UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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OFFICE OF ATMOSPHERIC PROGRAMS
CLIMATE CHANGE DIVISION

MEMO

TO: John Conti, EIA, Andy Kydes, EIA, and Dan Skelly, EIA

FROM: Adam Daigneault, Allen Fawcett

CC: Dina Kruger, Reid Harvey

DATE: March 31, 2009

SUBJECT: Updated Forestry and Agriculture Marginal Abatement Cost Curves

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Purpose

EPA is currently tasked with conducting analyses of legislative climate change policies. One key analytical tool that has recently been updated is the Forest and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG), the primary model we have used to estimate domestic offsets from land use and land use change. Key changes include updated energy prices, commodity prices, and demand specifications for the forest and agriculture sectors, improved spatial and temporal resolution, and a revision of policies that could impact land use including the projected volume of biofuels outlined in the new renewable fuels standards (EISA/RFS2). This memo reviews these updates to FASOMGHG and the resulting marginal abatement cost (MAC) curves used to estimate GHG offsets from the U.S. forest and agricultural sectors. This memo also highlights the changes in the estimates for international forestry offsets from the Global Timber Model (GTM), which are now broken out by credits available through afforestation, forest management, and avoided deforestation practices for both the developed and developing regions of the world.

FASOM Background

EPA has conducted several economic analyses of proposed climate change legislation[1]. The analyses use the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOMGHG) to estimate the domestic offset potential from land use (EPA 2005, EPA 2007). Important offset practices include increasing terrestrial carbon

[1] EPA analyses of S.280, S.1766, S.2191 are available online at www.epa.gov/climatechange/economics/economicanalyses.html

sequestration through afforestation, forest management, and reduced tillage on agricultural soils, and reducing CH_4 and N_2O emissions from changes in crop production and livestock management. FASOMGHG also tracks the GHG emissions that can be abated using bioenergy feedstocks, such as switchgrass and short-rotation tree species. These crops can be grown and used instead of fossil fuels to generate electricity or transportation fuels, and therefore compete for available land with feedstocks for conventional forest products and agricultural commodities.

Previous legislative analyses conducted by EPA have found that offsets and set-asides can have a large role in containing the cost of the climate policy. For example, in S.2191, forest and agriculture contributed to 77% of the cumulative domestic offsets under the provision that only 15% of annual abatement can be met through offsets. The largest contributions of offsets from the sector came from afforestation (47%), forest management (24%), and soil carbon sequestration (22%), with some contribution from non-CO_2 practices (7%). Concerns have been raised though that new land use policies and increased demand for agricultural commodities could change the baseline projections and mitigation potential. As a result, we have developed an updated baseline and new set of MAC curves.

Overview of FASOMGHG

FASOMGHG is a dynamic nonlinear programming model of the U.S. forest and agricultural sectors[2]. The model solves a constrained dynamic optimization problem that maximizes the net present value of the sum of producer and consumer surplus across the two sectors over time. The model is constrained such that total production is equal to total consumption, technical input/output relationships hold, and total land use must remain constant. FASOMGHG simulates the allocation of land over time to competing activities in both the forest and agricultural sectors and the associated impacts on commodity markets. In addition, the model simulates environmental impacts resulting from changing land allocation and production practices, including accounting for changes in net GHG emissions. The model was developed to evaluate the welfare and market impacts of policies that affect land allocation and alter production activities within these sectors. Previous versions of FASOMGHG have been used in numerous studies to examine issues such as climate policy, potential impacts of climate change, timber harvest policy on public lands, federal farm programs, bioenergy production, and a variety of other policies affecting the forest and agricultural sectors.

The model is used to evaluate the joint economic and biophysical effects of GHG mitigation scenarios in U.S. forestry and agriculture. FASOMGHG covers private timberlands and all agricultural activity across the conterminous United States, broken into 11 regions, and tracks five forest product categories and more than 2,000 production possibilities for field crops, livestock, and biofuels. The model accounts for the stocks

[2] FASOM is developed by Dr. Bruce McCarl of Texas A&M University, Dr. Darius Adams of Oregon State University, Dr. Ralph Alig of the USDA Forest Service, and Dr. Brian Murray of Duke University. Detailed documentation can be found at: http://agecon2.tamu.edu/people/faculty/mccarl-bruce/FASOM.html

and flows of GHGs for more than 50 categories. FASOMGHG runs simulations, typically for 70 to 100-year periods, and reports results on a five year basis. The model simulates the actions of producers and consumers with perfect foresight of future demands, yields, technologies, and GHG prices.

Updated FASOMGHG Baseline

There have been several updates to FASOMGHG since the version used in previous legislative analyses to reflect the current state of the world and to provide a more detailed representation of the U.S. forestry and agricultural sector. Key improvements include:

- New policies that impact land use, such as the projected volumes in the new renewable fuel mandate of 30 billion gallons per year from forestry and agriculture sector by 2022 (Energy Independence and Security Act of 2007 (EISA) / Renewable Fuels Standard (RFS2))
- Bioenergy sector tracks more than a dozen feedstocks used for the production of starch- and sugar-based ethanol, cellulosic ethanol, biodiesel, and bioelectricity
- Agriculture sector updates with new rates of technological change, tilling practices, inputs costs, and output prices
- Forestry sector updates to private timberland stocks, distribution of land ownership, and harvest schedules
- GHG accounting has been expanded to account for 60 categories of stocks and flows in forestry and agriculture
- Intertemporal dynamics are now modeled in 5 year time steps across 11 market regions.
- Assumptions about growth in demand for developed land have been updated to reflect recent projections of income and population growth.
- Energy prices updated with AEO 2008 projections

The new and old baseline GHG estimates from 2010-2050 are compared in Table 1 and listed as average annual emissions in million metric tons of carbon dioxide equivalent ($MtCO_2e$) for each ten year period[3]. Categories with positive values are net emitters, while those with negative values are a net sink. Apparent in the table is that the sector has relatively high estimated emissions in the early periods (402 $MtCO_2e$/yr from 2010-2019) as forests are cut and cropland is expanded, but these emissions gradually reduce over time (219 $MtCO_2e$/yr from 2050-5059) with changes in technology, yields, and the expansion of carbon sequestering biofuels that are used as substitutes for fossil fuels.

[3] Values are for the decade following the date, e.g., 2010 represents 2010-2019. While FASOMGHG was modeled in five year time-steps, results were aggregated to a decadal average to be consistent and comparable with previous analyses.

Table 1: FASOMGHG v1 and v2 Baseline GHG Net Annual Emissions by Activity and Decade for the United States: 2010-2050 (Average $MtCO_2e\ yr^{-1}$)

Source/Sink	2010		2020		2030		2040		2050	
	v1	v2	v1	v2	v1	v2	v1	v2	v1	v2
Forest Management	(322)	165	(314)	(99)	(163)	(174)	(229)	(152)	(196)	(163)
Afforestation	(114)	(89)	92	(19)	18	(14)	4	(56)	26	48
Agricultural Soil C Sequestration	32	(77)	10	(25)	(83)	(13)	(148)	(2)	(167)	(27)
Biofuel Offsets*	(11)	(82)	(11)	(133)	(11)	(135)	(11)	(185)	(11)	(241)
Agricultural CH4&N2O	489	511	503	522	560	543	597	570	626	590
Fossil Fuel from Crop Production^	197	58	200	64	213	70	229	74	242	81
C Sequestration on Developed Land#	-	(84)	-	(80)	-	(76)	-	(72)	-	(69)
Total	271	402	480	232	534	201	442	177	520	219
Total without Biofuels	282	484	491	365	545	335	453	362	531	460

*Emissions avoided from substituting biomass for fossil fuels

^Emissions from direct use of fossil fuels in agricultural production

Carbon sequestration on land that is converted for development assumes 20% paved over soil, 40% grassland, and 40% forests

Results indicate that the new baseline is different from the previous version (EPA 2005). The differences in the projected emissions can be attributed to several things. First, the changes in global GDP growth, population, and consumer preferences (e.g., greater demand for meat) have all led to an increase in the demand for agricultural commodities, potentially leading to large emissions from forests being converted in the early years of the model. Second, although the updated assumptions about technological innovation allow the supply of commodities to meet this demand with little expansion of cropland after 2010, the reversion in cropland over time is less than the previous baseline. Third, there is now a larger demand for biofuels in the baseline because of EISA/RFS2. The low impact production of some of these feedstocks (reduced or no till, limited irrigation, and minimal fertilizer application) coupled with the emissions reductions created from substituting biofuels for fossil fuels reduces the total emissions in the baseline. In the old baseline, there was little demand for biofuels, so most agricultural land was devoted to conventional crops. In the updated version, the demand for biofuels is much higher and the improvements in the representation of cellulosic technology increase the amount of liquid biofuels that can be produced, hence increasing its contribution as a net sink in the baseline.

Domestic Forest, Agricultural and Biofuel Sector MAC Curves

To construct GHG mitigation potential for the forest and agricultural sector, we applied the model to simulate equilibrium outcomes over the next century under a wide range of alternative CO_2 equivalent prices. The GHG prices in this analysis are varied to evaluate the total GHG mitigation potential from these sectors at different economic incentive levels and can combined to identify the mix of practices in a cost-effective mitigation portfolio. The first set of scenarios assumes that GHG prices remain constant from 2010 through the terminal year of the model (2080) and range from $1 to $50 per metric ton CO_2e. The second group of scenarios assumes that GHG prices will rise over time at a rate of 5% until they reach an exogenous price cap. The modeled price scenarios are outlined in Table 2.

Table 2: Core Price Scenarios in FASOMGHG

Initial Price in 2010	Annual Price Growth	Price Cap
Constant Prices ($/tCO$_2$e)		
$1	0	None
$5	0	None
$15	0	None
$30	0	None
$50	0	None
Rising Prices ($/tCO$_2$e)		
$1	5%/yr	None
$5	5%/yr	None
$15	5%/yr	$250
$30	5%/yr	$250

The updated MAC curves were developed in a similar fashion as the EPA's previous analyses (EPA 2007), where each source type is divided into capped and non-capped sources of emissions and then used to construct capped and offset mitigation cost schedules. The estimates for both the constant and rising price runs are in the attached spreadsheet, March 2009 Domestic, ag, forest, biomass.XLS.

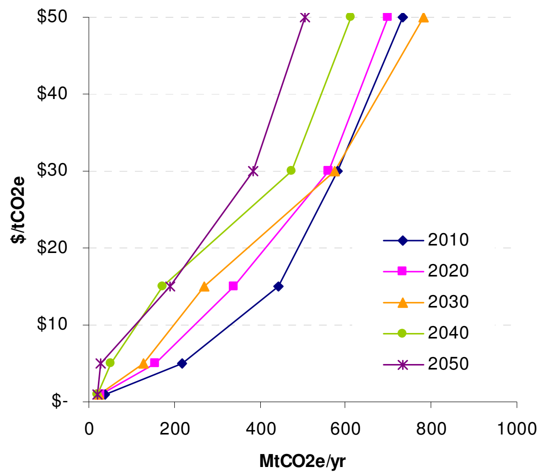
Application to EPA Legislative Analyses

EPA's previous legislative analyses have used a mix of constant and rising price runs to estimate the amount of offsets from the forestry and agriculture sector. A draft analysis of S.3036 used the constant price scenarios to determine annual offset supply because offset prices were found to be relatively constant when the potential contribution is binding at 15% of total U.S. emissions. The rising carbon price pathways, however, were used to estimate biofuels mitigation because the biomass feedstock is a substitute for fossil fuels in the capped transportation and electric power sectors, and hence follows the assumed rising abatement price path of 5%. The S.2191, S.1766, and S.280 analyses used only the rising price scenarios for both the offset and bioenergy sectors.

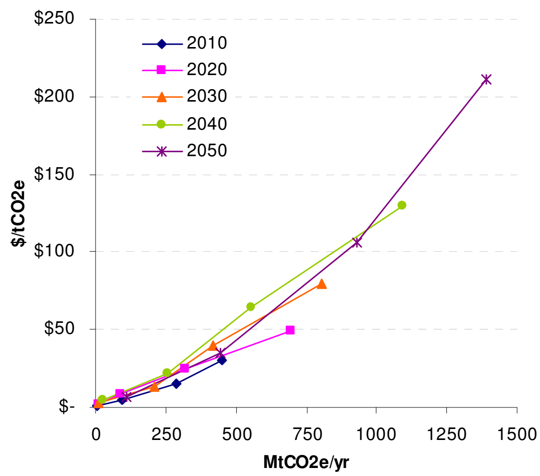
We should note that these updated MAC curves were also constructed with the assumption that all mitigation in the biofuels sector comes from renewable electricity generation. This is because the liquid biofuels section of the model is still being updated to sufficiently estimate substitutions in the petroleum sector as a result of a carbon policy. The liquid fuels portion of the FASOMGHG baseline was thus constrained to the exact volumes projected in RFS2/EISA until 2035 and then allowed to grow with increases in capacity at about 1.2 billion gallons per year through 2050. While this constraint places some limit on the potential allocation of land and GHG abatement, previous analyses showed no liquid biofuels entering the market because it is more economical to use the feedstock in a power plant.

The MAC curves used for the agricultural and forestry sector offsets are shown in Figure 1a (constant prices) and 1b (rising prices). Mitigation potential is generally lower for new curves compared to the curves constructed from estimates published in EPA (2005). The share of offset practices has changed too, with a majority of the mitigation potential estimated to occur on private timberland through the form of forest management and afforestation (Figure 2).

Figure 1: Total Domestic Forest and Agriculture Offset MACs for constant (a) and rising (b) prices (avg $MtCO_2e\ yr^{-1}$)

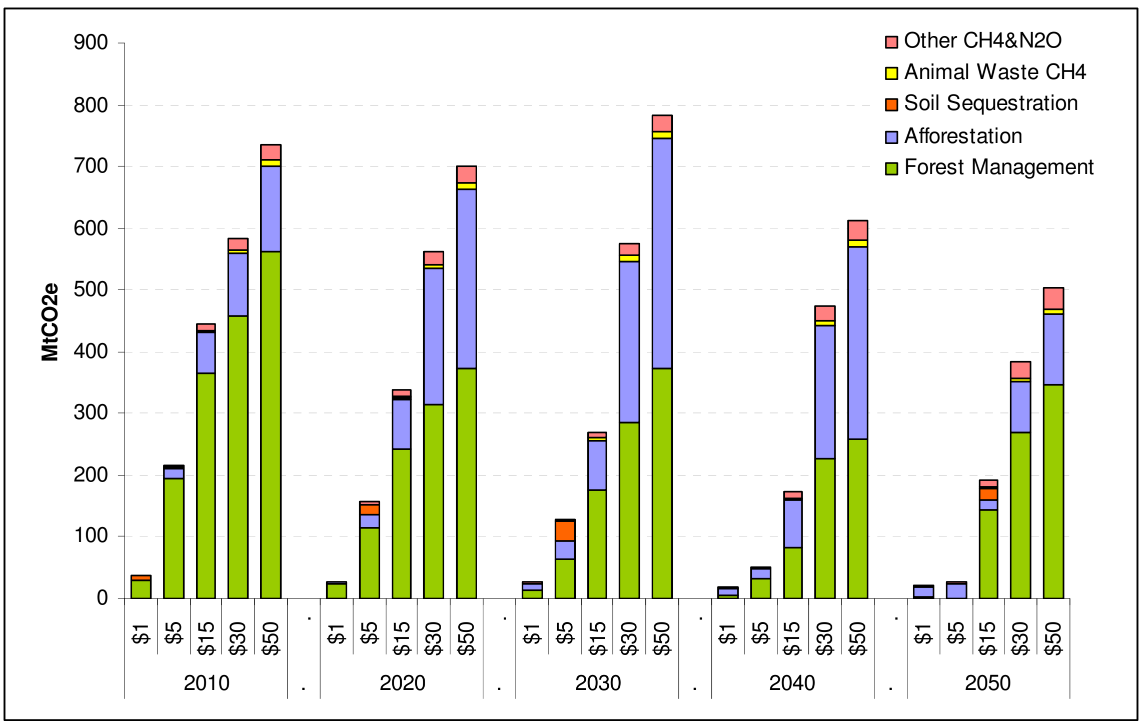


(a)

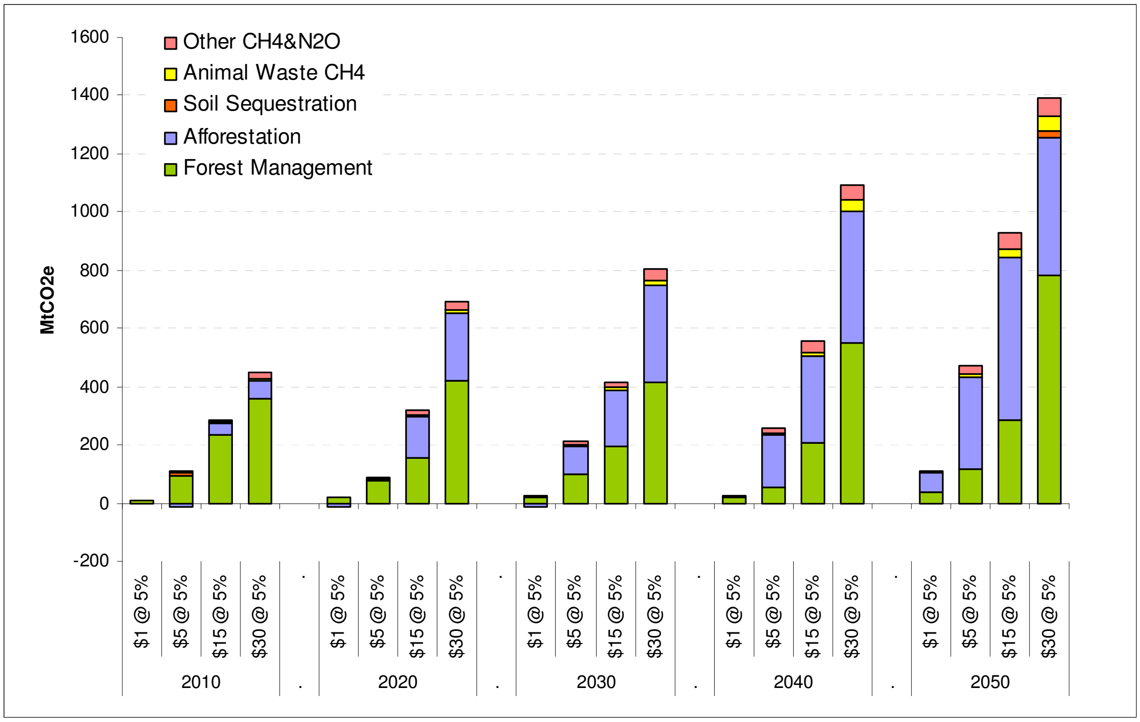


(b)

Figure 2: Average Domestic Forest and Agriculture Offset MACs, by Practice, 2010-2050 MACs for constant (a) and rising (b) prices (avg $MtCO_2e\ yr^{-1}$)



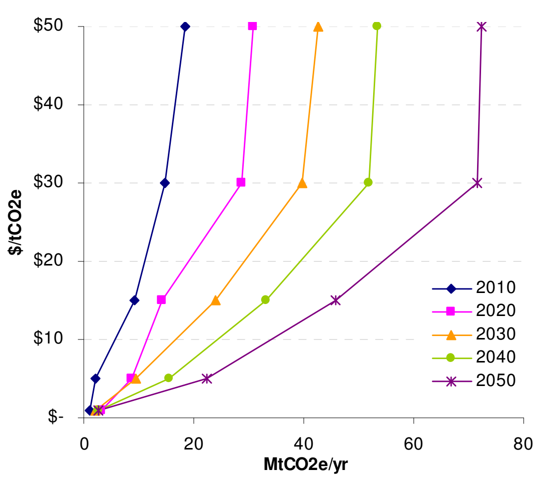
(a)



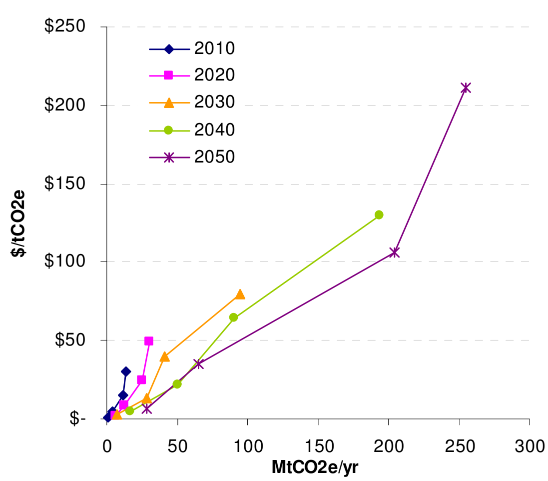
(b)

The MAC curves used for the biofuels sector are shown in Figure 3. As mentioned above, all of the abatement over the baseline comes from bioelectricity. Abatement potential is increasing over time as the sector expands and biomass feedstock yields improve. The level of abatement is significantly less than the previous MAC curves though, as there is more land in the baseline devoted to growing energy crops to meet the RFS2 requirements. This limits the amount of biomass that can be grown and co-fired in the electricity sector under a climate policy.

Figure 3: Domestic Bioelectricity MACs, 2010-2050 for constant (a) and rising (b) prices (avg $MtCO_2e\ yr^{-1}$)



(a)

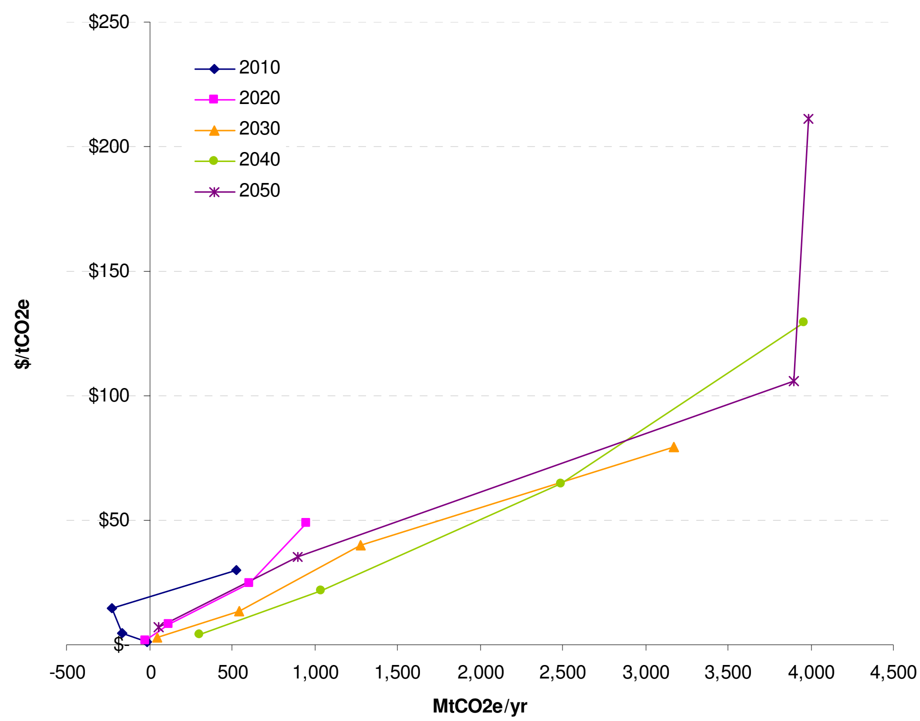


(b)

Updated International Forest Sector MAC Curves

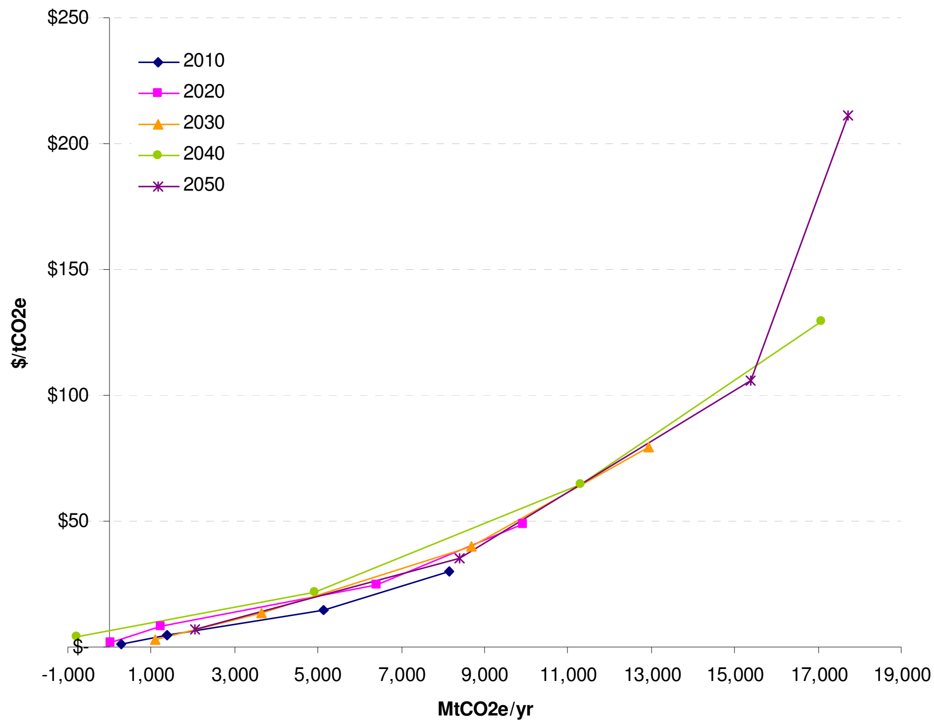
EPA has estimated international forestry-based offset potential for the same legislative analyses as FASOM using the Global Timber Model (GTM). The GTM baseline is the same as in previous analyses (Sohngen and Mendelsohn, 2007), however we now assume that all practices in all regions of the globe (outside of the U.S.) are eligible from 2010 through 2050 and that the mitigation options are now broken out by avoided deforestation, afforestation, and forest management. As in past analyses, we only ran the model with carbon prices of $1, $5, $15, and $30 that rise at 5% per year (same as FASOMGHG rising runs). The aggregate international forestry MACs are shown in Figures 4a (group 1 countries) and 4b (group 2 countries)[4]. Further investigation shows that the most mitigation potential is achieved through avoided deforestation in the developing regions of the world, although there is still significant contribution from afforestation and forest management in the later years of the policy. The estimates for both the international forestry offsets are in the attached spreadsheet, March 2009 Int'l forest carbon sequestration.XLS.

Figure 4: International Forestry MACs, 2010-2050 for Group 1 (a) and Group 2 (b) countries, rising prices (avg $MtCO_2e\ yr^{-1}$)



(a)

[4] Group 1 countries are Canada, EU, AUS/NZ, and Japan. Group 2 Countries are all other regions of the world, except the United States.



(b)

Conclusions

FASOMGHG has undergone several updates to account for a more detailed model structure and recent changes in land use policy. As a result, the overall direction of the new MAC curves varies depending on the GHG price assumption, year, and mitigation practice. The new domestic forestry and agriculture show less mitigation potential than the curves used in previous analyses. Abatement from the bioelectricity is increasing over time, but the overall contribution is also significantly less compared to the old curves. The most consistent outcome of the updated domestic baseline and resulting MACs is that the U.S. forestry and agriculture sector is still estimated to have an important role in providing cost-effective options to mitigate climate change. The updated international forestry MACs developed with GTM show that most mitigation potential is achieved through avoided deforestation in the developing regions of the world, although there are still significant contributions from afforestation and forest management in the later years of the policy. Finally, we note that because FASOMGHG and GTM are continually being updated and improved, the estimates presented here are subject to change.

References

EPA, 2005. *Greenhouse Gas Mitigation Potential in U.S. Forestry and Agriculture,* U.S. Environmental Protection Agency, EPA 430-R-05-006, Washington D.C., November 2005.

EPA, 2007. *EPA S.280 mitigation cost schedules for capped sectors and domestic and international offsets*, EPA memo to the Energy Information Administration (EIA), March 2007 (www.epa.gov/climatechange/economics/economicanalyses.html).

Sohngen, B. and R. Mendelsohn. 2007. A Sensitivity Analysis of Carbon Sequestration. Chapter 19 in *Human-Induced Climate Change: An Interdisciplinary Assessment*. Edited by M. Schlesinger, H.S. Kheshgi, J. Smith, F.C. de la Chesnaye, J.M. Reilly, T. Wilson, and C. Kolstad. Cambridge: Cambridge University Press.