[SUMMARY TABLE THAT WILL BE UPDATED AS QUANTIFICATION IS COMPLETED]

Table x.
Agriculture, Forestry, and Waste Management Technical Work Group
Summary List of Mitigation Options

	Mitigation Option	GHG Reductions ($MMtCO_2e$)			Net Present Value 2007–2020 (Million $)	Cost-Effective-ness ($\$/tCO_2e$)	Level of Support
		2010	2020	Total 2007-2020			
	AGRICULTURE, FORESTRY, AND WASTE MANAGEMENT						
AFW-1	Manure Digesters & Energy Utilization	0.2	0.9	6.3	387	67	TBD
AFW-2	Biodiesel Production (incentives for feedstocks and production plants)	0.2	0.8	5.1	286	56	TBD
AFW-3	Soil Carbon Management (including organic farming incentives)	0.4	0.4	4.9	-26	-5	TBD
AFW-4	Preserve Agricultural Land	0.2	0.3	2.6	294	114	TBD
AFW-5	Agricultural Biomass Feedstocks for Electricity or Steam Production	0.003	0.01	0.1	0	0	TBD
AFW-6	Policies to Promote Ethanol Production	0.9	6.9	38	200	5	TBD
AFW-7	Forest Protection – Reduced Clearing and Conversion to Nonforest Cover	1.7	4.3	31	TBD	2	TBD
AFW-8	Afforestation and/or Restoration of Nonforested Lands	0.2	2.4	15	18	3	TBD
AFW-9&10	Expanded Use of Forest Biomass and Better Forest Management	1.4	3.6	37	TBD	11	TBD
AFW-11	Landfill Methane and Biogas Energy Programs	0.2	1.9	13	TBD	TBD	TBD
AFW-12	Increased Recycling Infrastructure and Collection	0.2	0.5	4.1	4	1	TBD
AFW-13	Urban Forestry Measures	TBD	TBD	TBD	TBD	TBD	TBD
	SECTOR TOTAL AFTER ADJUSTING FOR OVERLAPS						
	REDUCTIONS FROM RECENT ACTIONS (table to be added below)						
	SECTOR TOTAL PLUS RECENT ACTIONS						

AFW-1. Manure Digesters & Energy Utilization

Mitigation Option Description

The methane emissions inherent from the anaerobic decomposition process of manure and other wastes may be captured and used as an energy source. In so doing, it is possible to both reduce methane emissions and to offset fossil-based energy. However, the cost of emission capture and energy production can be higher than the value of the energy collected, making this option cost prohibitive for producers operating in a tight margin business. This option covers programs to increase the number of methane capture and energy recovery projects using manure or other waste (including food processor waste).

Mitigation Option Design

Provide economic incentives / cost offsets for producers interested in manure to energy projects.

- **Goals:** Capture 20% of available methane from confined animal operations by 2020 for use in energy projects.
- **Timing:** By 2010, implement projects to capture 5% of available methane energy at confined animal operations. By 2020, implement projects to capture 20% of methane energy.
- **Parties Involved: ?**
- **Other:** [Insert text if/as appropriate]

Implementation Mechanisms

- Education of opportunities for farmers from NRCS & NCCES (including technical assistance).
- Incentives in the form of tax breaks (sales and/or income) for incurred capital costs.
- Inclusion in voluntary programs such as NC Green Power and NC Agriculture Cost Share. Increased funding from General Funds.
- Increased research to improve return on investment for digesters.
- Education for farmers of power purchase agreements and interconnection with the grid.

Related Policies/Programs in Place

- NRCS cost share program.
- NC Renewable Energy Property tax credit. State income tax credit for 35% of construction costs not to exceed $2.5M or 50% of tax burden.
- EPA AgStar Program.
- Federal Renewable Electricity Production Tax Credit.

Types(s) of GHG Reductions

- CH_4 – methane is captured and typically combusted in an energy recovery system or flare. Small amounts of N_2O and CH_4 are emitted from the combustion process.
- CO_2 – carbon dioxide is reduced when the methane is converted to energy and that energy is used to offset fossil-based energy (e.g. electricity, natural gas, etc.). Small amounts of N_2O and CH_4 are also reduced from the fossil-based energy that is offset.

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.2, 0.9
- **Net Cost per MtCO2e:** $67
  The cost per ton is the average for dairy ($74) and swine ($60). For beef feedlots, the cost effectiveness estimate is much higher ($672; due to much lower methane emissions/head), so the TWG does not recommend adopting this policy to address feedlots.
- **Data Sources:** NC GHG I&F, NCSU technology determinations for swine farms,[1] other technical reports and presentations on implementing digesters at confined animal operations.[2]
- **Quantification Methods:** Methane emissions data from the I&F was used as the starting point to estimate the GHG benefits of capturing and controlling the volumes of methane targeted by the policy and to add in the additional benefit of electricity generation using this captured methane (through offsetting fossil-based generation). For 2010 and 2020, the GHG benefit for capturing methane was estimated by multiplying the methane emissions from dairy, feedlot, and swine operations by the applicable goal (5% or 20%) and then by an assumed collection efficiency of 75%[3], and converting to CO_2e.

  The second portion of the GHG benefit for offsetting fossil-based electricity generation was estimated by converting the methane to captured in each year to its heat content (in BTUs) and then multiplying by an energy recovery factor of 17,100 BTU/kW-hr to estimate the electricity produced (assumes a 25% efficiency for conversion to electricity in an engine and generator set). The CO_2e associated with this amount of electricity in each year was estimated by converting the kW-hrs to MW-hrs and then multiplying this value by the NC-specific emission factor for electricity production from the I&F (0.542 Mt/MW-hr).

  The total GHG benefit was estimated as the sum of both portions of the benefit described above.

  For swine, costs were estimated using annualized costs for the Barham Farm study, which was part of the NCSU technology determinations referenced in the footnote below. Data from this study indicate a range of annualized costs from $18 to $45/head to cover installation and

[1] NCSU Animal and Poultry Waste Management Center, *Development of Environmentally Superior Technologies: Phase 3 Report Between the Attorney General of North Carolina and Smithfield Foods, Premium Standard Farms, and Frontline Farms*, March 8, 2006, information from this study compiled for the Barham swine farm.
[2] Leonard Bull, Animal and Poultry Waste-to-Energy, PowerPoint presentation, North Carolina State University, http://www.cals.ncsu.edu/waste_mgt/waste%20to%20energy.pdf, accessed June 2006.
http://www.methanetomarkets.org/resources/ag/docs/animalwaste_prof_final.pdf, accessed March 2006. Williams, Douglas, Valley Air Solutions, presentation "Joseph Gallo Farms Dairy Manure Digester", January 18, 2006. DPNM Biomass Project Final Report, prepared by Agri-Energy and the Dairy Producers of New Mexico, 2005.
[3] The collection efficiency is an assumed value based on engineering judgment. No applicable studies were identified that provided information on methane collection efficiencies achieved using manure digesters (as it relates to collection of entire farm-level emissions).

operation of a digester and an engine-generator set/flare. For dairies and feedlots, data from the EPA methane to markets report and Gallo Farms studies referenced below provided an average cost of $450/head for digesters and engine-generator sets (dairies >1,000 head). From the New Mexico Dairy Producers report, capital costs for regional digesters (those serving multiple nearby operations) were estimated to be $190/head. Annualized costs per head were estimated assuming a 5% interest rate and a 15-year project life, annual operations and maintenance costs of $38/head were taken from the Gallo Farms Study, and the value of the electricity produced was assumed to be $0.05/kW-hr. The annualized per head cost estimates were multiplied by the head of livestock to be controlled in each year to estimate total costs.

- **Key Assumptions:** Representativeness of the cost data for the studies cited; 75% collection efficiency for farm-level methane emissions for the digester.

Key Uncertainties

See key assumptions in the quantification section above.

Additional Benefits and Costs

- Additional reductions in emissions of ammonia and volatile organic compounds;
- Possible nutrient management benefits;
- Economic benefits of digester industry.

Feasibility Issues

- Currently a very long return on investment.
- Demand from electric utilities.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-2. Biodiesel Production (incentives for feedstocks and production plants)

Mitigation Option Description

Use of biodiesel offsets the consumption of diesel fuel produced from oil (fossil diesel). Since biodiesel has a lower GHG content than fossil diesel, overall GHG emissions are reduced. By producing biodiesel in the state for consumption within the state, the highest benefits can be achieved, since the fuel is transported over shorter distances to the end user. This option covers incentives needed to increase biodiesel production in North Carolina.

This option is linked with TLU Option 7 on Biofuels. This option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biodiesel using feedstocks with greater GHG benefits than the likely business as usual national production methods. In addition, NC consumption of biodiesel produced in-state will produce better GHG benefits than biodiesel obtained from a national market due to lower embedded CO2 associated with transportation of biodiesel or its feedstocks from distant sources.

Mitigation Option Design

- **Goals:** Produce enough biodiesel to offset 12.5% of NC's fossil diesel consumption by 2020.
- **Timing:** By 2010, produce enough biodiesel to offset 5% of fossil diesel consumption. By 2020, produce enough biodiesel to offset 12.5% of in-state fossil diesel consumption.
- **Parties Involved:**
- **Other:**

Implementation Mechanisms

- Incentives in the form of grants or tax breaks (sales and/or income) for incurred capital costs for feedstock producers (oil crops, methanol/ethanol).
- Streamlined permitting of production facilities. Technical assistance for new producers.
- Incentives and grants for expanded research for oilseed production and processing (including canola and other crops not typically grown in NC).
- Active solicitation of new producers.
- Expanded consumer education to drive demand.
- Expanded producer education to develop skilled workforce.

Related Policies/Programs in Place

- NC Renewable Energy Property tax credit. State income tax credit for 35% of construction costs not to exceed $2.5M or 50% of tax burden.
- Federal Biodiesel Mixture Tax Credit. Federal excise tax credit for biodiesel mixtures, ranges from $.50 to $1.00/gallon depending on feedstock.

Types(s) of GHG Reductions

- CO_2 – Lifecycle emissions are reduced to the extent that biodiesel is produced with lower embedded fossil-based carbon than conventional (fossil) diesel fuel. Feedstocks used for producing biodiesel can be made from crops, which contain carbon sequestered during photosynthesis (i.e., biogenic or short-term carbon). The primary feedstocks are vegetable oils (soy, canola, sunflower, algal, etc.) and alcohols (either methanol or ethanol). From a recent report (Hill et al., 2006)[4], biodiesel from soybeans contains 93% more useable energy than its petroleum equivalent and reduces lifecycle GHG emissions by as much as 41%. Higher oil production potential of different feedstocks (e.g., other oil crops, algae) will likely adjust the lifecycle GHG emissions further downward as they are developed as biodiesel sources. Local production of biodiesel also decreases the embedded CO2e of biodiesel compared to importation of out of state vegetable oil supplies.

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.2, 0.8
- **Net Cost per MtCO2e:** $56
- Data Sources: Data from the NC Inventory & Forecast were the starting point for quantifying the benefits of offsetting fossil diesel consumption with biodiesel produced within the state (these do not incorporate future reductions in consumption due to TLU options). Fossil diesel consumption estimates are (under business as usual):

Year	Diesel Consumption (MMgal/yr)
2010	1,470
2020	2,157

The policy design calls for 5% of the fossil diesel consumption to be offset by 2010 from in-state production and 12.5% offset by 2020. Therefore, biodiesel production targets are:

Year	Biodiesel Production Needed (MMgal/yr)
2010	71
2020	259

By 2010, BAU biodiesel production in the state is expected to be 3 MMgal.[5] By projecting the 2007 to 2010 BAU production growth rate (0 to 3 MMgal/yr), the estimated 2020 BAU production level would be 10 MMgal/yr. Hence, by 2020, this option would try to increase the production levels to about 249 MMgal/yr.

Year	Biodiesel Production Needed beyond BAU (MMgal/yr)

[4] Hill et al, 2006, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels", *Proceedings of the National Academy of Sciences*, volume 103, pp. 11206-11210, July 25, 2006.

[5] www.eere.energy.gov/states/state_news_detail.cfm/news_id=10298/state=NC; USDOE Energy Efficiency and Renewable Energy website, accessed 1/16/07; Piedmont Biofuels begins operation in late 2006 (1 MMgal/yr capacity); One of three plants being built in NC; Assume similar capacity for the remaining two and that these will be operational by 2010.

2010	68
2020	249

The CO2e emission factor for fossil diesel used in the inventory and forecast is 10.04 Mt/1,000 gallons. The lifecycle fossil diesel emission factor is 12.3 Mt/1,000 gallons (Hill et al, 2006; cited in the footnotes).

- **Quantification Methods:**

GHG Reductions

A new study on lifecycle GHG benefits for biodiesel production and use was used to estimate the CO2e reductions for this option (Hill et al, 2006; cited in footnotes to this option). This study covered biodiesel production from soybean production, which is currently the predominant feedstock source for biodiesel production in the US and is assumed to remain that way for the purposes of this analysis (it is also the predominant source of vegetable oil production in NC). Lifecycle CO_2e reductions (via displacement of fossil diesel with soybean-derived biodiesel) were estimated by Hill et al to be 41%. This value is being used by the TLU TWG to estimate the benefit of the biodiesel component of the TLU biofuels option. Hence, this analysis focuses on incremental benefits of in-state feedstocks production with the focus on vegetable oils.

For this option, the incremental benefit of in-state production is derived from the lower embedded GHG content of biodiesel feedstocks (vegetable oil) avoided from having to transport the feedstocks from their likely source region. For this assessment, the likely source regions for soybean or canola oil are the U.S. mid-west or northern plains regions. Using South Dakota as a potential source region, rail transport would require shipments to central North Carolina of about 1,400 miles.[6] Rail fuel consumption is about 400 ton-miles/gallon.[7] The density of vegetable oil is about 3,700 tons/MMgal. From these inputs, a GHG emission rate of 130 MtCO2/MMgal oil was calculated.

When combined with the other feedstocks needed to produce biodiesel (e.g., either methanol or ethanol)[8], a gallon of vegetable oil will produce slightly more than one gallon of biodiesel. For the purposes of this estimate, each gallon is assumed to produce one gallon of biodiesel.

In addition to soybean oil, other oil feedstocks included in this analysis include animal oils (yellow grease, poultry fat, lard, and tallow), canola, and algal oils. As mentioned under the feasibility section below, current production of these feedstocks in NC would not meet the goals of the proposed policy (no canola or algal oils are currently produced). Even after substituting canola production for all of the current wheat production in NC, the 2020 production goal would not be met. Hence, it is assumed that technology advances will occur during the policy period that will allow for commercial scale production of algal oil to make up the shortfall (e.g. in the post-2015 period). With sufficient technology advancement, another option could be Fischer-Tropsch biodiesel from cellulose.

[6] U.S. National Atlas, http://nationalatlas.gov/natlas/Natlasstart.asp.
[7] U.S. National Atlas, http://nationalatlas.gov/articles/transportation/a_freightrr.html.
[8] While the analysis here focuses on the primary feedstock for biodiesel, vegetable oil, the policy should also promote the production and use of alcohol feedstocks produced from renewable resources (e.g., starch or cellulosic ethanol, renewable methane to methanol).

For oil sources other than soybean oil, the benefit for substituting in-state biodiesel for fossil diesel is estimated starting with the lifecycle soybean emission factor (7,261 MtCO_2e/MMgal from the Hill et al study). As mentioned previously, the benefits of the biodiesel component of the TLU biofuels option is based on displacement with soybean-based biodiesel. Hence, this analysis was designed to only account for the incremental benefit of in-state feedstock (oil) production using GHG preferential feedstocks. These include vegetable oils that produce greater volumes of oil per unit of energy input (e.g. canola), animal fats, and, in the future, algal oils.

Canola produces 127 gallons of oil per acre compared to soybeans at 48 gallons/acre. Assuming canola production energy inputs are not significantly greater than soy, the lifecycle emission rate for canola would be 7,261 x 48/127 or 2,744 MtCO2e/MMgal. So the incremental benefit of canola over soy is 7,261 - 2,744 = 4,517 MtCO2e/MMgal.

For animal fats and algal oils, CCS assumes that these have negligible embedded energy. So the incremental benefit over soy equals the lifecycle fossil diesel EF (12,306 MtCO_2e/MMgal) minus the soybean based EF (7,261 MtCO_2e/MMgal), which is 5,045 MtCO_2e/MMgal.

To meet the in-state production goals for 2010 and 2020, the table below provides the mix of oil feedstocks assumed in this analysis. The assumed mix relies heavily on new technologies (e.g., algal oil) to produce feedstocks in the post-2010 period. The new production data summarized below exclude BAU production, which is estimated to be 3 MMgal/yr in 2010 and 10.3 MMgal/yr in 2020[9] (BAU production is further assumed to be soybean-based with little incremental benefit above the TLU Option 6 benefit).

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Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2010	Soy	0.40	27
2010	Canola	0.10	7
2010	Animal	0.50	34
2010	Algal	0.00	-
		2010 Total	68
2020	Soy	0.12	30
2020	Canola	0.25	62
2020	Animal	0.20	50
2020	Algal	0.43	107
		2020 Total	249

Excludes BAU production estimated to be 3 MMgal/yr in 2010 and 10.3 MMgal/yr in 2020.

GHG reductions were estimated by multiplying the production of each oil feedstock by the applicable incremental benefit (i.e., by oil type). Total reductions in each year were estimated by summing the incremental benefit for each oil type.

[9] USDOE Energy Efficiency and Renewable Energy; Piedmont Biofuels begins operation in late 2006. One of three plants being built. Assume similar capacity for the remaining two to be operational by 2010. www.eere.energy.gov/states/state_news_detail.cfm/news_id=10298/state=NC, USDOE Energy Efficiency and Renewable Energy; Piedmont Biofuels begins operation in late 2006. One of three plants being built. Assume similar capacity for the remaining two to be operational by 2010. After 2010, assumes BAU growth is at the estimated 2007-2010 growth rate (0.7 MMgal/yr).

Costs

Costs were estimated using information from an analysis of biodiesel production costs from the US DOE.[10] The value of incentives needed is assumed to be equivalent to the difference in the costs of producing fossil diesel and soy-based biodiesel ($0.34/gallon). This value is very close to the incentive offered in a State of Missouri incentives program.[11] This program offers production incentives of $0.30/gallon to producers up to 15 million gallons of production/yr. The incentive grants last for five years.

CCS assumed a similar incentive structure and that these would cover the costs of all grants or tax incentives associated with this policy (all other implementation mechanisms are assumed to be achieved within existing programs). The cost estimates are based on multiplying the amount of biodiesel produced in each year by the production incentive. This assumes that all production occurs at production facilities of less than 15 million gallons/yr. The production incentive runs out after five years of production.

- **Key Assumptions:** Life-cycle GHG emission factors utilized/derived for this analysis are representative for each feedstock and for fossil diesel. Production incentives offered by this option are sufficient to drive production of GHG-superior feedstocks (i.e., superior to soybeans) and to increase the level of research and development needed for non-crop based feedstocks (e.g., algal biodiesel, Fischer-Tropsch biodiesel).

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

- Additional markets for oilseed crops and animal fats.
- Economic growth from locally produced fuels.

Feasibility Issues

Current production of biodiesel feedstocks in NC are provided below:[12]

Soy oil:	60.5 million gallons per year[13]
Canola oil:	Zero gallons per year.
Yellow grease:	10 million gallons per year.
Poultry fat:	21 million gallons per year.
Lard:	21 million gallons per year.
Tallow:	2 million gallons per year.
Total Current Feedstocks:	114.5 million gallons per year.

[10] www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html; accessed January 2007.
[11] Information on the Missouri Program: www.newrules.org/agri/mobiofuels.html#biodiesel, accessed January 2007.
[12] Henry Tsai, economist, NCSU Solar Center, 2004 slideshow, "Implications of Rising Energy Cost on the Economy: 3 Different Perspectives."
[13] NC Biomass Resource Inventory 2003. This oil production figure was calculated based on 43,200,000 bushels of soy grown in North Carolina.

By converting all NC wheat to canola production, another 66 MMgal/yr could be produced[14], yielding a total of about 180 MMgal/yr. Given that the policy requires about 250 MMgal/yr by 2020, these data show the importance of additional research and development and production incentives for other non-crop sources of biodiesel feedstock oil. These include production of oil from algae and Fischer-Tropsch biodiesel from cellulose.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

[14] Kurt Creamer, North Carolina State University, personal communication with S. Roe, CCS, January 16, 2007.

AFW-3. Soil Carbon Management

Mitigation Option Description

Use of conservation tillage/no-till and other soil management practices can increase the level of organic carbon in the soil, which sequesters carbon dioxide. In addition, some practices lower fossil fuel consumption through less intensive equipment use. Other practices, such as the application of bio-char can also increase the level of soil carbon and improve the soil. This option is designed to increase the acreage using soil management practices that lead to higher soil carbon content. Another element of this option is the promotion of organic farming techniques. A number of studies have found that organic farming techniques result in significantly higher levels of organic carbon in the soil relative to conventional cultivation methods.

Mitigation Option Design

- **Goals:** *By 2020, apply soil management practices on 50% of cultivated lands that currently do not use these techniques.*
- **Timing:** *By 2010, apply soil management practices on 20% of acres that currently do not use these practices. Achieve an increase to 50% of these acres by 2020.*
- **Parties Involved:** NC Department of Agriculture, NC DENR, NCSU (CALS, CNR), NC Extension, other agricultural organizations and associations
- **Other:** *Studies in NC have found the potential to sequester one ton of carbon per acre through conservation tillage/no-till practices*[15] *(equivalent to about 3.3 MtCO2e/acre).*

Implementation Mechanisms

- Increase NC Agriculture Cost Share funding to include additional acreage in no-till and organic farming techniques.
- Continue educational programs through NCCES on conservation tillage and organic farming techniques.
- Research the availability and effectiveness of bio-char application.

Related Policies/Programs in Place

- NC Agriculture Cost Share Program for no-till - $125/acre with a 120 acre cap for switching to no-till for 5 consecutive years.
- NRCS cost share programs.

Types(s) of GHG Reductions

- CO_2: Reducing tillage and soil disturbance slows the breakdown of plant material on the soil surface and in the root zone, accelerating the microbial processes that stabilize carbon and

[15] Source: http://southeastfarmpress.com/news/030106-Naderman-conservation/.

protecting carbon from oxidation, inhibiting the release of carbon back into the atmosphere. Depending on how the adoption of conservation tillage affects the overall crop production process, additional CO_2 reductions can occur through lower fossil fuel consumption in farm equipment.

- N_2O: Research also indicates the potential for higher N_2O emissions as soil organic carbon levels increase (see Feasibility Issues Section below).

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.4, 0.4
  NOTE: because agricultural soils will only accumulate carbon up to a certain level before tapering off, the GHG benefit decreases in the post-2020 period to about 0.05 MMtCO$_2$e/yr after 2025. The remaining benefit, which is permanent, is associated with lower fossil fuel consumption.
- **Net Cost per MtCO2e:** -$5
- **Data Sources:** Agricultural soil carbon accumulation levels were taken from a 2006 study by Naderman et al.[16] This study found a range of soil carbon accumulation in different NC cropping systems of 1,000-3,000 lb/acre. These accumulations occurred following a period of six consecutive years of no-till farming. The USDA 2002 Census of Agriculture shows than NC has 5,472,128 acres of cropland. 2004 NRCS National Crop Residue Management Survey found that 42% of NC cropland currently uses conservation tillage/no-till methods.

  The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 3.5 gallons/acre.[17] From the NC Inventory & Forecast, the fossil diesel GHG emission factor is 8.37 MtCO$_2$e/1,000 gallons.

  Adoption of conservation tillage/no-till practices are estimated to result in a cost savings for the grower. Work by NCSU on applying these practices to cotton growing in NC resulted in a range of cost savings from about $3 to $14 per acre per year.[18] CCS used the low end of the range as a conservative estimate of cost savings for this policy option. An older cost study for no-till versus conventional tillage methods for corn and soybeans in NC showed significant cost savings for no-till methods for most cropping systems and tillage methods ($5-$20/acre).[19] Given that these were based on 1981 data (including fuel prices), the cost savings in today's dollars would be much larger.
- **Quantification Methods:** Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation are shown in the table below. The mid-point of the estimated range for carbon sequestration (2,000 lb/acre) in NC agricultural soils was used to estimate the total amount of carbon to be sequestered. Based on the study above, it

[16] Naderman, G., B.G. Brock, G.B. Reddy, C.W. Raczkowski, *Long Term No-Tillage: Effects on Soil Carbon and Soil Density Within the Prime Crop Root Zone*, Project Report, NCSU, January 2006.
[17] Reduction associated with conservation tillage compared to conventional tillage - http://www.ctic.purdue.edu/Core4/CT/CRM/Benefits.html, accessed August 2006.
[18] $3-$14/acre savings dependent on comparison of no-till to either strip till or conventional tillage. From: Economic Comparison of Three Cotton Tillage Systems in Three NC Regions, S. Walton and G. Bullen, NCSU, www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt, accessed February 2007.
[19] *No-Till Crop Production Systems in North Carolina – Corn, Soybeans, Sorghum, and Forages*, North Carolina Agricultural Extension Service, date unknown, accessed February 2007 at: www.ag.auburn.edu/aux/nsdl/sctcsa/Proceedings/1981/1981_SCTCSA.pdf.

was further assumed that this additional carbon would be sequestered in the soil over a period of six years (after six years no further carbon is stored). The resulting annual carbon accumulation rate was converted into its CO_2 equivalent yielding 0.55 $MtCO_2$/acre-yr.

To estimate carbon stored each year, the annual accumulation rate was multiplied by the number of acres in the policy program each year. After six years, the crop acres that entered the program were assumed to not store additional carbon. Results are shown in the table below.

GHG savings from reduced fossil fuel consumption were estimated by multiplying the fossil diesel emission factor and diesel fuel reduction per acre estimate provided above. Results are shown in the table below along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

Year	Acres in Program	Acres Still Accumulating Carbon	$MMtCO_2$ Sequestered	Diesel Fuel Saved (1,000 gal)	MMtCO2e from Diesel Avoided	Total $MMtCO_2e$ Saved
2007	158,692	158,692	0.088	555	0.0047	0.0926
2008	317,383	317,383	0.176	1,111	0.0093	0.1853
2009	499,879	499,879	0.277	1,750	0.0147	0.2918
2010	634,767	634,767	0.352	2,222	0.0186	0.3705
2011	729,982	729,982	0.405	2,555	0.0214	0.4261
2012	825,197	825,197	0.457	2,888	0.0242	0.4817
2013	920,412	761,720	0.422	3,221	0.0270	0.4493
2014	1,015,627	698,243	0.387	3,555	0.0298	0.4169
2015	1,110,842	610,963	0.339	3,888	0.0326	0.3713
2016	1,206,057	571,290	0.317	4,221	0.0354	0.3521
2017	1,301,272	571,290	0.317	4,554	0.0381	0.3549
2018	1,396,487	571,290	0.317	4,888	0.0409	0.3577
2019	1,491,702	571,290	0.317	5,221	0.0437	0.3604
2020	1,586,917	571,290	0.317	5,554	0.0465	0.3632
2021	1,586,917	476,075	0.264	5,554	0.0465	0.3105
2022	1,586,917	380,860	0.211	5,554	0.0465	0.2577
2023	1,586,917	285,645	0.158	5,554	0.0465	0.2049
2024	1,586,917	190,430	0.106	5,554	0.0465	0.1521
2025	1,586,917	95,215	0.053	5,554	0.0465	0.0993
2026	1,586,917	0	0.000	5,554	0.0465	0.0465
2027	1,586,917	0	0.000	5,554	0.0465	0.0465
2028	1,586,917	0	0.000	5,554	0.0465	0.0465
2029	1,586,917	0	0.000	5,554	0.0465	0.0465
2030	1,586,917	0	0.000	5,554	0.0465	0.0465

Costs were estimated by multiplying the estimated savings per acre cited above ($3) by the number of acres in the program each year. The effects of other existing incentive programs were not taken into account in these estimates.

- **Key Assumptions:**

These include the representativeness of the assumed carbon sequestration potential across all of the crop systems to which the policy is applied; six year period for accumulating the soil carbon; any potential increase in N_2O emissions (see Feasibility Section below) is not large enough to significantly effect the estimated benefits; the cost savings is a representative average of savings to be achieved across all crop systems.

Key Uncertainties

See "key assumptions" in the previous section. Note that the benefits and costs of the application of bio-char to agricultural soils have not been included in this analysis. Within the period of analysis for this policy, bio-char application could become another element of this program to increase soil carbon levels in agricultural soils. The North Carolina legislature is considering a bill calling for additional study of bio-char and the associated benefits and costs of its use in the state.[20]

Additional Benefits and Costs

- Reduced soil erosion for no-till.
- Potential for lower nitrogen leaching to ground or surface water.
- Reduction in fossil fuel use and associated emissions.

Feasibility Issues

Research has indicated a potential for increased N_2O emissions as soil organic carbon levels increase.[21] Additional study and field work on NM cropping/soil systems will be needed to verify the GHG reduction potential estimated in this policy analysis.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

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[20] The Bill is to be entitled "An Act To Appropriate Funds For Research And Development Of Bio-Char For Carbon Sequestration, Increased Crop Yield, And Soil Improvement", and if passed, would be effective in July of 2007.

[21] Li et al, "Carbon Sequestration in Arable Soils is Likely to Increase Nitrous Oxide Emissions, Offsetting Reductions in Climate Radiative Forcing", *Climate Change*, (2005) 72: 321–338.

AFW-4. Preserve Agricultural Land

Mitigation Option Description

Reduce the rate at which existing crop and pasture are converted to developed uses. The carbon sequestered in soils and aboveground biomass is much higher in croplands than in developed land uses. Policies are needed to preserve working farms and forests (see AFW-7) from unwise and unplanned development. This option should be seen as a companion measure to TLU Option 1a (Land Development Planning).

Mitigation Option Design

State and national programs have been established to protect farm communities from conversion to development. Funding state farmland preservation programs will help meet goals and act as a needed match to national programs. Programs are being investigated that help farmers transition lands to beginning farmers.

- **Goals:** Reduce the rate at which agricultural lands are converted to developed use by 50% by 2020 from current levels.
- **Timing:** By 2010, reduce the rate of conversion by 20% from current levels. By 2020, reduce the rate of conversion by 50%.
- **Parties Involved:** NCDA&CS, NC Farm Bureau, NCDF, USDA-FS, NCFR, NCSU, NC Farm Transition Network
- **Other:** North Carolina lost 2000 farms and 100,000 acres between 2004-2005. North Carolina has lost over 7 thousand farms and 300,000 acres since 2000.

Implementation Mechanisms

- Increased funding for state farmland preservation programs.
- Increased public education on the benefits of preserving agricultural land.
- Inclusion in voluntary programs such as NC Agriculture Cost Share.
- Increased funding from General Funds.
- Increase funding for Agricultural Development and Farmland Preservation Trust Fund (protects forest and farmlands).
- Farm Bill Conservation Title- EQIP, CRP, CREP.
- Encourage counties to construct County Farmland Protection Plans in order to identify and plan to protect their farm and forestland production areas.
- Engage local governments and nongovernmental organizations on recruiting farmers to take part in protection programs and in developing funding mechanisms to support the plans.

Related Policies/Programs in Place

- Agricultural Development and Farmland Preservation Trust Fund
- Present Use Tax Valuation

- North Carolina Conservation Tax Credit
- Farm and Ranchlands Protection Program
- Forest Legacy Program
- EQIP, WRP, CRP, CREP,WHIP
- Million Acre Initiative

Types(s) of GHG Reductions

- CO2: Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass. Also, emissions are indirectly reduced to the extent that development patterns are influenced and vehicle miles traveled (VMT) are reduced (see TLU Option 1a).
- CH4 and N2O: Are also indirectly reduced as VMT are reduced.

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.3, 0.4
- **Net Cost per MtCO2e:** $114

  NOTE: the reductions and cost per Mt estimated for this option only refer to the direct benefits and costs associated with the estimated loss of soil carbon from agricultural soils due to development. They do not include the indirect benefits that occur as a result of more efficient development patterns that could result from this option (see TLU Option 1a).

- **Data Sources:**

  The annual rate of agricultural land conversion in NC (101,600 acres) was taken from a 2001 study.[22] The typical level of soil carbon in agricultural soils in NC was taken from a 2002 study of Piedmont soils (0.017 MMtC/1,000 acres for the top eight inches of soil).[23] The cost of establishing conservation easements on agricultural lands surrounding developing areas was taken from NRCS information on the Farm Preservation Program (FPP).[24] The FPP program provides cost share to establish conservation easements on agricultural lands (up to 50% cost share). As the available data were taken from a 2001 summary for NC, CCS used the high end of the range of costs per acre to represent potential costs in 2007 dollars ($2,069/acre). This cost is nearly identical to the nationwide average determined by the American Farmland Trust ($2,000/acre).[25]

- **Quantification Methods:**

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[22] 1992-1997 rate of conversion from - Commission on Smart Growth, *Growth Management and Development: Findings and Recommendations*, Fall 2001, www.eatsmartmovemorenc.com/resources/documents/aces/aces_smartgrowth.pdf.

[23] Franzluebbers, A.J., B. Grose, L.L. Hendrix, P.K. Wilkerson, B.G. Brock, "Surface-Soil Properties in Response to Silage Intensity under No-Tillage Management in the Piedmont of North Carolina", presented at the 25th Southern Conservation Tillage Conference for Sustainable Agriculture, Auburn, AL, June 24-26, 2002, www.ars.usda.gov/SP2UserFiles/Place/66120900/SoilManagementAndCarbonSequestration/2002ajfP02.pdf, the data associated with high intensity crop tillage were used to develop the value used in this analysis.

[24] NRCS, 2001. Range of Farmland Protection Program costs for easements, range $1,660 - $2,059/acre, average $1,885/acre; Farmland Protection Program, NC Summary, December 2001; www.nrcs.usda.gov/programs/frpp/StateFacts/NC_2001.pdf.

[25] American Farmland Trust, A National View of Agricultural Easement Programs, http://www.aftresearch.org/PDRdatabase/NAPidx.htm.

GHG Benefits

Studies are lacking on the changes in below and above-ground carbon stocks when agricultural land is converted to developed uses. For some land use changes, carbon stocks could be higher in the developed use relative to the agricultural use (e.g., parks). In other instances, carbon stocks are likely to be lower (graded and paved surfaces). CCS assumed that the agricultural land would be developed into typical tract-style suburban development. It was further assumed that 50% of the land would be graded and covered with roads, driveways, parking lots, and building pads. The final assumption was that 75% of the soil carbon in the top eight inches of soil for these graded and covered surfaces would be lost and not replaced. CCS assumed no change in the levels of above-ground carbon stocks.

The benefit in each year was determined by: 1) determining the amount of land protected in each year by multiplying the annual rate of agricultural land lost by the percent of agricultural land protected; 2) multiplying the soil carbon content on the protected land by 50% (representing graded and covered areas) and by 75% (fraction of soil carbon lost); 3) converting the soil carbon lost to CO_2 by multiplying by 44/12. The table below provides a summary of the estimates for each year.

Year	% of Conversion Reduced	Ag Acres Protected	MMtCO2e Saved
2007	0	0	0.00
2008	10	10,160	0.07
2009	10	10,160	0.07
2010	20	20,320	0.13
2011	20	20,320	0.13
2012	30	30,480	0.19
2013	30	30,480	0.19
2014	30	30,480	0.19
2015	30	30,480	0.19
2016	40	40,640	0.26
2017	40	40,640	0.26
2018	40	40,640	0.26
2019	50	50,800	0.32
2020	50	50,800	0.32
	Totals	**406,400**	**2.6**

Costs

To estimate program costs in each year, CCS used multiplied the estimated agricultural acres protected from development by the conservation cost ($2,069/acre) and an assumed cost share of 50%. This cost share is assumed to be available from the NRCS or other sources (e.g. city or county governments, or non-government organizations). The resulting cost effectiveness is $114/Mt. This estimate only accounts for the direct reductions associated with soil carbon losses estimated above and does not include potentially much larger indirect benefits associated with reductions in vehicle miles traveled (see TLU Option 1a).

Note that the availability of this cost share is a significant assumption for this policy option, since the number of acres to be protected is substantially higher than the average protected during the 1996-2001 period (about 200 acres/year). Without the cost share, the cost effectiveness would be twice the value presented here.

- **Key Assumptions:** No change in above-ground carbon stocks; 75% loss of soil carbon on 50% of developed land; 50% cost share available from NRCS, city/local governments, or other sources.

Key Uncertainties

As described above, these include the estimated above and below ground carbon stocks for agricultural and developed land uses and the availability of cost share programs to offset the costs of purchasing conservation easements.

Additional Benefits and Costs

• Human and Social Issues: Protection of working lands will provide a better quality of life for the citizens of North Carolina and protect its rural Landscapes and heritage.

• Environmental Issues: 1) Working lands provide environmental services to the citizens of North Carolina by providing clean air, clean water, and wildlife habitat that all North Carolinians enjoy. It has been well documented that impervious surfaces and development has a detrimental affect on our natural resources; 2) The Preservation of working lands can also suppress suburban sprawl and help decrease transportation related emissions.

• Economic Issues: 1) Cost of community service studies show that reidential development does not pay for itself in taxes. However, working lands require an average of .34 cents in services for every $1 collected from local governments. This is a net gain for local and county budgets (AFT); 2) Agriculture is the #1 industry in North Carolina at $68 billion dollars in total revenue.

Feasibility Issues

[Insert text as appropriate]

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-5. Agricultural Biomass Feedstocks for Electricity or Steam Production

Mitigation Option Description

Offset fossil fuels use with agricultural biomass as feedstock for electricity, steam, or heat generation. Agricultural biomass includes, but is not limited to, poultry litter, livestock manure, and crop residues, as well as energy crops (e.g., switchgrass, hybrid poplar). Offsetting fossil fuels use reduces the GHG emissions associated with these fuels.

This option links with AFW-1, which promotes the use of anaerobic digesters and energy utilization. It explores additional opportunities for agricultural biomass energy use. This option also has linkages to ES Options 1 (Renewable Energy Incentives), 2 (Environmental Portfolio Standard), and 10 (NC Greenpower Renewable Resources Program) and to RCI Option 10 (Distributed Renewable and Clean Fossil Fuel Power Generation).

Mitigation Option Design

- **Goals:** Increase agricultural biomass use for electricity, steam, and heat generation to utilize 10% of available biomass by 2010, 25% of available biomass by 2020 and 50% of available biomass by 2030. Voluntary, incentive-based programs should be used to foster development of the industry and associated economic markets.
- **Timing:** See above.
- **Parties Involved:** NCDA&CS, NCSU, NCA&T, Cooperative Extension, NC State Energy Office, DAQ, Utilities Commission, Electric Utilities, Livestock & Poultry Producers, Crop Producers.
- **Other:** Explore biomass utilization for electricity, steam, and heat generation using 100% biomass and/or co-firing with other feedstocks (as described in the ES and RCI options cited above).

Implementation Mechanisms

- Incentives in the form of tax breaks (sales and/or income) for incurred capital costs.
- Inclusion/Expansion of voluntary programs such as NC Green Power and NC Agriculture Cost Share.
- Increased research to improve return on investment.
- Education for potential producers of power purchase agreements and interconnection with the grid.
- Public education of benefits of electricity produced from biomass, drive demand.
- Additional research for utilization of available biomass for electricity production.
- Additional research for more efficient biomass products for utilization in electricity production.

Related Policies/Programs in Place

- NC Renewable Energy Property tax credit. State income tax credit for 35% of construction costs not to exceed $2.5M or 50% of tax burden.
- Federal Renewable Electricity Production Tax Credit.
- NC Green Power.

Types(s) of GHG Reductions

- **CO2:** Savings occur as a result of displacing fossil fuel use in the production of electricity or steam.

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0., 0.
- **Net Cost per MtCO2e:** $

  NOTE: the costs and benefits shown above are those associated with in-state biomass feedstock delivery to a power plant or heat/steam end user. The GHG benefits from offsetting fossil-based power or heat/steam generation with biomass generation are covered in the ES and RCI sectors.

- **Data Sources:** Information on available biomass feedstocks was taken from a recent study supporting a renewable portfolio standard in NC.[26] A primary source of information for this study is a 2004 report from the NC Solar Center.[27] Estimates of available agricultural biomass feedstocks are shown below:

Feedstock	Annual Resource (dry tons)	Annual Resource (MMBtu)
Corn Stover	963,494	14,259,711
Wheat Straw	60,413	942,443
Poultry Litter[28]	50,000	650,000
Dairy, Beef, and Hog Manure[29]	2,800,000	36,400,000
Switchgrass	263,132	4,210,112
Hybrid Poplar	302,909	5,149,453
Totals	**3,039,948**	**61,611,719**

[26] *Analysis of a Renewable Portfolio Standard for the State of North Carolina,* prepared by La Capra Associates for the NC Utilities Commission, December 2006.

[27] *Use of Agricultural and Forest Waste as a Distributed Generation Power Resource in North Carolina,* NC Solar Center, July 16, 2004.

[28] The estimate for poultry litter assumes a broiler population of 100,000,000 in NC and heat content of 6,500 Btu/lb dry solids ("Animal and Poultry Waste-To-Energy", L. Bull, NCSU; accessed at: www.cals.ncsu.edu/waste_mgt/waste%20to%20energy.pdf) and litter production of one ton per thousand birds (www.fibrowattusa.com/US-Press/WattPoultryUSA%20Dec%2001%20on%20Nutrient%20Mgt.pdf) . Moisture content of litter is assumed to be 50%. Additional litter produced in turkey or hen/breeder operations not included.

[29] These values represent the total annual manure production for these animal populations. The assumed heat content is 6,500 Btu/lb dry solids. The estimates are taken from the L. Bull reference cited in the footnote above.

Additional text on quantification methods and assumptions is under development.

- **Quantification Methods:**
- **Key Assumptions:**

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

- Additional markets for agricultural biomass.
- Economic growth from electricity produced from local feedstocks, rural economy benefits.

Feasibility Issues

- Demand from electric utilities.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-6. Policies to Promote Ethanol Production

Mitigation Option Description

Offset fossil fuel use (gasoline) with production and use of starch-based and cellulosic ethanol. Offsetting gasoline use with ethanol can reduce GHGs to the extent that the ethanol is produced with lower GHG content. Provide incentives for the production of ethanol from crops, forest sources, animal waste, and municipal solid waste.

Note that this option is linked to the TLU biofuels option (TLU-7). That option focuses on mechanisms to increase biofuels consumption in North Carolina. The quantification of benefits and costs for each option takes into account the anticipated GHG reductions to be achieved by each.

Mitigation Option Design

- **Goals:** Several projects are being proposed that would result in the production of 150 million gallons of ethanol annually in North Carolina by 2008. Incentives could increase this amount to a volume equivalent to offsetting gasoline consumption in the state by 10% in 2015 and 25% by 2025. These goals are based on cellulosic ethanol being commercially viable by 2015.
- **Timing:** See above.
- **Parties Involved:** NCDA&CS, Department of Administration, Motor Carrier Enforcement Division, DENR, Department of Commerce, NC Rural Center, NCSU, NCA&T, other state agencies, agricultural associations which represent producers of feedstock, petroleum industry trade groups, and various industry and forestry associations.
- **Other:** Identify incentives that encourage the growing of feedstocks, production of ethanol in North Carolina, and the utilization of ethanol all across the state.
    - Consider impact of expected increases in transportation costs on delivery of feedstocks to processing facilities, and how this effects optimal distribution of production infrastructure.

Implementation Mechanisms

- Incentives in the form of tax breaks (sales and/or income) for incurred capital costs.
- Streamlined permitting of production facilities. Technical assistance for new producers.
- Active solicitation of new producers.
- Expanded consumer education to drive demand.
- Expanded producer education to develop skilled workforce.
- Expanded research for cellulosic ethanol production, including energy specific crops.

Related Policies/Programs in Place

- NC Renewable Energy Property tax credit. State income tax credit for 35% of construction costs not to exceed $2.5M or 50% of tax burden.
- Federal Ethanol Mixture Tax Credit, currently $.50/gallon.

Types(s) of GHG Reductions

- CO_2 – Lifecycle emissions are reduced to the extent that ethanol is produced with lower embedded fossil-based carbon than conventional (fossil) gasoline. Feedstocks used for producing ethanol can be made from crops or other biomass, which contain carbon sequestered during photosynthesis (i.e., biogenic or short-term carbon). There are two different methods for producing ethanol based on two different feedstocks. Starch-based ethanol is derived from corn or other starch/sugar crops. Cellulosic ethanol is made from the cellulose contained in a wide variety of biomass feedstocks, including agricultural residue (e.g., corn stover), forestry waste, purpose grown crops (e.g., switchgrass) and municipal solid waste. Local production of ethanol also decreases the embedded CO_2e of ethanol compared to importation from the current U.S. primary ethanol producing regions. Current research indicates that cellulose-based ethanol production provides up to 72-85% reduction in GHGs compared to gasoline, whereas an 18-29% reduction is measured from starch-based ethanol production compared to gasoline.

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.9, 6.9
- **Net Cost per MtCO2e:** $5
- **Data Sources:** In-state production targets were estimated based on the current and projected levels of gasoline consumption (from the GHG Inventory & Forecast), the policy design parameters, and information on BAU ethanol production.[30] The total BAU production (194 MMgal/yr) is based on information gathered from a variety of sources for proposed ethanol plants in NC. The first step in estimating in-state production targets is shown in the table below. The estimated in-state production volumes are the volumes needed in each year to show progress toward the 2015 and 2025 policy goals minus the estimated BAU production:

Parameter	2010 (MMgal)	2020 (MMgal)
BAU Gasoline Consumption	5,076	5,764
Ethanol Needed for Policy Targets	193	896
BAU Ethanol Production	194	194
Ethanol Production Needed	0	702

[a] Based on 3.8% gasoline offset by 2010 and 17.5% by 2020 (toward 2025 goal of 25%).

Since the BAU production meets the levels of production needed for 2010, a different ramp up schedule was set up for incentives in the early part of the policy period (2007-2014) to stimulate production using GHG-superior methods (cellulosic ethanol, starch-based ethanol using renewable energy). The overall production schedule is shown below:

[30] BAU production assumes first phase of Agri-Ethanol Plant in operation - 57 MMgal/yr in 2007; second phase in 2008 - 57 MMgal; E85 Inc. and Clean Burn Fuels also have proposed plants (capacities unknown) - assume another 80 MMgal/yr BAU production in 2008. Total BAU production is 194 MMgal/yr. This value is assumed to remain constant through 2020.

Assumed Ethanol Production Schedule (MMgal/yr)			
2007	-	2017	584
2008	10	2018	686
2009	60	2019	790
2010	110	2020	896
2011	160	2021	1,026
2012	210	2022	1,142
2013	260	2023	1,262
2014	310	2024	1,384
2015	362	2025	1,509
2016	484		

The methods used to estimate GHG reductions and the costs for the policy are provided below.

- **Quantification Methods:**

GHG Reductions

The benefits for this option are dependent on developing in-state production capacity that achieves benefits above the levels of existing and planned (BAU) starch-based production in the U.S. (the benefits of using ethanol from starch-based production are already accounted for under TLU Option 7). Emission factors for reformulated gasoline, starch-based ethanol, and cellulosic ethanol were taken from a General Motors/Argonne National Lab study.[31] These emission factors incorporate the GHG emissions during the entire life-cycle of fuel production (e.g., extraction, transport, refining, distribution, and consumption for gasoline; crop production, feedstock transport, processing, distribution, and consumption for ethanol). These life-cycle emission factors are referred to as “well-to-wheels” emission factors:

Fuel	Emission Factor (grams CO_2e/mi)
Reformulated gasoline	552
Starch-based ethanol	451
Cellulosic ethanol	154

In addition to cellulosic ethanol production, the other types of ethanol production processes targeted by this option include starch-based processes that achieve similar levels of life-cycle GHG reductions to cellulosic ethanol. These would be starch-based plants that use renewable fuels, such as biomass, biogas, landfill gas, or other renewable fuels. While CCS is not aware of any lifecycle emission factors for these types of plants (although several have been proposed in the U.S.), CCS assumes that reductions similar to cellulosic ethanol can be achieved.

Based on the emission factors shown above, the incremental benefit of the production targeted by this policy over conventional starch-based ethanol is 66% (reduction of CO_2e by

[31] *Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems— A North American Study of Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions*, General Motors, Argonne National Lab, and Air Improvement Resource, Inc., May 2005.

offsetting gasoline consumption). This value was used along with the lifecycle emission factor for gasoline[32] and the production in each year to estimate GHG reductions.

Costs

Costs for the incentives needed by this policy option are based on the difference in estimated production costs between conventional starch-based ethanol and cellulosic ethanol. The DOE EIA estimated that the cost to produce starch-based ethanol is $1.10/gal compared to $1.29/gal, or a difference of $0.19/gal (in $1998).[33] In 2006 dollars, the difference is $0.23/gal. These incentives are considered necessary in the near term (up to 2015) to help commercialize technologies that produce ethanol from cellulose or produce starch-based ethanol using renewable fuels. The incentives should also help to establish the infrastructure to deliver biomass to biorefineries, since producers will seek the local feedstocks or renewable fuels for their operations.

By 2015, it is assumed that advances in cellulosic ethanol production (e.g., enzyme costs, production processes) will make cellulosic ethanol production cost competitive with starch-based production. Hence, the incentives are discontinued beginning in 2015. Note that there is currently federal legislative proposal to offer cellulose an incentive of $0.765/gallon compared to the $0.51/gallon currently offered for ethanol production.[34] If enacted, this $0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of North Carolina. Obviously, the federal incentives do not assure that production facilities would locate in NC. These federal incentives have not been factored into the cost estimates for this option.

The costs for this option were estimated using the $0.23/gal incentive multiplied by the production needed in each year. By 2015, it is assumed that these incentives will no longer be needed as cellulosic ethanol technologies become fully commercialized. Below is the assumed schedule for these incentives:

Year	New Capacity (MMgal)	Incentives Cost (MM 2006$)	GHG Benefit ($MMtCO_2e$)
2007	-	$0.00	0
2008	10	$2.3	0.08
2009	60	$13.8	0.46
2010	110	$25.3	0.85
2011	160	$36.8	1.24
2012	210	$48.3	1.62
2013	260	$59.8	2.01
2014	310	$71.3	2.40
2015	362	$0.0	2.80
2016	484	$0.0	3.74
2017	584	$0.0	4.52
2018	686	$0.0	5.30
2019	790	$0.0	6.11

[32] In the study mentioned above, the average fuel economy used was 21.3 miles/gallon or 100 miles/4.7 gallons. Multiplying this value by the emission factor of 552 grams/mile yields 11,745 grams/gallon.

[33] DOE EIA analysis can be found at: www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed January 2007.

[34] D. Morris, *Making Cellulosic Ethanol Happen: Good and Not So Good Public Policy*, Institute for Local Self-Reliance, January 2007, www.newrules.org/agri/cellulosicethanol.pdf, accessed January 2007.

Year	New Capacity (MMgal)	Incentives Cost (MM 2006$)	GHG Benefit ($MMtCO_2e$)
2020	896	$0.0	6.93

After discounting and levelizing the costs from 2007-2020, the cost effectiveness is just under $5/MtCO₂e.

- **Key Assumptions:** Starch-based ethanol production using renewable fuels achieves equivalent GHG lifecycle benefits as cellulosic ethanol; cellulosic production or starch-based production with renewable fuels can achieve the production levels in the near term (2014 production of 310 MMgal/yr) required by this policy option; Federal tax incentives do not preclude the need for the additional state incentives assumed for the cost estimate.

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

- Additional markets for starch/sugar crops and possibly dedicated energy crops.
- Economic growth from locally produced fuels.

Feasibility Issues

- Feedstock supply for corn based ethanol production.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-7. Forest Protection – Reduced Clearing and Conversion to Nonforest Cover

Mitigation Option Description

Reduce losses of forested lands and their carbon sequestration potential to development or poor forest management. Developed areas contain lower amounts of biomass and its associate carbon. These areas also sequester less carbon dioxide than forested areas.

Mitigation Option Design

North Carolina is losing on average 61,390 acres of productive forest each year over the last 30 years to development and a lack of regeneration post-harvest. This amounts to a loss of about 10% since 1974, or about 0.36% annually compounded loss.

- **Goals:** Reduce the rate of conversion by 10% by 2010 and 25% by 2020.
- **Timing:** see above
- **Parties Involved:** NC Division of Forest Resources, NC Extension, NCSU College of Natural Resources, NC Forestry Association, NC Woodlands
- **Other:** The loss of forested lands is not consistent; between 1984 and 1990, there was actually an increase in the timberland area of 260,000 acres. This offers hope that one might reverse the overall trends in forest losses.

Implementation Mechanisms

- Use valuation, perhaps subsidize where use value is same as commercial value
- Higher value to forestry, see AFW 9 & 10
- Economic inducements to not harvest in priority zones.

Related Policies/Programs in Place

[Insert text as appropriate]

Types(s) of GHG Reductions

[Insert text as appropriate]

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 1.7, 4.3
- **Cumulative GHG reduction potential (MMtCO2e, 2007-2010):** 31.2
- **Net Cost per MtCO2e:** TBD

- **Data Sources:** US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343; also published as part of the Department of Energy Voluntary GHG Reporting Program, revised Technical Guidelines
- **Quantification Methods:**
- **Key Assumptions:** Assume 95% of carbon is biomass and soils is lost when forests are converted to developed uses, based on input from TWG regarding the complete removal of biomass and topsoil when land is developed in NC. Assume protected forests are primarily pine dominant forest types.

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

[Insert text as appropriate]

Feasibility Issues

[Insert text as appropriate]

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-8. Afforestation and/or Restoration of Nonforested Lands

Mitigation Option Description

Afforest nonforested lands or restore degraded habitats to forests in order to sequester and store carbon above pre-existing conditions. Existing afforestation programs are underfunded for the task of this afforestation, typically there is a long wait list for landowner forestation projects. This option covers the provision of additional incentives to increase the rate of afforestation and restoration.

Mitigation Option Design

[Insert text as appropriate]

- **Goals:** Initiate afforestation/restoration projects on 540,000 acres by 2020.
- **Timing:** By Fall 2007 planting season have candidate acreage identified (by county) in cooperation with NRCS, FSA and NC SWCD and NC DFR[35]. By 2010, achieve afforestation projects on 40,000 acres. Achieve a total of 540,000 acres of afforestation projects by 2020.
- **Parties Involved:** Seek to establish a unified cooperative alliance of farm (NC Farm Bureau), forest landowner (North Carolina Woodland Owners Association, North Carolina Forestry Association)**,** agencies (NC DFR, NC DA), utilities (Duke, Progress Energy), industrial and non-governmental organizations to promote and implement the coordination needed to reach this historic goal.
- **Other:** Afforestation, the planting of trees on lands that have not recently supported forests, has both carbon sequestration and other environmental benefits: storing up to two tons of carbon per acre each year (7.3 tons of CO_2, on-site, not including off-site storage and offsets in products); deliver other important benefits such as improved wildlife habitat, reduced soil erosion and fertilizer runoff, and new recreational opportunities. There is a large opportunity for afforestation on agricultural, brownfields, and other lands in NC (possibly greater than 1.5 million acres).[36] These lands are relatively productive for forestry, as the croplands have typically been previously fertilized with mineral nutrients. The average cost-sharing for forestation success in the NC Forest Development Program (FDP) averages between $90 and $200 per acre[37]. The FDP has been the major funding mechanism for state assistance to landowners foresting their lands (~90% of all acres cost

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[35] Natural Resources Conservation Service & Farm Services Agency (USDA), North Carolina Soil and Water Conservation Districts and Division of Forest Resources

[36] Conservation Compliance: the Clock is Running. Cook, M. and D. Hoag. 1997 SoilFacts , AG-439-23 http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-23/ Accessed 10/3/2006.

[37] Forest Development Program, Annual Accomplishment Summary, 2006, Joann Hocut, NC Division of Forest Resources.

shared by currently active NCDFR administered forestation programs, see Figure below[38]) and has reached approximately 85% of NIPF landowners doing forestation over the last 6 years (1999-2005)[39].

Implementation Mechanisms

Bioenergy markets can increase demand for energy plantations, and potentially influence afforestation/reforestation rates in NC

Related Policies/Programs in Place

[Insert text as appropriate]

Types(s) of GHG Reductions

[Insert text as appropriate]

Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO2e):** 0.2, 2.4
- **Cumulative GHG reduction potential (MMtCO2e, 2007-2010):** 14.8
- **Net Cost per MtCO2e:** $1.25
- **Data Sources:** US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343; also published as part of the Department of Energy Voluntary GHG Reporting Program, revised Technical Guidelines; NC Division of Forest Management, Forest Development Program, cost share rates.
- **Quantification Methods:**
- **Key Assumptions:** Assume planted forests are primarily pine dominant forest types; cost per acre of $9.50 annually for 13 years (total of $123/acre); cost includes site preparation, planting, and one fertilization.

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

[Insert text as appropriate]

Feasibility Issues

[Insert text as appropriate]

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

[38] Ibid.

[39] Chris Hopkins' synthesis of Forest Statistics for North Carolina, 2002 and FDP reports.

Barriers to Consensus

[Insert text as appropriate]

AFW-9 & 10. Expanded Use of Forest Biomass and Better Forest Management

Mitigation Option Description

Direct the products of forest management to the highest value markets that currently exist and the currently unmarketable logging residue, culls and saplings to the appropriate processing centers for electricity, heating or liquid fuels. Offsetting fossil fuel use reduces GHG emissions. Increase the growth and yield of production from sustainably managed forest resources through site preparation, competition control, thinning, fertilization, and improved genetics. These practices will increase the amount of carbon stored in forested areas and increase carbon dioxide sequestration rates.

Mitigation Option Design

The goal is the expansion of the production and use of wood products for solid wood products, fiber and fuel. The use of each of these offsets the use of fossil fuels in the production of substitute material (cement, steel for solid wood products, plastic for wood fiber) or directly in the case of fossil fuels for biomass energy. Having a market for relatively low value biomass products enables forest management for higher value solid wood products (see Additional Benefits and Costs section below for more background).

- **Goals:** Initiate programs to increase forest productivity by 100% on half of NC timberlands by 2020.
- **Timing:** Begin 2007 and increase to full implementation of management programs on 50% of timberlands by 2020. Increase coverage to all managed timberlands by 2030.
- **Parties Involved:** Division of Forest Resources, NC Extension, NCSU College of Natural Resources, NC Forestry Association, NC Woodlands
- **Other:** Increased benefits from forest management would increase forestland owner incomes and the probability of retaining forest cover.

Implementation Mechanisms

Below are some ideas for discussion, I am not committed to anyone:

- Incentives and education for management improvements (e.g., fertilization[40])
- Developing new markets for biomass energy, harvesting and use of post-disturbance biomass
- A renewable portfolio standard (depending on how it was defined) could generate a market for forest biomass, likewise some

[40] TWG has discussed whole-tree harvesting as another potential management practice to increase productivity, TWG will further review the appropriateness of this approach

- State incentive for cellulosic biomass to ethanol plant (see AFW-6).
- A state carbon tax could incentivise renewable fuel production (liquid and electricity) and encourage the use of durable wood products over steel and concrete. The largest emitters of CO2 (coal, liquid fuels, concrete, etc.) could be taxed on their emissions of fossil carbon. The funds could be allocated to carbon sequestration efforts in which forestry could compete cost effectively. FDP might be the mechanism to allocate carbon tax funds.
- Perhaps the state could participate in carbon trading and retain the carbon credits for any state funded carbon sequestration on private land through FDP.

Related Policies/Programs in Place

[Insert text as appropriate]

Types(s) of GHG Reductions

[Insert text as appropriate]

Estimated GHG Reductions and Costs (or Cost Savings)

[Insert text as appropriate]

- **Data Sources:**
- **Quantification Methods:**
- **Key Assumptions:**

Key Uncertainties

[Insert text as appropriate]

Additional Benefits and Costs

The goal is to double the productivity of timberland for high value products and claim these products and energy as carbon offsets. We estimate that 1.75% (~57 year rotation) of the state timberland (totaling 17.6 million acres) is cut each year, so most timberland is currently under some sort of management, although much of it is of a very low intensity, indeed 25% of harvested stands continue to be high-graded. Our goal is to improve the management and productivity of these lands, especially on the 11.4 million acres held by non-industrial private forest land owners.

A standard application of fertilizer on otherwise unmanaged land can increase average productivity about 66% for hardwood and 77% for softwoods. Improved genetics continues to add 5 to 10% in productivity for each improved generation. Improved thinning and competition control can increase high value product growth by 20%. The logging residue that currently is left in the woods is about 15% of total productivity and this too would be increased by fertilization and could be used for biomass energy. While not all improvements are directly multiplicative, it is clear that we can double forest productivity and more than double carbon sequestration by forests in North Carolina.

Feasibility Issues

[Insert text as appropriate]

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-11 Landfill Methane and Biogas Energy Programs

Mitigation Option Description

Provide incentives that will result in an increase in the recovery of landfill methane for use as an energy source. Increasing the recovery of landfill methane will reduce emissions of this GHG and will offset the use of fossil fuels for commercial/industrial heat/steam generation or electricity production.

Mitigation Option Design

Out of approximately 130 open and closed landfills in the state, only about 15 sites are currently recovering landfill methane for energy use.

- **Goals:** Increase the number of uncontrolled municipal solid waste landfills recovering methane as an energy source, such that 50% of the landfill gas being generated is controlled by 2020. This can be done through development of additional landfill gas to energy (LFGTE) projects. For sites where LFGTE is not feasible, implement flaring controls to achieve the goal.
- **Timing:** By 2010, implement LFGTE at 10 sites not currently using these technologies; by 2020, achieve full implementation of the policy (50% coverage of generated LFG).
- **Parties Involved:** Municipal and county governments, private solid waste management companies, local economic development agencies, NC Department of Environment and Natural Resources, NC Department of Commerce, NC Utilities Commission, non-government organizations, and public interest groups.
- **Other:** No distinction is made between the direct use of landfill methane (e.g. for heat or steam) and the use of methane for electricity generation.

Implementation Mechanisms

Undertake a GIS based assessment of landfill gas to energy project potentials focusing on identifying end-users (may have been undertaken by NC Solar Center and State Energy Office). Work with the NC Department of Commerce to use the findings for economic development purposes.

Establish and expand tax credits for the development of landfill gas to energy projects.

Develop policies that encourage state agencies to enter into fuel/power purchasing agreements that will result in increased landfill gas to energy projects.

Research the potential to alleviate burdens associated with the NC Utilities Commission rules regarding the treatment of landfill gas to energy projects as regulated utilities.

Develop a grant program or other incentives to encourage the installation of gas collection systems at landfills for the purpose of flaring landfill methane.

Related Policies/Programs in Place

NC State Energy Office, NC DENR, NC Solar Center, US EPA – Landfill Methane Outreach Program.

US Department of Energy, Renewable Energy Production Incentive; US Internal Revenue Code, Section 45; 15 NCAC 13B Section .1500, Standards for Special Tax Treatment of Recycling and Resource Recovery Equipment and Facilities.

Types(s) of GHG Reductions

Methane Destruction – Flaring or production of energy from landfill gas results in the destruction of methane.

GHGs Reduced via Fossil Fuel Reductions **–** Use of landfill gas for generating heat/steam or electricity can offset fossil fuel use (e.g. natural gas, coal), which will reduce emissions of CO_2, CH_4, and N_2O from the combustion of fossil fuels.

Estimated GHG Reductions and Costs (or Cost Savings)

- GHG potential in 2010, 2020 (MMtCO2e): 0.4, 1.9
- Net Cost per MtCO2e: TBD
- **Data Sources:** The NC GHG Inventory & Forecast was used as the source of data on available methane emissions.
- **Quantification Methods:** GHG savings were estimated by determining the CO_2 equivalent for the available methane to be reduced in 2010 (20%) and 2020 (50%) at uncontrolled landfills in the state.[41] Additional GHG reductions could be achieved by capturing and utilizing methane at flared sites; however these were not included in the estimates below. A portion of the benefit was estimated by converting the appropriate fraction of available methane into CO_2e in each year. The other portion of the benefit was estimated by assuming that the methane used would offset use of an equivalent amount (on a heat basis) of natural gas. The emissions associated with this amount of natural gas were added to the benefit for reducing methane emissions to arrive at the total benefit.

  The cost estimate was estimated from…
- **Key Assumptions:** For this analysis, available methane means 75% of the methane emitted at uncontrolled landfills which is the assumed amount that can be captured for energy use. In 2010, projects are implemented to capture 5% of the available methane; in 2020 this rises to 50%.

Key Uncertainties

[41] The 20% value in 2010 is assumed based on the goal of implementing projects at 10 of about 100 uncontrolled sites. These first sites are likely to be implemented at the largest (highest producing) sites. Based on emissions modeling conducted by CCS during the development of the Inventory & Forecast, implementing projects at 10 of the largest uncontrolled sites would cover at least 20% of the waste in place at these sites and the potential methane emissions.

[Insert text as appropriate]

Additional Benefits and Costs

[Insert text as appropriate]

Feasibility Issues

The practice of locating landfills in very rural areas often results in a lack of viable local end users. Furthermore, the possible treatment as a regulated utility can also prevent landfill gas to energy projects from being developed.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW-12 Increased Recycling Infrastructure and Collection

Mitigation Option Description

Increase the quantity of materials recovered for recycling with specific attention given to materials with the greatest ability to reduce energy consumption during the manufacturing process and to materials that may be used as a fuel source (e.g., clean wood waste). Reducing the quantify of materials being landfilled reduces future landfill methane emissions potential, while recycling reduces emissions associated with the manufacturing of products from raw materials.

Mitigation Option Design

- **Goals:** Increase per capita recovery in the state 25% by 2020.
- **Timing:** Achieve a 10% increase in per capita recovery by 2010 and a 25% increase in per capita recovery by 2020.
- **Parties Involved:** Municipal and county government, private solid waste and recycling management companies, commercial, industrial and institutional generators, NC Department of Environment and Natural Resources.
- **Other:** For the purpose of calculating per capita recovery, yard waste (yard trash as defined in G.S. 130A-290) and other vegetative debris are not included. Yard waste is banned from disposal in MSW and C&D landfills and experiences large annual fluctuations in both generation and recovery.

Implementation Mechanisms

Numerous options exist for increasing recovery in the state. These options should be thoroughly researched to determine the effectiveness of the various options.

Expand statewide waste reduction education campaigns to include the GHG mitigation benefits of increased waste reduction.

Research the feasibility and impacts of implementing statewide disposal bans for corrugated cardboard and clean wood waste. Make recommendations based on findings.

Conduct extensive research into increased food waste diversion covering at a minimum - infrastructure needs, barriers to increasing infrastructure, incremental cost of food waste diversion and potential climate change benefits of food waste diversion. Make recommendations based on findings.

Provide technical assistance to local governments on operating more effective recycling programs (ongoing).

Lead by example for state agencies? -

Legislative actions:

- Require any new host community agreements between a landfill developer and any local government to include provisions for a minimum prescribed level of recycling services within a maximum allowable service area per recycling drop-site.
- In lieu of, or in addition to existing local per capita waste reduction goals, require local government 10-year solid waste solid waste management plans to include an enforceable per capita recovery goal that increases annually until 2020. Enforceability may be achieved by requiring local governments to take specific actions to improve performance if goals are not met. An initial minimum recovery rate would have to be determined.
- Increase funding to the NC Solid Waste Management Trust fund for increased grants to local governments and to private sector for additional infrastructure expansion.

Related Policies/Programs in Place

State Solid Waste Management Trust Fund, NC DPPEA – Community Waste Reduction and Recycling Grants, Recycling Business Development Grants; Local Government Assistance Team, NC DPPEA; Recycling Business Assistance Center, NC DPPEA.

GS 130A-309.10(f) and (f1) – Materials Banned from Disposal and Incineration

GS 130A-309.09A – Local Government Solid Waste Responsibilities

Types(s) of GHG Reductions

Landfill Methane – Reducing the quantity of organic material entering the anaerobic environments found in landfills will result in a decrease in methane gas releases from landfills.

Upstream Energy Use Reductions – Less energy is generally required to manufacture goods from recycled feedstocks than from virgin feedstocks. For example, the addition of recycled glass cullet to the glass making process allows manufacturers to operate furnaces at lower temperatures.

Estimated GHG Reductions and Costs (or Cost Savings)

- GHG potential in 2010, 2020 (MMtCO2e): 0.20, 0.49
- Net Cost per MtCO2e: $1

EPA's WAste Reduction Model (WARM)[42] was used to estimate the emissions associated with the State's current level of recycling and with the goal of increasing recycling by 25% per capita.

[42] Version 7, August 2005. From http://www.epa.gov/climatechange//wycd/waste/calculators/Warm_home.html - EPA created the WAste Reduction Model (WARM) to help solid waste planners and organizations track and voluntarily report greenhouse gas emissions reductions from several different waste management practices. WARM is available both as a Web-based calculator and as a Microsoft Excel spreadsheet. WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in metric tons of carbon equivalent (MtCE), metric tons of carbon dioxide equivalent (MtCO2E), and energy units (million BTU) across a wide range of material types commonly found in municipal solid waste. For explanation of methodology, see the EPA report: *Solid Waste*

WARM is based on a life-cycle approach, which reflects emissions and avoided emissions upstream and downstream from the point of use. As such, the emission factors provided in WARM provide an account of the net benefit of recycling and source reduction actions to the environment.

- **Data Sources:** WARM input data for both the baseline and policy scenarios were provided by the NC Division of Pollution Prevention and Environmental Assistance.[43] WARM is provided by the EPA and can be accessed along with documentation at the website listed in the footnotes to this option.
- **Quantification Methods:** Two different runs of the WARM model were conducted. The first was done to represent the current levels of recycling in the state and the associated GHG emissions and reductions. The second was done to represent emissions and reductions associated with increasing the current level of recycling by 25% per capita. The table below summarizes the results of both model runs:

Analysis Results Using WARM

WARM Run	Total GHG Emissions ($MtCO_2e$)
Baseline (without existing recycling)	6,379,586
Baseline (with recycling)	4,439,516
25% Recycling Increase Above Baseline	3,952,224
GHG Reductions	**487,292**

The 2020 reductions is determined as the difference in emissions estimated for the baseline (with existing recycling programs) and the emissions estimated for the 25% increase in recycling run. For 2010, the reduction was estimated using a factor of 0.4 multiplied by the 2020 benefit (10/25, since a 10% per capita recovery is the policy goal for 2010).

The table below provides the WARM output for the 25% increase in per capita waste recycling. The following waste types are small quantities in NC and were excluded from modeling in WARM: motor oil, oil filters, antifreeze, lead-acid batteries, textiles and mixed C&D recovery. Since these waste types were left out, recycling for all of the other commodities was increased by just over 26 percent to mimic a 25 percent increase in per capita recovery. All commodities were increased by the same percentage. In reality, one would expect to see a differential increase that would likely result in more fiber recovery by percentage increase. No distinction was made between construction & demolition (C&D) waste and municipal solid waste (MSW). All of the waste was lumped together as mixed MSW. Yard waste was also left out of the modeling. It is

Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks (EPA530-R-02-006): http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html.

[43] Jim Hickman, NC Division of Pollution Prevention and Environmental Assistance and NC AFW TWG, personal communication and WARM spreadsheets provided to S. Roe, CCS, January 2007.

banned from disposal in C&D and MSW landfills in NC (it can be mulched, composted or sent to LCID landfills (a.k.a. stump dumps).

WARM Output for the 25% Increase in Recycling Run

Material	Incremental Recycling (Tons)	Incremental GHG Emissions from Recycling ($MtCO_2E$)	Incremental Landfilling (Tons)	Incremental GHG Emissions from Landfilling ($MtCO_2E$)	Total Incremental GHG Emissions ($MtCO_2E$)
Aluminum Cans	1,464	(21,855)	(1,464)	(56)	(21,912)
Steel Cans	1,981	(3,548)	(1,981)	(76)	(3,624)
Copper Wire	0	0	0	0	0
Glass	11,573	(3,238)	(11,573)	(445)	(3,683)
HDPE	1,871	(2,628)	(1,871)	(72)	(2,700)
LDPE	0	0	0	0	0
PET	2,927	(4,548)	(2,927)	(112)	(4,660)
Corrugated Cardboard	28,994	(79,455)	(28,994)	(17,019)	(96,474)
Magazines/third-class mail	819	(2,214)	(819)	185	(2,029)
Newspaper	38,794	(135,448)	(38,794)	31,095	(104,353)
Office Paper	694	(1,722)	(694)	(1,573)	(3,295)
Phonebooks	0	0	0	0	0
Textbooks	0	0	0	0	0
Dimensional Lumber	7,770	(19,058)	(7,770)	3,038	(16,020)
Medium Density Fiberboard	0	0	0	0	0
Food Scraps	NA	NA	0	0	0
Yard Trimmings	NA	NA	0	0	0
Grass	NA	NA	0	0	0
Leaves	NA	NA	0	0	0
Branches	NA	NA	0	0	0
Mixed Paper, Broad	476	(1,508)	(476)	(250)	(1,757)
Mixed Paper, Resid.	10,049	(31,857)	(10,049)	(4,237)	(36,094)
Mixed Paper, Office	0	0	0	0	0
Mixed Metals	25,383	(184,436)	(25,383)	(975)	(185,411)
Mixed Plastics	21	(31)	(21)	(1)	(32)
Mixed Recyclables	1,437	(4,122)	(1,437)	(401)	(4,523)
Mixed Organics	NA	NA	0	0	0
Mixed MSW	NA	NA	0	0	0
Carpet	0	0	0	0	0
Personal Computers	289	(712)	(289)	(11)	(723)
Clay Bricks	NA	NA	0	0	0
Aggregate	0	0	0	0	0
Fly Ash	0	0	0	0	0
Total	134,539	(496,379)	(134,539)	9,088	(487,291)

Columns associated with source reduction, waste combustion, and composting were removed from this WARM output table, since these management practices were not considered in the modeling.

Costs

Information on typical landfill tipping fees, current households served by curbside recycling, households not served by curbside recycling, and the costs for adding curbside recycling services and public education were provided by the NC Office of Pollution Prevention & Environmental Assistance:[44]

- Tons of municipal solid waste diverted by 25% per capita increase: about 134,000;
- Average Landfill tipping fee: $35 ton (conservative estimate, as communities served by transfer stations could pay up to $40/ton);
- Households currently served by curbside recycling: 1,384,653;
- Households not receiving curbside service in towns w/ populations of 5,000 or more: 516,941 (community size is assumed to be the minimum for cost effective recycling services);
- Estimated cost of enhancing education and/or adding more materials to what is already collected in areas receiving curbside recycling: $0.60 per household per year; and
- Estimated cost (based on state averages) for adding curbside collection: $27 per household per year.

The cost for enhancing existing programs is:

1,384,653 households x $0.60 = $830,792/yr

and the cost of adding programs is:

516,941 households x $27.00 = $4,239,884/yr

For a total cost of: $5,070,676/yr

The avoided costs of disposal are:

134,000 households x $35.00 = -$4,690,000/yr

For a net cost of $380,676/yr

From the annual cost above and the estimated GHG reductions estimated with WARM, a discounted and levelized cost effectiveness of $1/MtCO_2e$ was estimated.

- **Key Assumptions:** within WARM, the following modeling options were selected: 1) material that is source reduced comes from current mix of recycled/virgin materials, not 100% virgin material; 2) NC landfills recover landfill gas at the national average of recovery; 3) landfill gas that is recovered is used for energy recovery, not flared; 4) landfill gas collection system efficiency is 75%; and 5) default distances for materials delivery to management facility were used (20 miles).

Key Uncertainties

[44] Jim Hickman, NC Office of Pollution Prevention & Environmental Assistance, personal communication with S. Roe, CCS, January 2007.

[Insert text as appropriate]

Additional Benefits and Costs

[Insert text as appropriate]

Feasibility Issues

Some legislative action would be required (see Implementation Mechanisms section). Some infrastructure development might be required.

Status of Group Approval

[Pending or Completed]

Level of Group Support

[Insert text as appropriate]

Barriers to Consensus

[Insert text as appropriate]

AFW–13. Urban Forestry Measures

Mitigation Option Description

Mitigation Option Design

- **Goals:**
- **Timing:**
- **Coverage of parties**
- **Other:**

Implementation Mechanisms

TBD

Related Policies/Programs in Place

TBD

Types(s) of GHG Reductions

Estimated GHG Savings and Costs per $MtCO_2e$

TBD

- **Data Sources:** TBD
- **Quantification Methods:** TBD
- **Key Assumptions:** TBD

Key Uncertainties

TBD

Additional Benefits and Costs

TBD

Feasibility Issues

TBD

Status of Group Approval

TBD

Level of Group Support

TBD

Barriers to Consensus

TBD