation over a 120 year timescale. Lazarus et al (2009) estimate that carbon in wood products in the draft

		▪ 145% of emissions reductions in the soil sequestration MAC is creditable[40] ▪ 100% of EPA's MACs are creditable for all other activities	▪ 100% of EPA's MACs are creditable for all other activities	
Uncertainties (measurement, variation)	▪ No discounting for uncertainty	▪ No discounting for uncertainty	▪ 10% for ag soil sequestration[45] ▪ 25% for "other agricultural CH4 and N2O"[46] ▪ 10% for all forestry options[47] ▪ No other uncertainty discounts	▪ No discounting for uncertainty
Leakage	▪ Assume the EPA's MACs	▪ No leakage assessments[48]	▪ 24% leakage discount for afforestation[49]	▪ Assume the EPA's MACs already

CCAR protocol amounts to 31% of carbon in other pools. Including wood products would, therefore, expect to increase creditable carbon by 31% relative to the other pools assumed to be dominant in FASOM-GHG MACs.

[40] EPA (2005) uses a dynamic soil sequestration curve that reaches saturation at year 15 (page 2-10). The approximate annualized rate of sequestration based on such a curve is 0.34 tCO2/acre/year based on analysis of a similar curve (by the same author West) published in Kim, McCarl, and Murray (2008). Regional estimates in Lewandroski et al (2004) average 0.5 tCO2/acre/year and existing protocols (i.e., CCX) use sequestration rates up to 0.6 tCO2/acre/year. We assume a protocol could credit at 0.5 tCO2/acre/year, which is 45% higher than the inferred annualized figure of 0.34 tCO2/acre/year assumed to be included in FASOM. This additional 45% would be creditable but considered an additional environmental benefit in our analysis.

[41] Per comparative analysis of creditable carbon (before deductions for leakage, buffers, or uncertainty) for extended rotations in alternative protocols in Galik et al (2008). Supporting spreadsheets shared by the author indicate that, over a 100-year period in the modeled, hypothetical project in the Calhoun Experimental Forest, the CCX protocol would credit approximately 4,500 tCe for wood products and the hypothetical HFF protocol, which we assume (after discussion with Galik) to be most like what is likely included in FASOM-GHG, would credit approximately 6,300 tCE from all pools included in the HFF protocol (but excluding wood products). Inclusion of wood products could therefore increase crediting an estimated 71% relative to HFF (4,500/6,300), a figure that is used for a maximum crediting scenario relative to the FASOM-GHG MACs, which include only de minimis carbon sequestration in wood products. The same supporting spreadsheet indicates that crediting in optional pools within CCAR would total an estimated 2,100tCe, which represents 33% of the 6,x300 total under HFF (or, respectively, 40% of the total CCAR crediting). We therefore assume that a stringent protocol that did not include such optional pools could credit only 67% of the FASOM-GHG MAC. We recognize that this approach to over- or under-crediting obscures the high variability over time; however, our goal is not to specifically evaluate the crediting over time of specific protocols but instead to gain a single estimate of total potential over or under crediting under a range of possible crediting approaches.

[42] We assume that the creditable portion of increased management intensity would be the same as for longer rotation ages. See footnote 41 for discussion of estimate for longer rotation ages based on Figure 4 in Galik et al (2008).

[43] The EPA MACs in EPA (2006) represent methane recovery for energy and flaring (EPA 2003), which are the sole options currently credited in the offset market. Protocols differ, however, in their accounting for emissions reductions associated with methane destruction. Some protocols -- Regional Greenhouse Gas Initiative (RGGI), Climate Leaders, Climate Action Reserve (CAR) -- use the same 10% assumption for soil oxidation also used in the EPA national inventory, while others (CCX, CDM) do not. Assuming that 10% is a reasonable estimate for soil oxidation, these latter protocols overcredit reductions by slightly over 10% (1-1/1.1). Protocols also differ in their treatment of combustion efficiency from similar combustion devices, ranging in most cases from 90% (closed flare, CDM) to 100% (all devices, Chicago Climate Exchange or CCX). We assume that future protocols can follow a test-based approach to combustion efficiency (like CAR) under a "maximize environmental integrity" approach, while under a maximize crediting scenario a simple 100% combustion rate would be assumed. Assuming that 95% represents a reasonable average combustion rate, we suggest the follow over/under crediting rates relative to EPA MACs:
Max env. integrity = 0% difference from MACs; Max crediting = 15% overcrediting relative to MACs.

[44] According to information shared by the EPA, approximately 20% of sequestration in afforestation in the FASOM-GHG model is in forest soil, which is an optional pool in most protocols (e.g., RGGI, Climate Leaders, CCAR). A protocol that did not include forest soil is therefore assumed to credit about 80% of the mitigation potential in the FASOM-GHG MAC.

[45] Kim and McCarl (2009).

[46] Per Ogle (2009), the uncertainty in the national soil N2O inventory is +49%/-33%. According to FASOM-GHG results data provided by the EPA, soil N2O represents approximately 17% of the "Other agricultural CH4 and N2O" MAC. Uncertainty in enteric fermentation emissions factors provided by the IPCC is listed at 20%, a factor that is used for the enteric fermentation portion of the MAC, estimated at 43% from EPA-provided data. Given lack of information, this 20% figure was also assumed for the rice and other methane portion of the MAC (estimated at 17%) and the 33% figure was used for the agricultural pasture N2O emissions (estimated at 23% of the MAC). The weighted average uncertainty estimate used for this "Other agricultural CH4 and N2O" category is therefore 25%.

[47] Assumption used by Galik et al (2008) based on prior draft CAR protocol. Since the draft CAR protocol is for all forestry options (not just forest management), this 10% uncertainty discount is applied to all forestry options

[48] Note that by not using leakage discounts, the creditable offsets increase for any option where leakage was implicit in FASOM: namely, afforestation and lengthened timber rotations. See footnotes 49 and 50.

	already account for domestic leakage		▪ 53% leakage discount for extending rotation age[50] ▪ 5% leakage discount for Ag soil sequestration [51] ▪ 0% leakage discount for reforestation, increased forest management intensity component of forest management in FASOM[52] ▪ 0% leakage discounts for all other project types	account for domestic leakage, as in Scenario 1
Permanence / Crediting Periods	▪ No buffer requirements or permanence discounts are applied, implying the federal government absorbs this risk.	▪ 10% of each ag/forestry sequestration MAC is added back in to account for implicit treatment of permanence in FASOM-GHG[53] ▪ 0% permanence adjustments for all other options	▪ 10% net risk discount for all ag/forestry sequestration options[54] ▪ 0% permanence discounts for all other options	▪ No buffer requirements or permanence discounts are applied, as in Scenario 1
Transaction / Other Costs	▪ No transaction costs applied	▪ $0.41 per ton basic transaction costs for all forestry options; $0.76 for landfill and natural gas sector methane projects [57] ▪ $0.36 per ton for oil sector methane projects, $0.23 for coal mine methane projects[58] ▪ $0.89 per ton basic transaction costs for all other options[55] ▪ 10% adder to direct costs for all options for market intermediation[56]	▪ $0.41 per ton basic transaction costs for all forestry options; $0.83 for landfill and natural gas sector methane projects[57] ▪ $0.36 per ton for oil sector methane projects, $0.23 for coal mine methane projects[58] ▪ $0.89 per ton basic transaction costs for all other options[59] ▪ 10% adder to direct costs for all options for market intermediation[60]	▪ Same transaction costs as Scenario 3 except: o Additional higher cost tranche for small landowner portion of afforestation, lengthened timber rotation, and increased forest management intensity to reflect "inducement costs"

[49] For example, CCAR's December 2008 draft forest project protocol assigns a default leakage rate of 24% for afforestation on land that was cropland. Leakage risk for afforestation on land that was grazing land can be up to 50%. Note that this 24% leakage rate is assumed to cancel out the leakage implicit in FASOM-produced MACs, resulting in zero net change to the FASOM-produced MACs.
[50] The 53% estimate was calculated using the method outlined in Galik et al (2008) and based on Murray et al (2004) using national elasticities as in Willey and Chameides (2007). This leakage discount is assumed to cancel out leakage implicit in FASOM-produced MACs.
[51] Murray, Sohngen, and Ross (2007) suggest a leakage factor of approximately 5%. However, Table 6-2 in EPA (2005) suggests that agricultural soil carbon leakage is already accounted for in FASOM-GHG, at approximately 6%. Therefore, we assume any leakage factors applied by a protocol would cancel out with the leakage already accounted for in FASOM-GHG.
[52] CCAR's December 2008 draft forest project protocol assigns a leakage rate of 0% for reforestation on land that was historically timberland, a definition of reforestation that matches that in FASOM-GHG (EPA, 2005). Since increased management intensity is similar, in that it increases productivity on existing forest lands, we assume it also would have a 0% leakage rate.
[53] As described in footnote 54, we assume a buffer of 20%, half of which is already accounted for by FASOM-GHG's implicit treatment of permanence. If no risk buffer is used, then project-level crediting would increase relative to FASOM-generated MACs. Note that a protocol that used no risk buffer would, in effect, transfer the risk to the cap-and-trade program administrator.
[54] The MACs for all sequestration options (EPA, 2005; EPA, 2009) are generated using FASOM-GHG, which implicitly includes accounting for some impermanence (i.e., reversal) risk through a comprehensive accounting approach and use of average production rates. Protocols, however, typically require buffers of 20% (e.g., CCX) or more (e.g., CCAR , which uses a multi-step formula). Given lack of better information, we assume a 20% buffer discount, half of which we assume to already be accounted for in FASOM-GHG, for a net permanence discount of 10%.
[55] Per overall average in Antinori and Sathaye, 2007 updated to 2005 dollars
[56] 10% is assumed to be the total brokerage fees and risk-adjusted returns to investors
[57] Figures cited are the mean transaction costs for all forestry and fuel capture project types, respectively, in Antinori and Sathaye, 2007 updated to 2005 dollars from that study's 2002 dollars using the consumer price index.
[58] Unpublished survey of project developers conducted by World Resources Institute.
[59] Per overall average in Antinori and Sathaye, 2007 updated to 2005 dollars.
[60] 10% is assumed to be the total brokerage fees and risk-adjusted returns to investors.

				and/or substantial project aggregation needs

APPENDIX C: IMPLICATIONS FOR THE AMERICAN CLEAN ENERGY AND SECURITY ACT

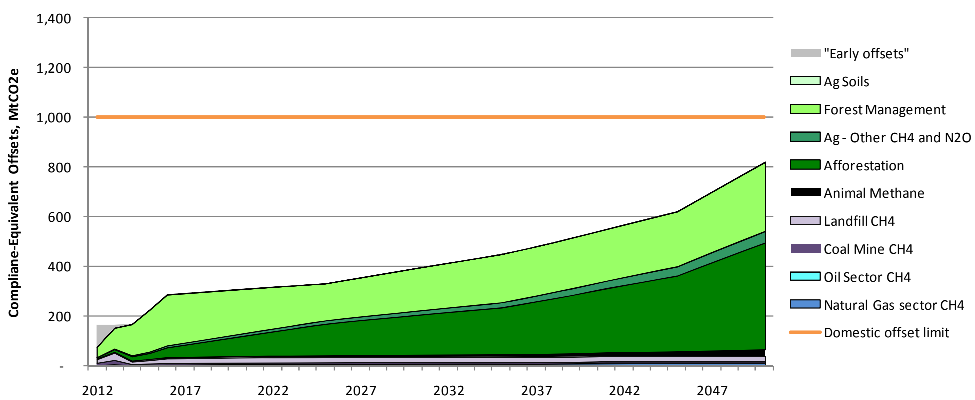
Section 4 analyzed the individual effects of several cap-and-trade design decisions on domestic offset supply. In this Appendix, we combine the various components of the analysis to analyze a single piece of comprehensive legislation: the American Clean Energy and Security Act (HR 2454), as passed by the US House of Representatives on June 26, 2009.[61] Provisions of the bill modeled here include:

- A limit of one billion tons of domestic offsets annually
- Regulation of large, uncapped, stationary sources of emissions under the Clean Air Act;
- Inclusion of "early offset" credits;
- Inclusion of international offsets that, unless bound by the offset limit, can compete with domestic offsets.

Section 4 of this report discussed the individual impacts of design decisions similar to each of these key provisions. The analysis that follows combines all of them to analyze potential offset supply under ACESA.[62]

Figure 11, below, presents projected (undiscounted) offset supply under ACESA for this study's Scenario 1, in which we use the EPA's underlying marginal abatement curves without modification (except for the introduction of early offset and scale-up assumptions as discussed in the previous section) to represent offset supply. Offset supply would increase rapidly to approximately 300 MMtCO2e in 2016, as administrative and technical capacity is expanded, and then grow to over 800 MMtCO2e in 2050, driven in large part by increasing potential in afforestation due to rising carbon prices that increase the viability of planting new forests relative to high opportunity costs, as well as due to continued tree growth. The domestic offset limit is never reached.

Figure 11. Potential Domestic Offset Supply under ACESA (Scenario 1)



Note that the estimates of future offset supply in Figure 11 and in subsequent figures assumes a moderate allowance price trajectory (approximately $14 per ton CO2e in 2012 rising at 5.6% per year[63]) based on the

[61] The American Clean Energy and Security Act passed the House on June 26, 2009. This analysis was conducted based on the version passed out of the House Energy and Commerce Committee on May 21, 2009. Changes made to the bill before its final passage on June 26, 2009 are not expected to have a significant impact on the results presented here.

[62] In the analysis that follows, we use a price trajectory of $14.41 in 2012 + 5.6% per year, which is roughly the same as the CBO's estimated price trajectory under ACESA converted from 2010 dollars (as in CBO, 2009) back to 2005 dollars (the constant-year dollars used in this analysis) using the consumer price index and assuming that 2010 dollars are the same as April 2009 dollars.

[63] This and all other cost values in this report are in constant 2005 dollars.

Congressional Budget Office's analysis of ACESA (CBO, 2009). The allowance prices in this trajectory are less than half those projected by the EPA in its estimate of S.2191 (EPA, 2008), but greater than those projected in the EPA's estimate of ACESA (EPA, 2009b). Higher allowance prices would increase the supply of offsets relative to the figures presented in this section, and lower allowance prices would decrease supply.

EFFECT OF OFFSET PROTOCOLS ON OFFSET SUPPLY

Early and final drafts of ACESA charge the US Environmental Protection Agency (US EPA) or the US Department of Agriculture (USDA), respectively, with promulgating methodologies that address offset additionality, activity baselines, measurement, leakage, uncertainty, and permanence. This analysis models two bounding cases of how the USDA and/or EPA administrator could approach offset methodologies. At one end, the administrator could select protocols and methodologies that emphasize offset credit generation and cost savings to regulated entities more than rigorous consideration of additionality, permanence, uncertainty, leakage, or other factors, an approach defined and modeled as Scenario 2. Alternately, the administrator could make strong efforts to ensure that offset credits represent real, additional emissions reductions or sequestration that would not have happened anyway and do not result in increased emissions elsewhere, even if some legitimately additional projects remain uncredited.[64] Such a choice, as represented in Scenario 3, would have clear implications for offset supply and emissions sequestration.

, Figure 11 below, displays estimated supply of offsets under lenient protocols as modeled under Scenario 2. After initial program startup (assumed to occur through 2016), annual offset supply could be greater than 600 million tons and rising. Reasons for the increase relative to the potential displayed in the underlying marginal abatement curves (Scenario 1) include:

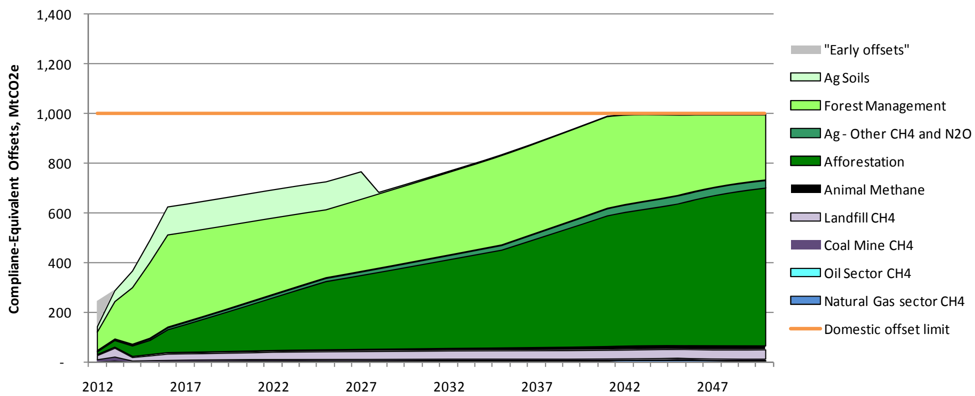
- **Generous approaches to project type inclusion, baseline crediting, leakage, and reversal risk management for forest management, afforestation, and other activities.** In particular, protocols that included very high crediting of the carbon embedded in forest products, no buffers or discounts to account for reversal risk, and no leakage discounts would result in over-crediting of these project types.[65] In addition, protocols that do not consider soil oxidation of some methane in the baseline (see Box 1) would over-credit landfill methane reductions.

- **Crediting of pre-existing and future business-as-usual growth in agricultural soil sequestration activities.** Millions of acres of cropland are already being managed using conservation and no-tillage practices, and millions more acres are projected to switch to no-till in the future absent any greenhouse gas policy (EPA, 2005). Although by definition these activities are part of the existing and projected baseline, lenient offset protocols may credit these activities as offsets. Even in this relatively lenient crediting scenario, crediting for pre-existing agricultural soil sequestration is assumed to expire after 15 years, an interval after which agricultural soils have been found to be largely saturated with carbon (EPA, 2005).

[64] The goal of the Administrator could, arguably, be to try and enact Scenario 1, where environmental benefit is exactly equal to offset credits. Because analyzing and recommending the exact policy mechanisms to achieve such an outcome is beyond the scope of this report, and because Scenario 1 is – in itself – likely to be highly variable due to the limitations described on page 23 (among others), we instead present scenarios 2 and 3 as bounding cases. For specific parameters used, please see Appendix B.

[65] For a review of forest management protocols with respect to these protocols, see Galik et al 2008; for afforestation, see Lazarus, Lee, and Smith, 2009.

Figure 12. Potential Domestic Offset Supply under ACESA (Scenario 2)



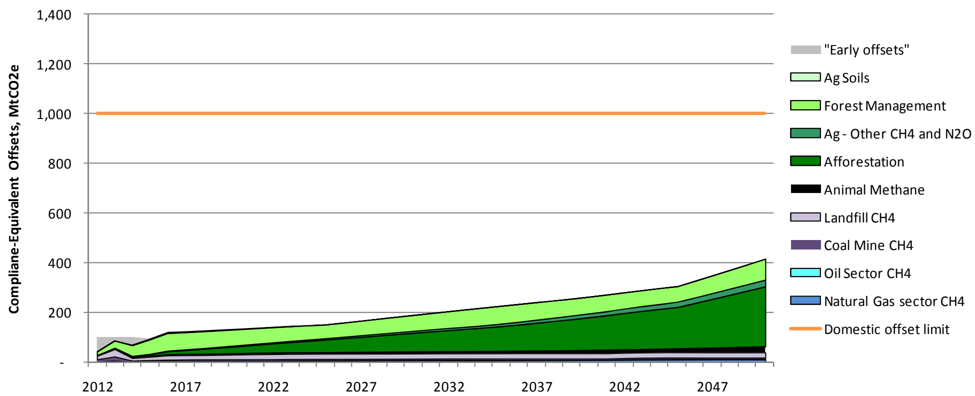
Just as lenient protocols and methodologies such as those modeled in Scenario 2 could increase potential offset supply, stricter methodologies modeled in Scenario 3 could decrease potential offset supply. Figure 12 projects offset supply under stricter offset protocols. The primary reasons for the decrease in creditable carbon relative to Scenario 1 are protocols' treatment of the following:

- **More stringent methods of assessing the baseline creditable carbon, leakage, and reversal risk (i.e., permanence) in forest management and afforestation activities.** For example, if protocols did not include carbon sequestered in forest soil and ground litter (due to uncertainty and/or conservativism) and did include adjustments for leakage and reversal risk management, then creditable carbon would be less than that estimated in the underlying marginal abatement curves.

- **Measurement uncertainty in most agricultural and forestry project types**. Measurement uncertainty in both agricultural and forestry sequestration projects has been characterized on the order of 10% (Kim and McCarl, 2009; Galik et al, 2008) – factors, that if applied as discount factors, could reduce creditable offset supply.

As indicated in Figure 13, offset supply under the relatively stringent protocols modeled in Scenario 3 is projected to be on the order of 100 million tons in early years rising steadily to just over 400 million tons in 2050.

Figure 13. Potential Domestic Offset Supply under ACESA (Scenario 3)



IMPLICATIONS OF PROTOCOLS ON EMISSIONS MITIGATION

Actual domestic mitigation under Scenario 2's lenient offset crediting protocols is significantly less than the quantity of offsets credited, as indicated in **Error! Reference source not found.** The lesson here is that while lenient protocols may help address stakeholders who demand large quantities of offsets, the extra offsets credited may not come with actual emissions benefits.

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As discussed in Section 4 of this report, some stakeholders have advocated for system-wide discounts on the use of offsets, in part to address such risk of under-performance of offset projects relative to the quantities credited. The initial Waxman-Markey discussion draft (but not the version passed out of the House on June 26, 2009) included a system-wide discount on the use of domestic offsets.[66] Similar discounts are also one of the topics currently under discussion in the international negotiations leading up to the post-2012 Copenhagen meeting in December, 2009.

Our analysis in Section 4 found that a system-wide discount of 20% is not likely enough to compensate for the potential loss of environmental benefits under lenient protocols such as those modeled in Scenario 2. Assuming a 20% discount as in the initial discussion draft version of ACESA, the conclusion here is the same.

[66] The final bill, as passed on June 26, 2009, still includes a discount on international offsets.

Figure 14. Offset Credits Versus Emissions Reductions under ACESA–Three Scenarios
(In year 2020 at price of $22/ton CO2e)

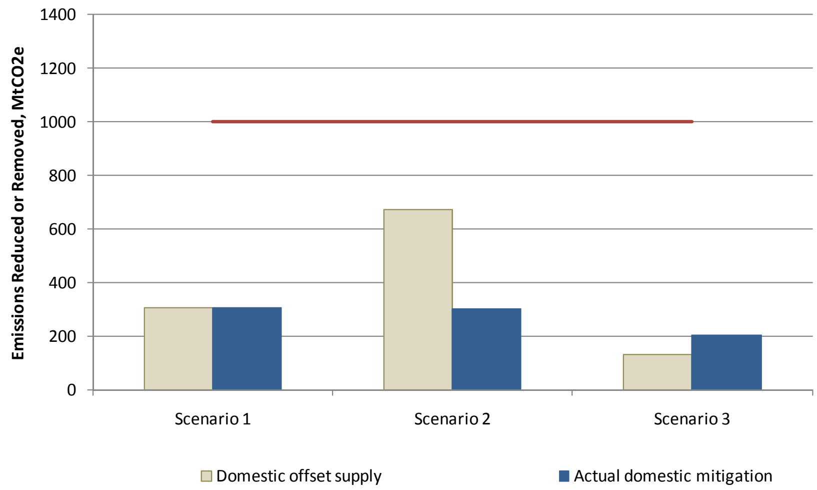

Table 6, below, presents select, summary-level results of these analyses of the effects of discounts and protocols on the supply of offsets under ACESA in the year 2020.

Table 6. Offset Credits Versus Emissions Reductions under ACESA –Three Scenarios
(In year 2020 at price of 22/ton CO2e)

	Scenario 1 (Offset supply as in underlying marginal abatement curves)	**Scenario 2** (Protocols emphasize maximizing crediting)	**Scenario 3** (Protocols emphasize environmental benefits)
Domestic offset supply (MtCO2e)	309	672	134
"Actual" domestic emissions mitigation (MtCO2e)	309	305	203
"Actual" domestic mitigation as a percentage of offset supply	100% (by definition)[67]	45%	152%

As indicated by the large impact of alternative approaches to offset protocols evident in Table 6. Offset Credits Versus Emissions Reductions under ACESA –Three Scenarios
(In year 2020 at price of 22/ton CO2e)our analysis suggests that the projected supply of offset credits under ACESA (as well as the associated emissions reduction) is highly dependent on decisions (yet to be made) regarding treatment of offset additionality, permanence, leakage, uncertainty, and other factors. Considering inherent uncertainty in the EPA's underlying assessment of gross mitigation potential (upon which our analysis builds), the variability in potential offset supply is even greater.

[67] Note we assume that the EPA's underlying marginal abatement curves accurately assess mitigation potential. A full evaluation of the EPA's underlying model was beyond the scope of this study.