

## Appendix H

# Agriculture, Forestry, and Waste Management

## Mitigation Option Recommendations

### Summary List of Mitigation Options

	Mitigation Option Name	GHG Reductions (MMtCO <sub>2</sub> e)			Net Present Value 2007–2020 (Million \$)	Cost-Effective-ness (\$/tCO <sub>2</sub> e)	Level of Support*
		2010	2020	Total 2007–2020			
AFW-1	Manure Digesters & Energy Utilization	0.2	0.9	6.4	199	31	UC
AFW-2	Biodiesel Production (incentives for feedstocks and production plants)	0.2	0.8	5.1	286	56	UC
AFW-3	Soil Carbon Management (including organic production methods incentives)	0.2	0.2	3.0	–16	–5	UC
AFW-4a	Preservation of Working Land – Agricultural Land	0.2	0.3	2.6	290	114	UC
AFW-4b	Preservation of Working Land – Forest Land (formerly AFW-7)	1.7	4.3	36	112	3	UC
AFW-5	Agricultural Biomass Feedstocks for Electricity or Steam Production	0.009	0.02	0.2	10	54	UC
AFW-6	Policies to Promote Ethanol Production	0.9	6.9	38	200	5	UC
AFW-7	<i>Moved to AFW 4a</i>						
AFW-8	Afforestation and/or Restoration of Non-forested Lands	0.2	2.4	15	128	9	UC
AFW-9&10	Expanded Use of Forest Biomass and Better Forest Management	1.5	5.9	48	–639	–13	UC
AFW-11	Landfill Methane and Biogas Energy Programs	1.1	2.9	20	23	1	UC
AFW-12	Increased Recycling Infrastructure and Collection	0.2	0.5	4.1	4	1	UC
AFW-13	Urban Forestry Measures	1.4	4.3	34	–376	–11	UC
	SECTOR TOTAL AFTER ADJUSTING FOR OVERLAPS	7.8	29	212	222	1	
	REDUCTIONS FROM RECENT ACTIONS (none)	0	0	0	0	0	
	SECTOR TOTAL PLUS RECENT ACTIONS	7.8	29	212	222	1	

\* UC = Unanimous Consent (all agree).

## 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. The policy is designed to apply to hog farms and dairies in the state.
- **Timing:** By 2010, implement projects to capture 5% of available methane energy at hog farms and dairies. By 2020, implement projects to capture 20% of methane energy.
- **Parties Involved:** NC Farm Bureau, Department of Environment and Natural Resources. (DENR), NC Department of Agriculture and Consumer Services ((NCDA&CS), livestock producers
- **Other:** Due to the levels of emissions and the cost effectiveness estimated for applying this option to livestock operations in NC, this policy is designed to address hog farms primarily and could also cover dairy producers.

### Implementation Mechanisms

- Increased education and outreach to farmers regarding the opportunities for manure digesters. Most farmers cannot implement these recommendations without technical assistance. Traditionally, many farmers rely on USDA's Natural Resource Conservation Service (NRCS) and North Carolina Cooperative Extension Service (NCCES) for this technical assistance. Additional training is needed for the technical assistance providers in order to better promote the technology.
- Incentives in the form of tax breaks (sales and/or income) for incurred capital costs. Current tax incentives are income tax credits up to 50% of tax burden. During the initial stages of this industry, income is likely to be low and therefore income tax credits will be drastically reduced from the maximum allowed. Restructuring the tax credit to allow for greater recovery of the capital costs will provide a greater incentive to install manure digesters. Exempt manure digester equipment from property and/or sales tax. Existing regulations exempt pollution abatement equipment from property tax, similar exemptions are needed for manure digesters.
- Increased funding for voluntary programs such as NC Green Power and NC Agriculture Cost Share to help offset costs of installing and maintaining manure digesters. These existing programs have a limited ability to fund manure digesters through higher electricity payments

(Green Power) and grants for installation costs (Ag Cost Share). Additional funding for these programs is another incremental step in reaching the recommended goal.

- Increased research to improve return on investment for digesters. Technological improvements have the potential to increase efficiency and lower costs thereby making the manure digesters more economically attractive.
- Allow utilities to pay above avoided cost rates for electricity purchased from manure digesters. Currently, utilities are required to pay small power producers the equivalent of what it would cost the utility to generate the electricity. Allowing the utilities to pay above avoided cost will increase the return on installing a manure digester.
- Education for farmers of power purchase agreements and interconnection with the grid. Farmers should be aware of the interconnection standards required by their local utility including the equipment that will be needed as well as any charges that may apply. Power purchase agreements are essentially the contract between the farmer and the utility that includes rates and length of contract. Making these items as simple as possible and educating the farmers about them will enhance the awareness of the procedures needed to provide electricity to 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.<sup>1</sup>
- EPA AgSTAR Program.
- Federal Renewable Electricity Production Tax Credit.
- USDA Farm Bill Renewable Energy and Energy Efficiency Loan and Grant Program - The Renewable Energy and Energy Efficiency loan and grant program was established under Section 9006 of the 2002 Farm Bill. It provides loan guarantees and grants to agricultural producers and rural small businesses for the purchase and installation of renewable energy systems or for energy efficiency improvements. Loan guarantees cover up to 50% of a project's cost, not to exceed \$10 million. Grants are available for up to 25% of a project's cost, not to exceed \$250,000 for energy efficiency improvements and \$500,000 for renewable energy systems. These loans and grants are expected to reduce greenhouse gas emissions by 0.97 million metric tons, replace 821 million barrels of foreign oil and generate almost 2 million kilowatt hours of electricity annually. USDA has funded more than 800 loans and grants since the renewable energy program began in FY 2003.

#### Type(s) of Green House Gas (GHG) Reductions

- **CH<sub>4</sub>**: methane is captured and typically combusted in an energy recovery system or flared. Small amounts of N<sub>2</sub>O and CH<sub>4</sub> are emitted from the combustion process.

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<sup>1</sup> North Carolina Incentives for Renewable Energy:

[http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive\\_Code=NC19F&state=NC&CurrentPageID=1&RE=1&EE=0](http://www.dsireusa.org/library/includes/incentive2.cfm?Incentive_Code=NC19F&state=NC&CurrentPageID=1&RE=1&EE=0).

- **CO<sub>2</sub>:** carbon dioxide is reduced when the methane is converted to energy and that energy is used to offset fossil-based energy (e.g., coal-fired electricity, natural gas, etc.). Small amounts of N<sub>2</sub>O and CH<sub>4</sub> 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 (MMtCO<sub>2</sub>e):** 0.2, 0.9.
- **Net Cost per MtCO<sub>2</sub>e:** \$32.  
The cost per ton is the weighted average for dairy (\$185) and swine (\$31). Since only a very small fraction of the emission reductions are achieved at dairies, the weighted cost effectiveness is nearly identical to that estimated for swine operations. Most of the reductions come from the swine sector. For beef feedlots, the cost effectiveness estimate is much higher (\$1,641; due to much lower methane emissions/head), so the Technical Working Group (TWG) does not recommend adopting this policy to address feedlots. These cost estimates include the effects of grants for renewable energy projects from the Federal Farm Bill but do not include the effects of other existing federal and state tax incentives.
- **Data Sources:** NC GHG Inventory & Forecast, North Carolina State University (NCSU) technology determinations for swine farms,<sup>2</sup> other technical reports and presentations on implementing digesters at confined animal operations.<sup>3</sup>
- **Quantification Methods:** *GHG Benefit.* 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%,<sup>4</sup> and converting to CO<sub>2</sub>e.

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<sub>2</sub>e associated with this amount of electricity in

<sup>2</sup> 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.

<sup>3</sup> Leonard Bull, Animal and Poultry Waste-to-Energy, PowerPoint presentation, North Carolina State University, See [http://www.cals.ncsu.edu/waste\\_mgt/waste%20to%20energy.pdf](http://www.cals.ncsu.edu/waste_mgt/waste%20to%20energy.pdf), accessed June 2006. See also [http://www.methanetomarkets.org/resources/ag/docs/animalwaste\\_prof\\_final.pdf](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.

<sup>4</sup> 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).

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.

### *Costs*

For swine, costs were estimated using annualized costs for the Barham Farm study, which was part of the North Carolina State University (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 operation of a digester and an engine-generator set/flare. Annual operations and maintenance costs from this study were \$8/head. These costs provide an estimate for the implementation of digester and energy projects at swine farms toward the upper end of the range for U.S. projects with documented costs.<sup>5</sup> Capital costs per head were about \$72 for Barham Farm compared to an average of \$52/head for seven U.S. swine digester to energy projects.

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. It is not clear based on available data how well regional digesters could be implemented in NC as they require several dairies in close proximity. Therefore, the average of \$450/head was used.

CCS assumed that the 25% Farm Bill grant would be available to each project initiated as a result of this policy.<sup>6</sup> After adjustment of the capital costs, 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. Additional incentives to the farmer from the Renewable Energy Production Incentives were not included but could have a small effect on the estimated costs (about \$1/MtCO<sub>2</sub>e reduced). 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:** That the cost data for the studies cited is representative of actual costs; 75% collection efficiency for farm-level methane emissions for the digester. Farm Bill grant will be available to all projects in subsequent cycles of the Farm Bill through 2020. The \$0.05/kWh is the assumed value to the farmer for the electricity produced (either to offset on-farm use or to sell back to the grid); this is a conservative estimate.

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<sup>5</sup> Moser, M., “A Dozen Successful Swine Waste Digesters”, RCM Digesters, Inc., accessed February 2007 at: [http://rcmdigesters.com/images/PDF/A\\_Dozen\\_Successful\\_Swine\\_Waste\\_Digesters.pdf](http://rcmdigesters.com/images/PDF/A_Dozen_Successful_Swine_Waste_Digesters.pdf).

<sup>6</sup> More information on the program is also available at: <http://www.rurdev.usda.gov/rbs/farmbill/index.html>. The application of this grant incentive was considered a reasonable assumption based on CCS discussions with EPA AgSTAR Program staff; Kurt Roos, personal communication with S. Roe, CCS, March 2007.

Higher values for this electricity would translate into a lower cost effectiveness estimate and a faster return on investment for the farmer.

### Key Uncertainties

See key assumptions in the quantification section above.

### Additional Benefits and Costs

- *Air & Water Pollution Impacts* - Reductions in emissions of ammonia, volatile organic compounds, and odors (sulfur compounds) are achievable. Reductions occur when anaerobic digesters and energy utilization are used to capture emissions that would have occurred from the lagoon surface. Note that these reductions occur at the lagoon surface and that there is a potential for increased ammonia emissions during application of digester effluent to fields due to high ammonium concentrations, if measures are not taken to avoid these emissions. Ammonia emissions are important in the formation of fine particulate matter and nitrogen deposition to sensitive water sheds. Also, there will be an increase in emissions of nitrogen and sulfur oxides during the combustion of biogas. Both of these pollutants are also fine particulate matter precursors, and oxides of nitrogen are a precursor of ozone.

Measures to reduce both air and water pollution impacts could include the use of nitrifying/denitrifying systems to reduce the ammonium concentration prior to application. In these systems, ammonium is converted to nitrogen which is released instead of ammonia. (Care must be taken to avoid excessive nitrous oxide emissions, however.) The other option is to identify and produce marketable products from the digester effluent, which would have to be trucked off the farm. The increased GHG emissions associated with transporting any such products have not been factored in to the analysis conducted for this option.

A study of an anaerobic digester project for a dairy farm<sup>7</sup> demonstrated that these projects can substantially reduce total volatile solids (39.5%) and chemical oxygen demand (38.5%). These reductions translate directly into a lower potential for depletion of dissolved oxygen in natural waters. Although anaerobically digested manure is not suitable for direct discharge to surface or ground waters, these reductions still are significant due to the potential for these wastes to enter surface waters by nonpoint source transport mechanisms. The study also showed that mesophilic anaerobic digestion at an average hydraulic retention time of 29 days reduced the mean densities of the fecal coliform group of enteric bacteria by 99% and fecal streptococcus group by 90%;

- Possible nutrient management benefits for situations where ammonium-rich effluent can be used without excessive ammonia emissions;
- Economic benefits for the digester industry.

### Feasibility Issues

- Currently a long return on investment.

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<sup>7</sup> “An Evaluation of a Mesophilic, Modified Plug Flow Anaerobic Digester for Dairy Cattle Manure”, prepared by Eastern Research Group, prepared for the U.S. EPA AgSTAR Program, July 20, 2005.

- Demand from electric utilities and other entities seeking renewable energy sources.
- Utility barriers including grid interconnection and electricity standby costs charged to the farmer.

**Status of Group Approval**

Complete

**Level of Group Support**

Unanimous

**Barriers to Consensus**

None

**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.

*Note: This option is linked with Transportation & Land Use (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 CO<sub>2</sub> 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:** NCDA&CS, Department of Administration, Motor Carrier Enforcement Division, DENR, Department of Commerce, NC Rural Center, NCSU, North Carolina Agricultural & Technical State University (NCA&T), other state agencies, agricultural associations which represent producers of feedstock, petroleum industry trade groups, and various industry associations.
- **Other:** NA

**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 \$0.50 to \$1.00/gallon depending on feedstock.

**Type(s) of GHG Reductions**

- **CO<sub>2</sub>:** 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 (e.g., 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),<sup>8</sup> 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 CO<sub>2</sub>e 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 (MMtCO<sub>2</sub>e):** 0.2, 0.8.
- **Net Cost per MtCO<sub>2</sub>e:** \$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 shown in **Table H-1** (under business as usual).

**Table H-1.**

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. Biodiesel production targets are shown in **Table H-2**.

<sup>8</sup> 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.

**Table H-2.**

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

By 2010, “business as usual” (BAU) biodiesel production in the state is expected to be 3 MMgal.<sup>9</sup> 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 (see Table H-3.

**Table H-3.**

Year	Biodiesel Production Needed Beyond BAU (MMgal/yr)
2010	68
2020	249

The CO<sub>2</sub>e 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 CO<sub>2</sub>e 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<sub>2</sub>e 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

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<sup>9</sup> [www.eere.energy.gov/states/state\\_news\\_detail.cfm/news\\_id=10298/state=NC](http://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.

to central North Carolina of about 1,400 miles.<sup>10</sup> Rail fuel consumption is about 400 ton-miles/gallon.<sup>11</sup> The density of vegetable oil is about 3,700 tons/MMgal. From these inputs, a GHG emission rate of 130 MtCO<sub>2</sub>/MMgal oil was calculated.

When combined with the other feedstocks needed to produce biodiesel (e.g., either methanol or ethanol),<sup>12</sup> 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.

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<sub>2</sub>e/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 only to 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 MtCO<sub>2</sub>e/MMgal. So the incremental benefit of canola over soy is 7,261 - 2,744 = 4,517 MtCO<sub>2</sub>e/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 emission factor (EF) (12,306 MtCO<sub>2</sub>e/MMgal) minus the soybean based EF (7,261 MtCO<sub>2</sub>e/MMgal), which is 5,045 MtCO<sub>2</sub>e/MMgal.

To meet the in-state production goals for 2010 and 2020, **Table H-4** 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

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<sup>10</sup> U.S. National Atlas, at <http://nationalatlas.gov/natlas/Natlasstart.asp>.

<sup>11</sup> U.S. National Atlas, at [http://nationalatlas.gov/articles/transportation/a\\_freightrr.html](http://nationalatlas.gov/articles/transportation/a_freightrr.html).

<sup>12</sup> 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).

MMgal/yr in 2010 and 10.3 MMgal/yr in 2020<sup>13</sup> (BAU production is further assumed to be soybean-based with little incremental benefit above the TLU Option 6 benefit).

**Table H-4.**

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	–
<b>2010 Total</b>			<b>68</b>
2020	Soy	0.12	30
2020	Canola	0.25	62
2020	Animal	0.20	50
2020	Algal	0.43	107
<b>2020 Total</b>			<b>249</b>

\* 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 (e.g., by oil type). Total reductions in each year were estimated by summing the incremental benefit for each oil type.

#### *Costs*

Costs were estimated using information from an analysis of biodiesel production costs from the US DOE.<sup>14</sup> 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.<sup>15</sup> 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.

<sup>13</sup> See [www.eere.energy.gov/states/state\\_news\\_detail.cfm/news\\_id=10298/state=NC](http://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).

<sup>14</sup> See [www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html](http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html); accessed January 2007.

<sup>15</sup> Information on the Missouri Program: [www.newrules.org/agri/mobiofuels.html#biodiesel](http://www.newrules.org/agri/mobiofuels.html#biodiesel), accessed January 2007.

- **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 (e.g., 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

Pending

### 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 in [Table H-5](#).<sup>16</sup>

**Table H-5.**

	Million gallons per year
Soy oil	60.5 <sup>17</sup>
Canola oil	0
Yellow grease	10
Poultry fat	21
Lard	21
Tallow	2
<b>Total Current Feedstocks</b>	<b>114.5</b>

By converting all NC wheat to canola production, another 66 MMgal/yr could be produced,<sup>18</sup> 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

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

<sup>16</sup> Henry Tsai, economist, NCSU Solar Center, 2004 slideshow, “Implications of Rising Energy Cost on the Economy: 3 Different Perspectives.”

<sup>17</sup> NC Biomass Resource Inventory 2003. This oil production figure was calculated based on 43,200,000 bushels of soy grown in North Carolina.

<sup>18</sup> 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 methods, cover cropping, 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.

Another element of this option is the promotion of certified organic production techniques. A number of studies have found that organic production of row crops result in GHG benefits, including higher levels of soil organic carbon, relative to conventional production methods. This option is designed to increase the acreage using soil management and production practices that lead to higher soil carbon content and other GHG benefits.

#### Mitigation Option Design

- **Goals:** By 2020, apply soil management practices on 50% of cultivated lands that currently do not use these techniques. Also, identify and promote organic production techniques that have been demonstrated in NC to achieve net GHG benefits.
- **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. By 2010, complete a systematic assessment of organic cultivation systems for NC crops and identify those that achieve net GHG benefits. Initiate programs to promote these organic cultivation methods through 2020.
- **Parties Involved:** NC Department of Agriculture (CEFS), NC Department of Environment and Natural Resources (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 over a six-year period<sup>19</sup> (equivalent to about 3.3 MtCO<sub>2</sub>e/acre). Studies in California<sup>20</sup> and Pennsylvania<sup>21</sup> have shown that certified organic production methods of row crops sequester dramatically more carbon than

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<sup>19</sup> Available at <http://southeastfarmpress.com/news/030106-Naderman-conservation/>.

<sup>20</sup> Source: *Conservation tillage and cover cropping influence soil properties in San Joaquin Valley cotton-tomato crop*, by Jessica J. Veenstra, William R. Horwath, Jeffrey P. Mitchell and Daniel S. Munk. California Agriculture Journal, July-Sept. 2006.

<sup>21</sup> Chapter in book: “The Rodale Institute Farming Systems Trial 1981 to 2005: Long Term Analysis of Organic and Conventional Maize and Soy-bean Cropping Systems,” pp15-30, in *Long Term Field Experiments in Organic Farming*, edited by J Rauppe, C Perkrun, M Oltmanns, U Kopke. ISOFAR - International Society of Organic Agricultural Research, Verlag Publishing, Berlin, 2006.

conventional practices. Both studies independently concluded that fully-tilled organic production can sequester 1000 lbs per acre per year.<sup>22</sup> Soil carbon accumulations up to 28,000 lbs per acre were observed in the 25-year field trial performed at the Rodale Institute.

A recent study in the United Kingdom<sup>23</sup> found that some organic production techniques have higher energy inputs or land requirements than conventional techniques (sometimes due to lower yields, longer production cycles for livestock like poultry). Because increases in soil carbon content do not fully reflect crop production cycle GHG emissions (due to changes in tillage practices, application of chemicals, etc.), research and pilot studies will be needed to determine which organic cropping systems in NC achieve net GHG benefits (see Feasibility Issues section below).

### Implementation Mechanisms

- Increase NC Agriculture Cost Share funding to include additional acreage in no-till and organic farming techniques.
- Create a Cost Share program to help producers through the process of organic certification.
- Expand educational programs through NCCES on conservation tillage and certified organic production techniques.
- Research the organic production systems suitable for North Carolina that produce net GHG benefits. Actively promote penetration of organic production methods within these systems.
- Research the availability and effectiveness of bio-char application.
- Research the need for infrastructure to facilitate in-state farmers moving their organically produced goods to market.
- Incentives in the form of grants, tax breaks, or loan guarantees for development of infrastructure needed for certified organic commodities and crops.

### 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.

### Type(s) of GHG Reductions

- **CO<sub>2</sub>**: 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 protecting carbon from oxidation, inhibiting the release of carbon back into

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<sup>22</sup> Source: Interview with Dr Paul Hepperly, Rodale Institute, February 8, 2007.

<sup>23</sup> *Environmental Impacts of Food Production and Consumption*, Manchester Business School, prepared for the Department for Environment, Food and Rural Affairs, December 2006, [http://www.defra.gov.uk/science/project\\_data/DocumentLibrary/EV02007/EV02007\\_4601\\_FRP.pdf](http://www.defra.gov.uk/science/project_data/DocumentLibrary/EV02007/EV02007_4601_FRP.pdf).

the atmosphere. Depending on how the adoption of conservation tillage and organic production methods affects the overall crop production cycle, additional CO<sub>2</sub> reductions can occur through lower fossil fuel consumption in farm equipment. Note that some studies have shown higher fuel consumption using organic techniques than conventional production. Also, organic production methods reduce GHG emissions associated with the production, transport, and application of pesticides, herbicides, and other chemical treatments.

- **N<sub>2</sub>O:** To the extent that fossil fuel consumption is lowered through the cultivation methods implemented under this policy, N<sub>2</sub>O emissions from fuel combustion will be lowered. *It is important to note that research also indicates the potential for higher N<sub>2</sub>O emissions as soil organic carbon levels increase (see Feasibility Issues Section below).*
- **CH<sub>4</sub>:** To the extent that fossil fuel consumption is lowered through the cultivation methods implemented under this policy, CH<sub>4</sub> emissions from fuel combustion will be lowered.

### Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 0.2, 0.1.  
*Note: The GHG reductions above and costs below do not reflect the organic production incentives elements of this option. 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<sub>2</sub>e/yr after 2025. The remaining benefit, which is permanent, is associated with lower fossil fuel consumption.*
- **Net Cost per MtCO<sub>2</sub>e:** -\$5.
- **Data Sources:** Agricultural soil carbon accumulation levels were taken from a 2006 study by Naderman et al.<sup>24</sup> 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. Data on current (2004) acres of cropland where conservation till/reduced till practices are employed were taken from the Conservation Technology Information Center (CTIC).<sup>25</sup> These data show that NC had 4,234,965 planted acres in 2004. In 2004, 2,292,104 acres were cultivated using conservation tillage or reduced tillage methods.

The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 3.5 gallons/acre.<sup>26</sup> From the NC Inventory & Forecast, the fossil diesel GHG emission factor is 8.37 MtCO<sub>2</sub>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

<sup>24</sup> 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.

<sup>25</sup> 2004 CTIC data provided by Paul Sherman of the NC Farm Bureau, February 2006.

<sup>26</sup> Reduction associated with conservation tillage compared to conventional tillage, at <http://www.ctic.purdue.edu/Core4/CT/CRM/Benefits.html>, accessed August 2006.

resulted in a range of cost savings from about \$3 to \$14 per acre per year.<sup>27</sup> 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).<sup>28</sup> Given that these were based on 1981 data (including fuel prices), the cost savings in today's dollars would be much larger. No additional cost benefits were incorporated for the cost share programs noted above.

- **Quantification Methods:** Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation are shown in **Table H-6**. 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 Naderman et al study referenced above, it 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<sub>2</sub> equivalent yielding 0.55 MtCO<sub>2</sub>/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 **Table H-6**.

Additional 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 **Table H-6** along with a total estimated benefit from both carbon sequestration and fossil fuel reductions.

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 of the assumed carbon sequestration potential is representative across all of the crop systems to which the policy is applied; a six-year period for accumulating the soil carbon; no additional significant accumulation of soil carbon after six years; any potential increase in N<sub>2</sub>O 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.

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<sup>27</sup> \$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, at [www.ces.ncsu.edu/depts/agecon/Cotton\\_Econ/production/Economic\\_Comparison.ppt](http://www.ces.ncsu.edu/depts/agecon/Cotton_Econ/production/Economic_Comparison.ppt), accessed February 2007.

<sup>28</sup> *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](http://www.ag.auburn.edu/aux/nsdl/sctcsa/Proceedings/1981/1981_SCTCSA.pdf).

**Table H-6. Assumed Schedule for Adoption of Conservation Tillage/No-Till Practices and Associated Benefits**

Year	Acres in Program	Acres still accumulating carbon	MMtCO <sub>2</sub> e Sequestered	Diesel Saved (1,000 gal)	Diesel GHG avoided (MMtCO <sub>2</sub> e)	Total MMtCO <sub>2</sub> e saved
2007	97,393	97,393	0.054	341	0.0029	0.0568
2008	194,786	194,786	0.108	682	0.0057	0.1137
2009	306,788	306,788	0.170	1,074	0.0090	0.1791
2010	389,572	389,572	0.216	1,364	0.0114	0.2274
2011	448,008	448,008	0.248	1,568	0.0131	0.2615
2012	506,444	506,444	0.281	1,773	0.0148	0.2956
2013	564,880	467,487	0.259	1,977	0.0166	0.2757
2014	623,316	428,530	0.238	2,182	0.0183	0.2558
2015	681,752	374,964	0.208	2,386	0.0200	0.2279
2016	740,188	350,615	0.194	2,591	0.0217	0.2161
2017	798,624	350,615	0.194	2,795	0.0234	0.2178
2018	857,059	350,615	0.194	3,000	0.0251	0.2195
2019	915,495	350,615	0.194	3,204	0.0268	0.2212
2020	973,931	350,615	0.194	3,409	0.0285	0.2229
2021	973,931	292,180	0.162	3,409	0.0285	0.1905
2022	973,931	233,744	0.130	3,409	0.0285	0.1581
2023	973,931	175,308	0.097	3,409	0.0285	0.1257
2024	973,931	116,872	0.065	3,409	0.0285	0.0933
2025	973,931	58,436	0.032	3,409	0.0285	0.0609
2026	973,931	0	0.000	3,409	0.0285	0.0285
2027	973,931	0	0.000	3,409	0.0285	0.0285
2028	973,931	0	0.000	3,409	0.0285	0.0285
2029	973,931	0	0.000	3,409	0.0285	0.0285
2030	973,931	0	0.000	3,409	0.0285	0.0285

### 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.

### Additional Benefits and Costs

Organic production under offers considerable economic market benefits: Certified producers are receiving premium prices for their harvests.

The dramatic increases in soil carbon with certified organic production methods offer further benefit in periods of drought or extreme rain. The Rodale Farming Systems Trial has quantified

superior crop production during droughts, compared to conventional no-till production, because soils in the organic plots captured more water and retained more of it in the crop root zone than in the conventional no-till plots. During torrential rains, water capture in the organic plots was approximately 100% higher than in conventional no-till plots.<sup>29</sup>

### Feasibility Issues

The goal of expanding organic production by 10% is modest and feasible, and has been easily beaten by our foreign competitors: During the period of 2002 to 2006, China's certified organic acreage grew 8,650% (from 40,000 to 3.5 million); Uruguay, 58,285% (1,300 to 759,000); Chile, 1,200% (3,000 to 39,000); and Mexico 243% (86,000 to 295,000). The growth in Uruguay, Chile, and Mexico was entirely driven by market demand, not subsidies or policies.<sup>30</sup>

Our acreage goal has been easily achieved and surpassed by other states in the USA: From 2000 to 2005 California's total certified organic acreage of cropland grew from 141,000 to 223,000, a more than doubling.<sup>31</sup>

Research has indicated a potential for increased N<sub>2</sub>O emissions as soil organic carbon levels increase.<sup>32</sup> Additional study and field work on NC cropping/soil systems will be needed to verify the GHG reduction potential estimated in this policy analysis for no till cultivation.

More importantly, additional study of organic production systems applicable to NC is needed to determine full crop production cycle GHG benefits. Known benefits for organic production systems include:

- **CO<sub>2</sub> Capture:** cover crops used in organic production actively capture atmospheric CO<sub>2</sub>, and full-tilling incorporates it into the soil deeper and faster than conventional no-till. Organic production methods cause crops to grow more root mass, deeper than with conventional methods, creating deeper accumulation of soil carbon, allowing for greater long-term accumulation.<sup>33</sup>
- **Avoided CO<sub>2</sub> Release:** by using animal manure, compost, and cover crops as fertilizers, certified organic production methods do not oxidize the soil carbon as nitrogen fertilizer does. The lime applied to adjust the pH actually releases CO<sub>2</sub>.<sup>34</sup>

<sup>29</sup> Source: "The performance of organic and conventional cropping systems in an extreme climate year," D.W. Lotter, R. Seidel, and W. Liebhardt, Rodale Institute, American Journal of Alternative Agriculture, September 2003, vol. 18, no. 3, pp. 146-154(9).

<sup>30</sup> Source: "The World of Organic Agriculture: Statistics & Emerging Trends 2006," by Helga Willer and Minou Yussefi, IFOAM (International Federation of Organic Agriculture Movements), 2006, Bonn, Germany. <http://orgprints.org/5161/01/yussefi-2006-overview.pdf>

<sup>31</sup> Source: Interview with Catherine Greene, USDA Economic Research Service, February 8, 2007.

<sup>32</sup> 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.

<sup>33</sup> Source: Interview with Dr. Paul Hepperly, Rodale Institute, February 8, 2007.

<sup>34</sup> Source: Interview with Dr. Paul Hepperly, Rodale Institute, February 8, 2007.

- *Avoided GHG Emissions in Production of Inputs:* nitrogen fertilizer, pesticides, and herbicides used in conventional agriculture (including conventional no-till), require process energy and petro-chemicals in their production. Organic production methods grow their fertilizers (or use manures and composts), and control weeds and pests in ways that have a lower life-cycle energy cost.<sup>35</sup>
- *Greater Overall Soil Carbon and GHG Benefits:* No-till conventional uses more energy and produces more CO<sub>2</sub> than full-tillage organic row crop production with cover crops. The energy burned in diesel fuel is less than the embodied energy in the avoided fertilizer and lime.<sup>36</sup>

Recent study in the United Kingdom found that in many but not all organic production systems that net GHG emissions were reduced.<sup>37</sup> Organic farming’s weaknesses were identified as: 1) similar inputs into the farm including manufacture/operation of machinery and packaging; 2) in some cases, significantly lower yields resulting in higher GHG emissions per ton of product; and 3) slower maturing of animals (more GHG per ton product).

It will be important for NC to study and identify the organic production systems best suited to the state and that produce net GHG benefits. In conjunction with implementation of this policy NCSU’s Agronomy Division, Soil Testing Service, can provide the service of soil carbon measurements on the soil samples certified producers are already required to submit.

### Status of Group Approval

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

<sup>35</sup> Environmental, Energetic and Economic Comparisons of Organic and Conventional. Farming Systems, David Pimentel, Paul Hepperly, James Hanson, David Douds, Rita Seidel. *BioScience*, July 2005 / Vol. 55 No. 7.

<sup>36</sup> Source: Interview with Dr. Paul Hepperly, Rodale Institute, February 8, 2007.

<sup>37</sup> Melchett, P., “One planet agriculture – the strengths and weaknesses of organic food and farming”, Soil Association Conference 2007, January 26, 2007, [http://www.soilassociation.org.uk/Web/SA/saweb.nsf/cfff6730b881e40e80256a6a002a765c/902f12def991d13a80256f9c005e300e/\\$FILE/conference\\_melchett.pps](http://www.soilassociation.org.uk/Web/SA/saweb.nsf/cfff6730b881e40e80256a6a002a765c/902f12def991d13a80256f9c005e300e/$FILE/conference_melchett.pps).

## AFW-4a. Preservation of Working Lands – 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-4b) from unwise and unplanned development. This option should be seen as a companion measure to TLU-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-Forest Service, NC Dept. of Forest Resources (NCDR), NCSU, and NC Farm Transition Network.
- **Other:** North Carolina lost 5,500 farms and 300,000 acres between 2003-2006.<sup>38</sup>

### 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.

<sup>38</sup> Max Merrill, NCDA&CS, personal communication with S. Roe, CCS, March 15, 2007.

**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, and WHIP.
- Million Acre Initiative.

**Type(s) of GHG Reductions**

- **CO<sub>2</sub>**: 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).
- **CH<sub>4</sub> and N<sub>2</sub>O**: Are also indirectly reduced as VMT are reduced.

**Estimated GHG Reductions and Costs (or Cost Savings)**

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 0.2, 0.3.
- **Net Cost per MtCO<sub>2</sub>e:** \$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 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 is 100,000 acres per year based on the footnoted reference above. This is very close to another estimate of 101,600 acres/yr taken from a 2001 study.<sup>39</sup> 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).<sup>40</sup> The cost of establishing conservation easements on agricultural lands surrounding developing areas was taken from NRCS information on the Farm

<sup>39</sup> 1992-1997 rate of conversion from - Commission on Smart Growth, *Growth Management and Development: Findings and Recommendations*, Fall 2001, at [www.eatsmartmovemorenc.com/resources/documents/aces/aces\\_smartgrowth.pdf](http://www.eatsmartmovemorenc.com/resources/documents/aces/aces_smartgrowth.pdf).

<sup>40</sup> Franzluebbbers, 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, at [www.ars.usda.gov/SP2UserFiles/Place/66120900/SoilManagementAndCarbonSequestration/2002ajfP02.pdf](http://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.

Preservation Program (FPP).<sup>41</sup> 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).<sup>42</sup>

- **Quantification Methods:**

*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<sub>2</sub> by multiplying by 44/12. **Table H-7** provides a summary of the estimates for each year.

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<sup>41</sup> 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, at [www.nrcs.usda.gov/programs/frpp/StateFacts/NC\\_2001.pdf](http://www.nrcs.usda.gov/programs/frpp/StateFacts/NC_2001.pdf).

<sup>42</sup> American Farmland Trust, A National View of Agricultural Easement Programs, at <http://www.aftresearch.org/PDRdatabase/NAPidx.htm>.

**Table H-7. Land Protection Schedule and Associated Benefits**

Year	% of Conversion Reduced	Ag Acres Protected	MMtCO <sub>2</sub> e 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
<b>Totals</b>		<b>406,400</b>	<b>2.6</b>

*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. Protection of these lands will also help to preserve lands for producing food, fuel and other resources needed by society.
- **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 residential 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**

None noted.

### **Status of Group Approval**

Complete

### **Level of Group Support**

Unanimous

### **Barriers to Consensus**

None

## AFW-4b. Preservation of Working Lands – Forest Land

### Mitigation Option Description

Reduce conversion of forest lands to non-forest cover such as development and to reduce the rate at which forested tracts are becoming parcelized and/or fragmented. Developed areas contain lower amounts of biomass and its associated carbon. These areas also sequester less carbon dioxide than forested areas. When landowners don't have the incentive to retain their ownership, they often not only sell for development, but they may sell a forested tract by smaller parcels which may then be too small to allow forest management to be practical. On tracts too small and fragmented to be managed, the goals of AFW 9&10 cannot be achieved. Managed stands sequester carbon faster than non-managed stands. Also, harvested products from managed stands sequester carbon long-term in durable products. Finally, biomass used for energy purposes can offset fossil fuel use.

### 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 post-harvest regeneration. This amounts to a loss of about 10% of the state's forestland since 1974, or about a 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, and NC Woodlands.
- **Other:** The conversion of forested lands to developed uses 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.
- Better funding for existing forest conservation easement programs
- Retain Forestry Present Use Valuation

### Related Policies/Programs in Place

- North Carolina Conservation Tax Credit Program
- North Carolina Forest Legacy Program

### Type(s) of GHG Reductions

- Prevention of emissions from forest conversions and retention of soil carbon
- Continued forest growth and sequestration on protected acres

- Carbon sequestration in the form of durable wood products and fossil fuel offsets from forest based energy (not quantified)

### Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 1.7, 4.3.
- **Cumulative GHG reduction potential (MMtCO<sub>2</sub>e, 2007-2010):** 35.5
- **Net Cost per MtCO<sub>2</sub>e:** \$3
- **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). Data from the USFS Forest Inventory Program were used to determine the average annual rate of forest loss over the last 30 years. North Carolina Conservation Tax Credit Program (<http://www.enr.state.nc.us/conservationtaxcredit/pages/creditperformance.html>). North Carolina Forest Legacy Program – internal Forest Legacy documents provided by Dr. Mark Megalos and ([http://www.dfr.state.nc.us/tending/tending\\_legacyoverview.htm](http://www.dfr.state.nc.us/tending/tending_legacyoverview.htm)).
- **Quantification Methods:** Carbon savings were estimated as the portion of carbon that would be lost as a result of forest conversion to developed uses. A carbon savings coefficient was calculated from standard carbon stock coefficients for a 65-yr old loblolly-shortleaf pine stand in the southeastern US (Table H-8). It was assumed that 95% of the carbon stocks would be lost in the event of forest conversion to developed uses with no appreciable carbon sequestration in soils or biomass following development.

**Table H-8. Carbon Stocks for 65-year-old Loblolly-Shortleaf Pine in the Southeastern US**

Forest Carbon Pool	MtC/acre	MtC/ha
Live tree	40.3	99.6
Standing dead tree	1.2	2.9
Understory	1.2	2.9
Down dead wood	3.3	8.1
Forest floor	5.8	14.4
Soils	28.2	69.6
<b>Total</b>	<b>79.9</b>	<b>197.5</b>

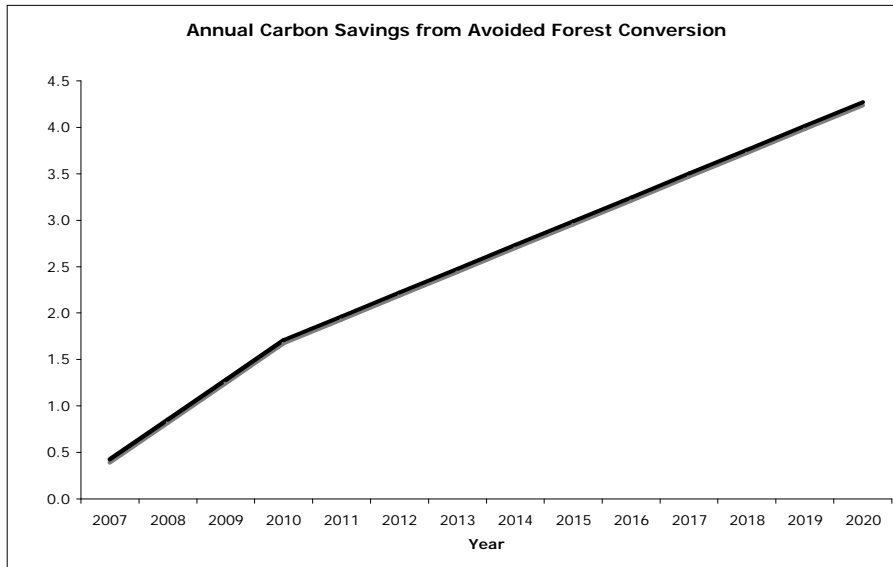
Source; USFS GTE NE-343, Table B39

Carbon savings were calculated using a gradual phase in of the goal levels. A 2.5% reduction in annual forest conversion rates was assumed in 2007 (i.e., conversion did not occur on 1,535 acres of forests as a result of the program). The number of acres that were not converted to developed uses was increased incrementally by 2.5% per year until 2010, at which point 6,139 acres of forest were maintained instead of being converted to development. From 2010 to 2020, the number of acres of forest not converted each year phases in more gradually (i.e., by 1.5% each year), such that by 2020, 15,348 acres of forest is maintained instead of converted. Each year, the number of acres estimated to

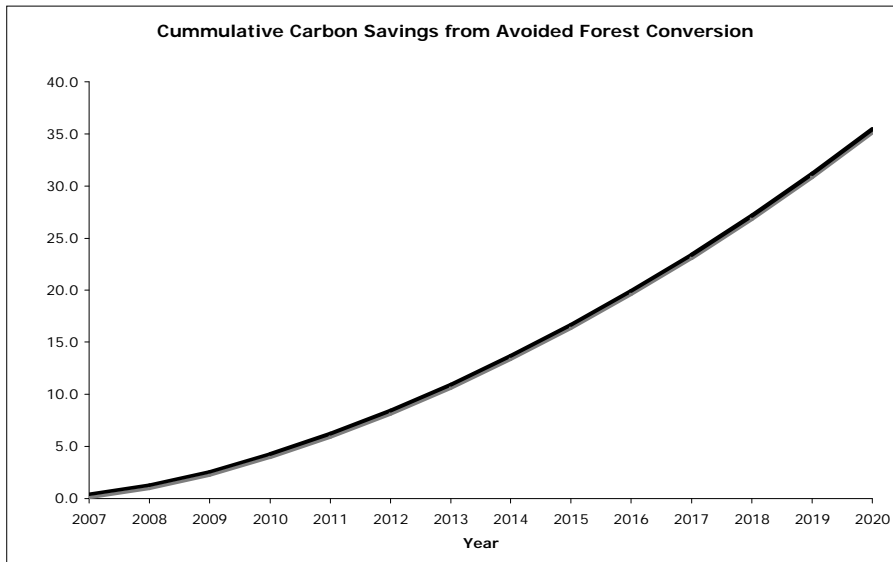
remain in forest as a result of the program was multiplied by 95% of the total carbon stock shown in **Table H-8**.

Annual carbon savings over the time period 2007-2020 are shown in **Figure H-1** and cumulative carbon savings are shown in **Figure H-2**.

**Figure H-1. Annual Carbon Savings**



**Figure H-2. Cumulative Carbon Savings**



The typical cost of conservation easements in North Carolina was used as a basis for the per acre cost of preventing forest conversion. The number of forest acres not converted each year as a result of the program was multiplied by \$1,300/acre to get total annual costs each year from 2007-2020. In 2007, annual costs were \$1,995,175, rising each year

to a total of \$19,951,750 in 2020. Annual discounted costs were estimated using a 5% interest rate. The cumulative cost effectiveness of the total program was calculated by summing the annual discounted costs and dividing by cumulative carbon sequestration, yielding \$3/tCO<sub>2</sub>e.

- **Key Assumptions:** The analysis assumes that 95% of total forest carbon is lost when forests are converted to developed uses and that no appreciable carbon sequestration occurs post-development. This is based on expert judgment of the TWG that nearly complete removal of biomass and topsoil occurs when land is developed in NC. The analysis does not account for carbon sequestration in harvested wood products, which may enhance carbon savings if forests falling under this option are managed for harvest. For the purposes of the analysis it was assumed that forests are primarily pine types and coefficients for loblolly-shortleaf stands were used.

The analysis assumes a cost of \$1,300/acre, based on data from the NC Forest Legacy Program and the NC Conservation Tax Credit Program. The Forest Legacy Program reports costs of \$1,304 - 1,573/ac for the period 2000 to 2005 for 6,500 acres of land conserved. The North Carolina Conservation Tax Credit Program reports an average cost to the state in tax credits of \$1,318/acre for 1999 to 2005 for 14,500 acres of land conserved. The cost of \$1,300/acre, which is at the low end of the range for the NC Forest Legacy Program was chosen with the rationale that product-oriented forest management on some portion of the lands would add value that could not be explicitly factored into the analysis.

### Key Uncertainties

- Whether the amount of land in this analysis would be developed during the period covered, in the absence of this option. A map of lands in the North Carolina Conservation Tax Credit Program (<http://www.enr.state.nc.us/conservationtaxcredit/images/ctcp2004.gif>) shows lands that are at some risk of development (primarily located in the coastal, Triangle and Triad areas of NC).
- The full range of factors that limit current development easement programs. Funding is a primary limiting factor. Program design is also an issue, for example, lack of term easements (35-50 years) and in some cases the inflexible nature of some easement agreements with regard to forest management/harvesting can limit their application.
- The future value of land prices. They could increase to the point of that these programs will not be cost effective. Easement values will always be less than the total value of the land.

### Additional Benefits and Costs

Non-quantified benefits include an improved or maintained quality of life for people near conserved lands as well as wildlife, recreation and watershed improvements.

### Feasibility Issues

Better funding of programs to purchase development easements for continued and improved forest management is needed to assure successful implementation of this policy.

### Status of Group Approval

Complete

**Level of Group Support**

Unanimous

**Barriers to Consensus**

None

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

### Mitigation Option Description

Offset fossil fuel 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.

*Note: 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, and 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

- To build a biomass fuel collection and distribution infrastructure, incentives will be needed in the form of tax breaks (sales and/or income) for incurred capital costs for biomass processing and transportation equipment.
- Inclusion/Expansion of voluntary programs such as NC Green Power or other energy production-specific cost share programs.
- 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 processing and delivery for utilization in electricity or heat/steam 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.

### Type(s) of GHG Reductions

- **CO<sub>2</sub>**: 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 (MMtCO<sub>2</sub>e):** 0.009, 0.022
- **Net Cost per MtCO<sub>2</sub>e:** \$54.

*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 benefit is based on offsetting coal use. The GHG benefits and costs from offsetting fossil-based power or heat/steam generation with biomass generation are covered in the ES and RCI sector. While the costs for purchasing biomass are covered in the ES and RCI sectors, the costs represented here relate to the incentives program needed to develop a biomass collection and distribution infrastructure within the state. Since, the ES-1 and 2 analysis captures fuel lifecycle benefits, the benefits shown above largely overlap with those quantified under the ES options (most of the biomass generated under this option was to be directed to the electricity sector and only a small amount directed to RCI). Accordingly, the benefits shown above, have been removed from the sector totals adjusted for overlap.*

- **Data Sources:** Information on available biomass feedstocks was taken from a recent study supporting a renewable portfolio standard in NC.<sup>43</sup> A primary source of information for this study is a 2004 report from the NC Solar Center.<sup>44</sup> Estimates of available agricultural biomass feedstocks are shown in **Table H-9**.

<sup>43</sup> *Analysis of a Renewable Portfolio Standard for the State of North Carolina*, prepared by La Capra Associates for the NC Utilities Commission, December 2006.

<sup>44</sup> *Use of Agricultural and Forest Waste as a Distributed Generation Power Resource in North Carolina*, NC Solar Center, July 16, 2004.

**Table H-9. Estimated Annual Agricultural Biomass Resources**

<b>Feedstock</b>	<b>Annual Resource (dry tons)</b>	<b>Annual Resource (MMBtu)</b>
Corn Stover	963,494	14,259,711
Wheat Straw	60,413	942,443
Poultry Litter <sup>45</sup>	50,000	650,000
Switchgrass	263,132	4,210,112
Hybrid Poplar	302,909	5,149,453
<b>Totals</b>	<b>1,639,948</b>	<b>25,211,719</b>

NOTE: Dairy and beef cattle and hog manure could be an additional biomass resource for this option, but were left out of this analysis to avoid overlap with AFW-1.

- **Quantification Methods:**

*GHG Benefits*

Since the direct benefits of using biomass energy in place of fossil fuels at the combustion source (e.g. power plant, industrial boiler) are captured in the applicable ES or RCI analysis, the benefits assessment here focused on the incremental GHG benefits associated with fuel delivery. The analysis assumes that biomass will replace coal.

National average emission factors for coal mining/processing and transport were taken from Argonne National Laboratory's GREET model.<sup>46</sup> The sum of these emission factors is 0.0044 MtCO<sub>2</sub>e/MMBtu of coal delivered. To estimate the emissions associated with delivering biomass in NC, an emission factor of 0.0009 MtCO<sub>2</sub>e/MMBtu was developed.<sup>47</sup>

The GHG benefit was estimated as the difference between the emissions from coal delivery and biomass delivery. Emissions for each were based on the amount of fuel to be delivered in each year determined from the goals of the policy (2.5 x 10<sup>6</sup> MMBtu in 2010 and 6.3 x 10<sup>6</sup> MMBtu in 2020).

*Costs*

Implementation of this option notes the need for building biomass collection and distribution infrastructure in the state. To address this need, CCS assumes that a five-year incentives program will be needed. The cost of these incentives was estimated as the difference in the

<sup>45</sup> 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, at: [www.cals.ncsu.edu/waste\\_mgt/waste%20to%20energy.pdf](http://www.cals.ncsu.edu/waste_mgt/waste%20to%20energy.pdf) and litter production of one ton per thousand birds, at [www.fibrowattusa.com/US-Press/WattPoultryUSA%20Dec%2001%20on%20Nutrient%20Mgt.pdf](http://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.

<sup>46</sup> Michael Wang and Ye Wu, Argonne National Laboratory, personal communication with S. Roe, CCS, February 23, 2007.

<sup>47</sup> This emission factor is based on the following data and assumptions: diesel emission factor 10.04 MtCO<sub>2</sub>e/gal; 23 ton diesel truck fuel consumption - 6 miles/gallon; round trip delivery of 100 miles; biomass has a moisture content of 30%; average heat content of dry biomass is 7,687 Btu/lb.

cost of delivered coal versus the cost of delivered biomass from agricultural residues as estimated by the US DOE (\$1.27/MMBtu).<sup>48</sup> The five year program assumes that sufficient demand will be put in place through the ES and RCI renewables options after five years, such that additional incentives for collection and distribution infrastructure are not needed.

- **Key Assumptions:** National average coal emission factors for mining/processing and transport are representative of the coal consumed in NC; the emission factor developed for NC biomass delivery does not include emissions for equipment used for on-site collection/processing of biomass due to a lack of information (the high end of the range of transport radius, 50-miles, was selected to compensate for this lack of data); the cost difference between coal and delivered biomass (national data) are representative for NC and provide a sound basis for the size of the incentives program needed to build collection and transportation infrastructure in the state. All biomass is utilized by the RCI or ES options.

### Key Uncertainties

See key assumptions above. Of these assumptions, those associated with the cost and length of the incentives program are the most uncertain. It is also assumed that all of the biomass resource is utilized by the ES or RCI sectors (and the fossil fuel offset benefit remains with those sectors).

### 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 and the RCI sector.

### Status of Group Approval

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

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<sup>48</sup> Biomass price differential between agricultural residues and coal from EIA in NEMS biomass supply modeling; \$2.50/MMBtu for biomass compared to \$1.23 for coal; \$2.50/MMBtu represents the price where significant resource potential becomes available; [www.eia.doe.gov/oiaf/analysispaper/biomass/table3.html](http://www.eia.doe.gov/oiaf/analysispaper/biomass/table3.html).

## 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: 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. Additional research needed to verify that sufficient cellulosic feedstocks are available to sustainably achieve the long-term (post-2020) production goals of this policy option.

### 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 \$0.50/gallon.

### Type(s) of GHG Reductions

- **CO<sub>2</sub>:** 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<sub>2</sub>e of ethanol compared to importation from the current U.S. primary ethanol producing regions. Current research indicates 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 (MMtCO<sub>2</sub>e):** 0.9, 6.9.
- **Net Cost per MtCO<sub>2</sub>e:** \$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.<sup>49</sup> 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 **Table H-10**. 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:

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<sup>49</sup> 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.

**Table H-10. Estimating In-State Ethanol Production Needs**

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
<sup>a</sup> 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 in [Table H-11](#).

**Table H-11. Assumed ethanol production schedule (MMgal/yr)**

Assumed Ethanol Production Schedule (MMgal/yr)			
<b>2007</b>	–	<b>2017</b>	584
<b>2008</b>	10	<b>2018</b>	686
<b>2009</b>	60	<b>2019</b>	790
<b>2010</b>	110	<b>2020</b>	896
<b>2011</b>	160	<b>2021</b>	1,026
<b>2012</b>	210	<b>2022</b>	1,142
<b>2013</b>	260	<b>2023</b>	1,262
<b>2014</b>	310	<b>2024</b>	1,384
<b>2015</b>	362	<b>2025</b>	1,509
<b>2016</b>	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-7). Emission factors for reformulated gasoline, starch-based ethanol, and cellulosic ethanol were taken from a General Motors/Argonne National Lab study.<sup>50</sup> These emission factors incorporate the GHG emissions during the entire life cycle of fuel production (e.g., for gasoline: extraction, transport, refining,

<sup>50</sup> *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.

distribution, and consumption; for ethanol: crop production, feedstock transport, processing, distribution, and consumption). These life-cycle emission factors are referred to as “well-to-wheels” emission factors (see Table H-12 below).

**Table H-12. Well-to-Wheels Emission Factors**

Fuel	Emission Factor (grams CO <sub>2</sub> e/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<sub>2</sub>e by offsetting gasoline consumption). This value was used along with the lifecycle emission factor for gasoline<sup>51</sup> 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).<sup>52</sup> 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.<sup>53</sup> If

<sup>51</sup> 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.

<sup>52</sup> DOE EIA analysis can be found at [www.eia.doe.gov/oiaf/analysispaper/biomass.html](http://www.eia.doe.gov/oiaf/analysispaper/biomass.html), accessed January 2007.

<sup>53</sup> D. Morris, *Making Cellulosic Ethanol Happen: Good and Not So Good Public Policy*, Institute for Local Self-Reliance, January 2007, at [www.newrules.org/agri/cellulosicethanol.pdf](http://www.newrules.org/agri/cellulosicethanol.pdf), accessed January 2007.

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. **Table H-13** contains the assumed schedule for these incentives.

**Table H-13. Projected Ethanol Capacity, Incentives Cost, and GHG Benefit: 2007–2020**

Year	New Capacity (MMgal)	Incentives Cost (MM 2006\$)	GHG Benefit (MMtCO <sub>2e</sub> )
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
2020	896	\$0.0	6.93

After discounting and leveling the costs from 2007–2020, the cost effectiveness is just under \$5/MtCO<sub>2e</sub>.

- **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

These include the assumption that commercial-scale cellulosic ethanol production is viable by 2015. Also, that sufficient biomass feedstocks are available in the state to achieve the levels of production proposed in this policy option (see Feasibility Issues below). Finally, that the level of incentives proposed for this option is sufficient to drive the creation of a sustainable biomass

ethanol production industry in the state (both in terms of feedstock delivery and production facilities).

### 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. It is not clear whether additional production beyond that needed to supply the current and planned facilities can be achieved without negatively affecting food and feed crop production.
- Feedstock supply for cellulosic ethanol production: Assuming that all of the new production would come from cellulosic technology, **Table H-14** provides estimates of the amount of biomass feedstock needed in each year. These estimates were derived using biomass conversion factors that range from 70 gallons ethanol/ton biomass thru 2011 to 100 gallons/ton by 2020.<sup>54</sup>

**Table H-14. Projected Ethanol Capacity and Feedstock Needs: 2007–2025**

Year	Ethanol Capacity Needed (MMgal)	Cellulosic Feedstock Needed (tons dry biomass)
2007	–	–
2008	10	142,857
2009	60	857,143
2010	110	1,571,429
2011	160	2,285,714
2012	210	2,333,333
2013	260	2,888,889
2014	310	3,444,444
2015	362	4,020,419
2016	484	5,378,883
2017	584	6,487,503
2018	686	7,619,897
2019	790	8,776,457
2020	896	8,961,825
2021	1,026	10,256,697
2022	1,142	11,422,706
2023	1,262	12,616,196

<sup>54</sup> Source: John Ashworth, National Renewable Energy Laboratory, personal communication with S. Roe, CCS, April 2007. Values used were 70 gallons/ton thru 2011; 90 gallons/ton 2012-2019; and 100 gallons/ton 2020-2025.

Year	Ethanol Capacity Needed (MMgal)	Cellulosic Feedstock Needed (tons dry biomass)
2024	1,384	13,837,169
2025	1,509	15,085,624

Forestry Options 9&10 yield 0.3 and 2.1 MMtons of biomass in 2010 and 2020, respectively. In addition to these biomass resources, two other studies<sup>55</sup> found that there was a potential for 6.4 to 12.0 MMtons of biomass resources in the state (the agricultural biomass resources from AFW-5 are captured in these studies as are purpose-grown energy crops, switchgrass and hybrid poplar, and urban wood waste). Based on these estimates, the resource begins to be fully utilized in the 2018 to 2025 timeframe. More detailed studies of NC biomass resource potential will be needed to verify the availability of feedstocks to achieve the levels of production envisioned by the policy option.

### Status of Group Approval

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

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<sup>55</sup> 6.4 MMtons estimated in the following report: National Renewable Energy Laboratory, *A Geographic Perspective on the Current Biomass Resource Availability in the United States*, Technical Report NREL/TP-560-39181, December 2005. 12 MMtons estimated in the following report: *Analysis of a Renewable Portfolio Standard for the State of North Carolina*, La Capra Associates, December 2006.

## 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

- **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.<sup>56</sup> 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 (NC Woodlands, North Carolina Forestry Association), agencies (NC DFR, NC DA), utilities (Duke, Progress Energy), and 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 over one ton of carbon per acre each year (on-site, not including off-site storage and offsets in products). Afforestation delivers 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).<sup>57</sup> 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.<sup>58</sup> The FDP has been the major funding mechanism for state assistance to landowners foresting their lands (~90% of all acres cost shared by currently active NCDFR administered forestation programs<sup>59</sup>) and

<sup>56</sup> Natural Resources Conservation Service & Farm Services Agency (USDA), North Carolina Soil and Water Conservation Districts and Division of Forest Resources.

<sup>57</sup> Conservation Compliance: the Clock is Running. Cook, M. and D. Hoag. 1997 SoilFacts, AG-439-23, at <http://www.soil.ncsu.edu/publications/Soilfacts/AG-439-23/>. Accessed 10/3/2006.

<sup>58</sup> Forest Development Program, Annual Accomplishment Summary, 2006, Joann Hocut, NC Division of Forest Resources.

<sup>59</sup> Ibid.

has reached approximately 85% of NIPF landowners doing forestation over the last 6 years (1999-2005).<sup>60</sup>

### Implementation Mechanisms

An Afforestation Task Force comprised of the Parties Involved would advise North Carolina Division of Forest Resources regarding an enhanced Forest Development Program, which will additionally target agricultural lands. The cost share rates would be 100% of establishment costs (only seedlings, planting, and herbicide the first year) plus \$200 of rent payments over 5 years which would be expected from a CRP type program. The overall cost to the state per acre of afforestation is about \$340. Program and salary costs for 3 foresters to implement this program would be about \$200,000 annually.

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

### Related Policies/Programs in Place

Federal Conservation Reserve Program  
Federal Conservation Reserve Enhancement Program  
North Carolina Agriculture Cost Sharing Program  
North Carolina Forest Development Program

### Type(s) of GHG Reductions

- Carbon sequestration from new forest growth
- Sequestration in durable wood products and fossil fuel offsets from forest based energy (not quantified, outside of analysis period)
- Prevention of emissions from forest conversions and improved retention of soil carbon over agriculture (included in AFW 7)

### Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 0.2, 2.4
- **Cumulative GHG reduction potential (MMtCO<sub>2</sub>e, 2007-2010):** 15
- **Net Cost per MtCO<sub>2</sub>e:** \$9
- **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). NC Division of Forest Management, Forest Development Program (Joann Hocutt), cost share rates.
- **Quantification Methods:** The amount of carbon sequestration achieved over time as a result of afforesting 40,000 acres by 2010 and 500,000 acres from 2010 to 2020 was quantified using carbon sequestration coefficients in [Table H-15](#).

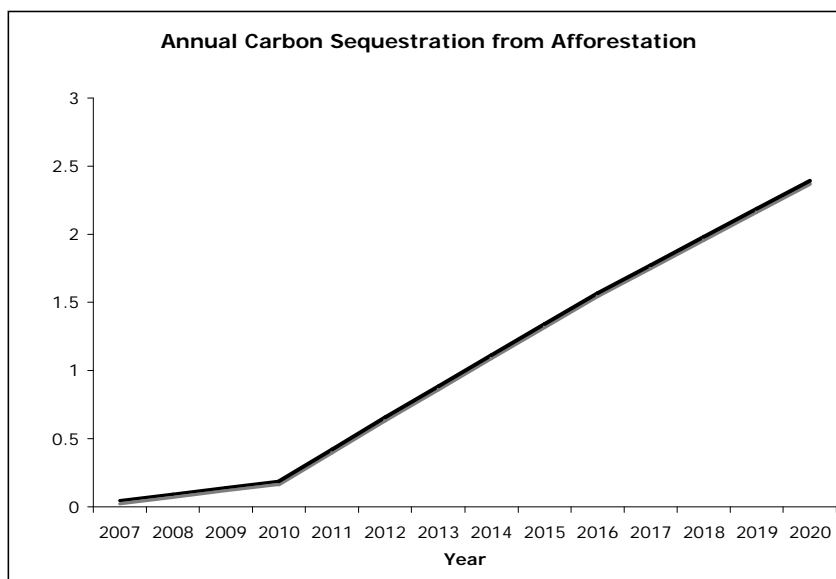
<sup>60</sup> Chris Hopkins' synthesis of Forest Statistics for North Carolina, 2002 and FDP reports.

**Table H-15. Carbon Sequestration Rates for Loblolly-Shortleaf Pine in the Southeastern US (Tons per Acre and Hectare)**

Stand age	tC/acre/yr	tC/ha/yr
0–5	1.28	3.16
5–15	1.12	2.77

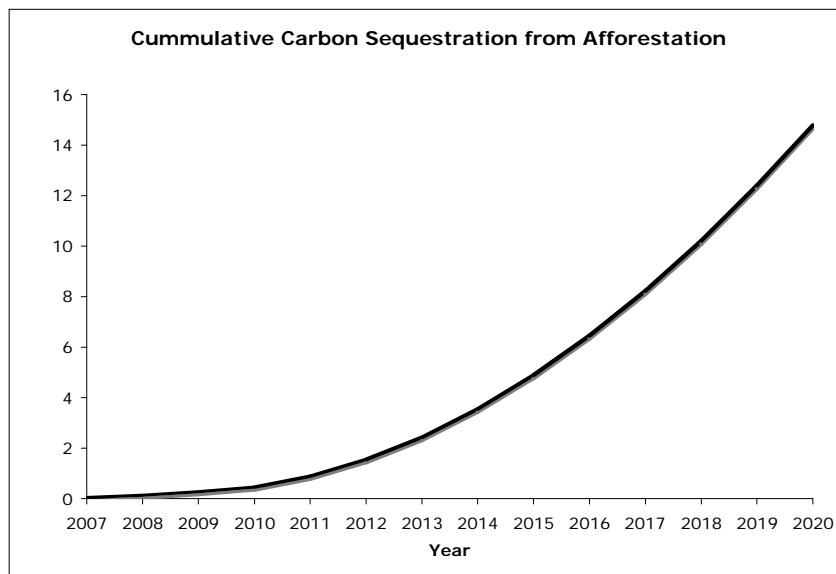
Source; USFS GTE NE-343, Table B39

Carbon sequestration was calculated annually, assuming afforestation rates of 10,000 acres/yr (4,045 ha/yr) from 2007-2010 and 50,000 acre/yr (20,225 ha/yr) from 2011-2020. Annual carbon sequestration was calculated separately for stands age 0-5 yrs and 5-15 yrs and summed for an annual total. Annual carbon sequestration as a result of afforestation over the time period 2007-2020, under full implementation of the goals outlined above, are shown in [Figure H-3](#). [Figure H-4](#) shows the cumulative total carbon sequestration over the same time period.

**Figure H-3. Annual Carbon Sequestration**

The cost of afforestation was estimated as an expense of \$340/acre (see key assumptions) multiplied by the number of acres planted each year plus \$200,000 per year for other program costs (i.e., forestry staff). Afforestation costs from 2007-2010 were \$3,600,000/yr and costs from 2011-2020 were \$17,200,000/yr. Annual discounted costs were estimated using a 5% interest rate. The cumulative costs effectiveness of the total program was calculated by summing the annual discounted costs and dividing by cumulative carbon sequestration, yielding \$9/MtCO<sub>2</sub>e.

- **Key Assumptions:** All planted forests were assumed to be primarily pine dominant stands. The cost per acre was assumed at \$340/acre based on 100% cost share rates for establishment (seedlings, planting, and herbicide the first year) plus \$200 of rent payments over 5 years, which would be expected from a CRP type program. An additional program cost covering salary for 3 foresters to implement this program was assumed at \$200,000 annually.

**Figure H-4. Cumulative Carbon Sequestration****Key Uncertainties**

Whether landowners with unforested land be willing to accept a new form of land management that may be unfamiliar and has a different investment structure than agriculture.

The rent payments of \$40 per acre per year for 5 years is shorter than the duration of CRP program payments which are usually 10 years; we believe this will be sufficient for North Carolina, but this is not certain

**Additional Benefits and Costs**

Non-quantified benefits include an improved or maintained quality of life for people near conserved lands as well as wildlife and watershed improvements.

**Feasibility Issues**

Better funding of the Forest Development Program to plant forests is feasible given adequate program funding.

**Status of Group Approval**

Complete

**Level of Group Support**

Unanimous

**Barriers to Consensus**

None

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

### Mitigation Option Description

Through proven and accepted forest management practices, increase forest stand productivity and then direct that productivity into the highest-value markets that currently exist. Move the 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. Such use offsets fossil fuel burning in the production of substitute materials (e.g., cement or steel for solid wood products, and plastic for wood fiber). Wood can substitute for fossil fuels directly in the case of biomass for energy. However these GHG benefits are not explicitly included in the analysis, which focuses on direct carbon sequestration in forests and in wood products. 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
- **Parties Involved:** Division of Forest Resources, NCSU Extension, NC Forestry Association, and NC Woodlands, NCSU, College of Forest Resources
- **Other:** 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 landowners.

### Implementation Mechanisms

Enhanced funding of the North Carolina Forest Development Program. The full funding level to accomplish program goals would be approximately \$230 million annually.<sup>61</sup> This program should include 10% of the budget reserved for forestry extension activities to help educate and

<sup>61</sup> Current program funding levels average \$2.6 million per year over the last several years.

motivate forest landowners and professional foresters to better manage their lands and to make the overall program more cost effective.

Improve markets for low value energy wood through the Renewable Environmental Portfolio Standard legislation.

Recognition and ability to trade carbon credits from both standing forests and harvested wood products.

### Related Policies/Programs in Place

North Carolina Forest Development Program

### Type(s) of GHG Reductions

- Carbon sequestration in forest ecosystems and durable wood products
- Fossil fuel offsets from forest based energy (GHG benefits accounted for elsewhere, i.e., in AFW-6 and in RCI and ES sectors)
- Prevention of emissions from forest conversions and improved retention of soil carbon (not quantified)

### Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 1.5, 5.9.
- **Cumulative GHG reduction potential (MMtCO<sub>2</sub>e, 2007-2010):** 48
- **Net Cost per MtCO<sub>2</sub>e:** -\$13
- **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). US Forest Service Forest Inventory Program. Annual Survey of Manufactures (2005). NC Division of Forest Management, Forest Development Program (Joann Hocut), Forest Statistics for North Carolina 2002.
- **Quantification Methods:** There are two parts to this analysis. The first quantifies the impact of the program on forest carbon (i.e., carbon in living and dead biomass and in soils within the forest ecosystem) and the second quantifies the impact on carbon removed from the forest as durable wood products. The starting point for both parts of the analysis is the same. The Forest Inventory Analysis (FIA) database from the US Forest Service was queried to determine forest productivity (cubic feet of harvested volume) and area of timberlands in North Carolina for the most current year available (2002). Productivity and area data were classified into two categories, pine-dominant forest types and all other forest types (most of which contain oak species) ([Table H-16](#))

**Table H-16. Baseline Forest Productivity in North Carolina (FIA, 2002)**

Forest Type	Area (acres)	Productivity (cubic feet)	Productivity per area (cubic ft/acre)
Pine (all pine dominant types)	4,960,656	8,483,024,291	1,710
Oak (all other types)	12,716,225	21,841,789,468	1,718

Forest ecosystem carbon sequestration was estimated using average annual carbon sequestration coefficients in [Table H-17](#). Coefficients for pine-dominant stands were based on carbon sequestration rates in Loblolly-shortleaf pine stands in the Southeastern US and coefficients for all other forests were based on carbon sequestration in Oak-hickory forests in the Southeastern US (USFS GTR NE-343). Separate coefficients were available for average and high productivity Loblolly-shortleaf pine stands. Coefficients for improved productivity Oak-hickory stands were not available and thus were estimated by assuming increased rates of carbon sequestration equivalent to 50% of the increases reported for the high productivity Loblolly-shortleaf pine stands.

**Table H-17. Forest Ecosystem Carbon Sequestration Coefficients for North Carolina**

	Pine (average productivity)	Pine (high productivity)	Oak (average productivity)	Oak (high productivity)*
Stand age			Carbon Stocks (MtC/ac)	
0	40.16	44.41	26.84	27.46
90	90.00	96.56	89.84	91.92
Avg. annual carbon sequestration (tC/ac/yr)	0.55	0.58	0.70	0.71

\* USFS does not provide high-productivity carbon values for Oak forest types in the Southeast. These values were calculated by assuming a 2.3% increase in carbon sequestration, which is half the percent increase reported by the USFS for Pine.

Source: USFS GTR NE-343, Tables A39, A40, A44

Baseline annual carbon sequestration was calculated by applying the average productivity coefficients in [Table H-17](#) to the forest areas in [Table H-16](#) each year from 2009-2020. To calculate carbon sequestration under program implementation, the forest areas achieving high and average productivity each year were modeled for the time period of 2009-2020. Under program implementation, forest treatments to improve productivity were assumed to begin in 2007. By 2009, high levels of productivity would be realized on 10% of the targeted area split equally between Pine and Oak classes (total targeted area is 50% of all NC timberland, or 8,838,441 acres). Each year, the area of forests at high productivity levels was increased by 10% until the full goal level was achieved in 2018. Total forest area was held constant each year.

High productivity and average productivity carbon sequestration coefficients were applied to the relevant forest area estimates each year to calculate forest carbon sequestration under program implementation. Baseline levels were subtracted to calculate the incremental increase in carbon sequestration as a result of the program. The results are shown in [Table H-18](#).

**Table H-18. Summary of Forest Area and Forest Carbon Sequestration from 2009-2020 (under baseline and program implementation)**

Year	High productivity forests (ac)	Average productivity forests (ac)	Carbon sequestration under the program (MMtC/yr)	Baseline carbon sequestration MMtC/yr	Carbon sequestration above baseline (MMtC/yr)
2009	883,844	16,793,037	11.66	11.65	0.02
2010	1,767,688	15,909,193	11.68	11.65	0.03
2011	2,651,532	15,025,349	11.70	11.65	0.05
2012	3,535,376	14,141,505	11.71	11.65	0.07
2013	4,419,220	13,257,661	11.73	11.65	0.08
2014	5,303,064	12,373,817	11.75	11.65	0.10
2015	6,186,908	11,489,973	11.76	11.65	0.12
2016	7,070,752	10,606,129	11.78	11.65	0.13
2017	7,954,597	9,722,285	11.80	11.65	0.15
2018	8,838,441	8,838,441	11.81	11.65	0.17
2019	8,838,441	8,838,441	11.81	11.65	0.17
2020	8,838,441	8,838,441	11.81	11.65	0.17

Forest sequestration in harvested wood products (HWP) was calculated following guidelines published by the US Forest Service. Details on each step of the analysis can be found in the guidelines, following the methodology referred to as “Land-based estimation.” In general, forest productivity is used as a starting point and regional patterns in the disposition of carbon through various HWP pools are used to model carbon stock changes in HWP over time. The methodology calculates the transfer of carbon through four pools over time: wood in use (i.e., building materials, furniture), wood in landfills (i.e., products that were previously in use and have been discarded), wood burned for energy capture, and wood that has decayed or burned without energy capture. The difference in the amount of carbon entering the “in use” and “landfill” pools at the beginning of a year and the amount remaining one year later equals total net annual carbon flux in HWP.

For this analysis, carbon sequestration in HWP was compared under baseline and program implementation levels. Baseline levels of carbon sequestration in HWP were calculated using forest productivity values in [Table H-16](#) and default coefficients for pine and oak forest types and for the southeast region. Two modifications were made to estimate carbon sequestration under program implementation. First, productivity levels were gradually increased as described above for the analysis of forest ecosystem carbon. Second, the disposition pattern was modified such that 10% less wood was disposed in landfills and instead shifted to use for energy production, thus providing more feedstocks for bioenergy. In both cases, the annual area harvested in NC was assumed to be 317,800 acres (Forest Statistics for NC, 2002).

The results of the analysis are summarized in **Table H-19**, which show the amount of carbon stored in landfills and products in-use each year above what would have happened in the baseline, spanning the time period 2009-2020. While the amount of additional carbon in landfills and in products from a given harvest decreases each year (as it is emitted through decay or energy capture), additional wood is harvested each year and at increasing levels of productivity. Thus for every year in the time series, the carbon stocks in the wood products pool are increasing. This analysis is carried out until 2020 and does not capture the continued disposition of carbon through the wood products pools in time.

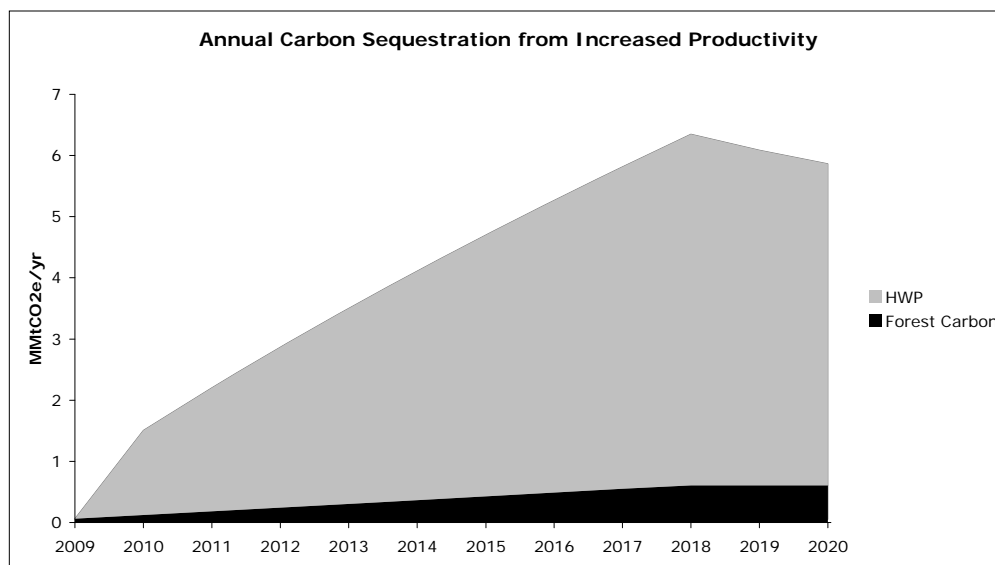
An alternative approach for estimating carbon stored in wood products is to estimate the amount of carbon remaining in products and landfills after 100 years and apply that value to the year of harvest (GTR NE-343, 1605b technical guidelines). This approach accounts for emissions that would occur over 100 years following harvest in the year of the harvest, and assumes that the carbon remaining after 100 years is stored permanently. This approach was developed to simplify annual reporting of carbon stored in wood products and to account for the long term dynamics of carbon flows in harvested wood products pools. For comparison to the analysis covering 2009-2020, the amount of carbon above baseline levels that would be stored in products and landfills 100-yr after harvest is shown in the last column of **Table H-19**. The total carbon still stored in HPW from harvests that occurred during 2009-2020, after 100 years is 5.15 MMtC (compared to the cumulative carbon stored in HWP during 2009-2020, of 11.93 MMtC).

**Table H-19. Disposition of Carbon Stored in Landfills and in Products over Time (amount is additional carbon above baseline levels)**

Year of harvest	Carbon from the harvest in yr x (x=row) that is in use or landfill by the end of year y (y=column) (MMtC)												
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	100 yrs later
2009	0.19	0.18	0.17	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.12	0.07
2010		0.39	0.37	0.35	0.33	0.31	0.30	0.29	0.28	0.27	0.26	0.25	0.14
2011			0.58	0.55	0.52	0.49	0.47	0.45	0.43	0.42	0.40	0.38	0.21
2012				0.78	0.73	0.69	0.66	0.63	0.60	0.57	0.55	0.53	0.27
2013					0.97	0.92	0.87	0.82	0.78	0.75	0.72	0.69	0.34
2014						1.17	1.10	1.04	0.99	0.94	0.90	0.86	0.41
2015							1.36	1.28	1.21	1.15	1.10	1.05	0.48
2016								1.56	1.46	1.38	1.31	1.25	0.55
2017									1.75	1.65	1.56	1.48	0.62
2018										1.95	1.83	1.73	0.69
2019											1.95	1.83	0.69
2020												1.95	0.69
Carbon stored in HWP in year y (MMtC)	0.19	0.57	1.12	1.84	2.71	3.73	4.90	6.20	7.64	9.20	10.69	12.13	5.15
Annual Carbon Sequestration (MMtC/yr)	0.00	0.38	0.55	0.71	0.87	1.02	1.17	1.30	1.44	1.56	1.49	1.43	

**Figure H-5** shows the combined estimated GHG reductions from forest carbon and HWP.

**Figure H-5. Annual Carbon Sequestration**



There are also emissions reductions associated with the displacement of fossil fuels by bioenergy generated from the additional biomass feedstocks resulting from forest productivity enhancements. Under this option, an estimated 15 MMt more biomass would be used for bioenergy from harvests during 2009-2020.

The cost of management treatments to increase productivity was estimated at \$8.80/ac/yr multiplied by the number of acres treated each year (see **Table H-18** for annual area of high productivity forests). Revenue from the additional harvested wood products generated from productivity treatments was also taken into consideration. The value of additional wood products harvested during 2028-2037 as a result of productivity treatments during 2009-2020 was calculated assuming a future value of \$389.90/ac (a present value \$119.14/ac). If productivity is doubled on a total of 8,842,200 acres of forestland during 2009-2020, this gives a net present value (NPV) of \$1.05 billion in wood products. The combined NPV of the above costs and cost savings were summed for a total NPV of -\$639 million (cost savings). Annual discounted costs and cost savings were estimated using a 5% interest rate. The total NPV was divided by cumulative carbon sequestration, yielding a cumulative cost effectiveness of -\$13.21/tCO<sub>2</sub>e.

- **Key Assumptions:** Productivity increases were assumed to be distributed equally between pine and oak forest types; cost of productivity treatments were assumed at \$8.80 per acre per year over 30 years, based on NC Forest Development Program cost-share rates for a one site preparation and planting, three fertilization treatments, and one pre-commercial timber stand improvement. The added value of revenue generated from increased forest productivity was estimated at \$390 per acre. The analysis assumes no change in total forest area over the period of analysis.

**Key Uncertainties**

The silviculture of doubling forest growth is relatively well understood. The key questions involved are centered on feasibility of addressing all targeted land. Will 50% of forest landowners be willing to intensify their forest management with the full range of stand improvement and fertilization foreseen by this program? This may require new forms and levels of public outreach not previously practiced by forestry institutions.

Success of this mitigation option is heavily dependent on the expansion of markets for forest products including lumber and bio-fuels. Future housing markets are not predictable and it remains to be seen the degree to which wood-based renewable energy will be adopted. Use of wood for electricity production will be dependent on regulation and/or incentives. Technologies for cellulosic ethanol are still under development for commercial scale production. And, the future for all renewables is largely dependent of future fossil fuel prices.

**Additional Benefits and Costs**

Increased benefits from forest management would increase forestland owner incomes and the probability of retaining land in forest cover.

**Feasibility Issues**

NCDFR personnel have indicated they can substantially increase implementation of FDP with landowners given increased funding, but a many-fold increase in this program will require a large and unknown administrative and on-the-ground personnel demand. The Forest Development Program may not be funded at levels high enough to fully support this program. Other complimentary mechanisms of support may be necessary.

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. If goal levels were extended into the future, productivity could be doubled on all managed timberlands by 2030.

**Status of Group Approval**

Complete

**Level of Group Support**

Unanimous

**Barriers to Consensus**

None

## 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.

*Note: This option 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

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.

### Type(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<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O from the combustion of fossil fuels.

### Estimated GHG Reductions and Costs (or Cost Savings)

- **GHG potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 1.1, 2.9
- **Net Cost per MtCO<sub>2</sub>e:** \$1

*Information available from the RCI TWG indicates that Option RCI-10 will consume some landfill gas as part of the renewable energy portfolio. The benefit associated with this consumption of an equivalent amount of natural gas (to be claimed under the RCI option) is 0.002 MMtCO<sub>2</sub>e in 2010 and 0.007 MMtCO<sub>2</sub>e in 2020. These values were subtracted out as overlap in the Summary Table on page 1 of this appendix.*

- **Data Sources:** The NC GHG Inventory & Forecast was used as the source of data on available methane emissions. Cost information from EPA's Landfill Gas Cost Model (LFGcost), version 1.4 was used to estimate costs.<sup>62</sup>
- **Quantification Methods:** *GHG Savings.* GHG savings were estimated by determining the CO<sub>2</sub> equivalent for the available methane to be reduced in 2010 (20%) and 2020 (50%) at uncontrolled landfills in the state.<sup>63</sup>

Additional GHG reductions are achieved by offsetting fossil fuel that would have been used to create the thermal energy or electricity generated by these landfill gas projects. These reductions are provided as part of the LFG cost output and were added to the

<sup>62</sup> Four different runs of LFG cost were provided by A. Singleton, ERG, to S. Roe CCS, March 2007, based on the scenarios specified in the quantification methods section of this option.

<sup>63</sup> 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.

reductions associated with methane collection and destruction. The total benefits for each year are shown in **Table H-20**.

### Costs

Costs were estimated by applying EPA’s LFGcost-web Model (version 1.4) to three different scenarios. The parameters for these scenarios are shown below. These three scenarios were designed to capture the range of costs likely to be seen in NC to apply LFG capture and utilization projects to both uncontrolled and flared landfills. Data to support these three scenarios

**Table H-20. Three Landfill Gas Control Options Modeled**

Scenario	1	2	3
Current Controls	None	None	Collection & Flare
Year Landfill Opened	1988	1988	1983
Year Landfill Closed	2010	2010	2017
Annual Waste Acceptance Rate (tons)	38,000	38,000	88,000
Landfill Size (acres)	100	100	200
Technology Employed	Small Engine/ Generator Set	Direct Use (heat or steam)	Engine/ Generator Set
LFGcost Value of Energy Produced	\$0.045/kWh	\$4.50/MMBtu	\$0.045/kWh
Modeled Costs	\$2.72	-\$0.82	\$0.15

The data in **Table H-20** show that the direct use option results in a net savings (project revenues greater than costs), while the small and standard engine/generator set options result in net costs. Direct use is typically only cost effective when the landfill is within a short radius to the end user (usually a half mile or less). Hence, the opportunities for direct use are limited. Standard engine/generator set projects (800 kW and greater) are used at projects with moderate to large methane production (48 MM cubic feet/year collected on average). Small engine/generator set projects are applicable at smaller sites.

To develop an overall cost for this policy option, CCS used the following assumptions on the mix of projects that would be implemented to achieve the policy’s goals: 17% of methane reduced via standard engine/generator set projects (17% of the EPA Landfill Methane Outreach Program database waste in place is at flared sites, which could be candidates for these projects); 20% of methane is controlled by direct use projects (number of projects assumed to be limited by location of end users); and the remaining 63% is assumed to be controlled by small engine/generator set projects.

Using this blend of LFG energy projects and the LFG cost output data, a blended cost effectiveness estimate of \$1.57/MtCO<sub>2</sub>e was estimated. This cost effectiveness estimate was applied to the emission reductions to be achieved in each year by the policy to estimate costs in each year.

CCS did not include the effects of the Section 45 Tax Credit for production of renewable energy, since this credit may or may not be available to many of the projects that would be installed due to this policy. Inclusion of this tax credit would have a small effect at lowering the costs for the policy. For example, the cost effectiveness for the small

engine/generator set option would decrease from the \$2.72/Mt estimate shown above to \$2.46/Mt.

Information available from the RCI TWG indicates that Option RCI-10 will consume some landfill gas as part of the renewable energy portfolio. The latest estimates are 40 billion BTUs of LFG in 2010 and 138 billion BTUs in 2020. The benefit associated with the offset of an equivalent amount of natural gas (to be claimed under the RCI option) is 0.002 MMtCO<sub>2e</sub> in 2010 and 0.007 MMtCO<sub>2e</sub> in 2020. These were subtracted at the bottom of the Summary List of Mitigation Options on page 1 to account for this overlap.

- **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. Available methane also includes methane being flared at sites with collection and flaring. In 2010, projects are implemented to capture 20% of the available methane; in 2020 this rises to 50%. For costs, the key assumptions are the value of energy produced: \$0.045/kWh for electricity projects and \$4.50/MMBtu for direct use projects. Higher values for these energy products could reduce the costs of this option significantly.

### Key Uncertainties

See Key Assumptions in the section above.

### Additional Benefits and Costs

Additional benefits include reducing landfill gas emissions of volatile organic compounds, including some that are hazardous air pollutants.

### 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

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

## 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 quantity of materials being put in landfills 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, and 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 pre-consumer and post consumer food waste diversion<sup>64</sup> covering at a minimum: infrastructure needs, barriers to increasing infrastructure,

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<sup>64</sup> Pre-consumer food waste is the easiest to compost. It is simply the preparatory food refuse and diminished quality bulk, raw material food that is never seen by the consumer. This food waste is generally already separated from the rest of the waste stream generated, thus no change is needed to keep contaminants out of the future compost. Post-consumer food waste is more challenging because of separation issues. It is simply the table scrap food refuse. Often, after the consumer is done with the food, the waste is subject to contaminants and a decision has to be made on how to separate the food from other waste. This can be done by having an extra trash can that is only used for food waste.

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; requires local government 10-year 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 Division of Pollution Prevention and Environmental Assistance (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.

### Type(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 (MMtCO<sub>2</sub>e):** 0.20, 0.49.
- **Net Cost per MtCO<sub>2</sub>e:** \$1.

EPA's Waste Reduction Model (WARM)<sup>65</sup> was used to estimate the emissions associated with the State's current level of recycling and with the goal of increasing recycling by

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65 Version 7, August 2005. From [http://www.epa.gov/climatechange/wycd/waste/calculators/Warm\\_home.html](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

25% per capita. 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.<sup>66</sup> 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. **Table H-21** summarizes the results of both model runs:

**Table H-21. Analysis Results Using WARM**

WARM Run	Total GHG Emissions (MtCO <sub>2</sub> e)
Baseline (without existing recycling)	6,379,586
Baseline (with recycling)	4,439,516
25% Recycling Increase Above Baseline	3,952,224
<b>GHG Reductions</b>	<b>487,292</b>

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).

**Table H-22** 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% to mimic a 25% increase in per capita recovery. All commodities were increased by the same percentage. In reality, one would

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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 (MtCO<sub>2</sub>E), 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 Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks* (EPA530-R-02-006), at <http://epa.gov/climatechange/wyacd/waste/SWMGHGreport.html>.

<sup>66</sup> 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.

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 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).

**Table H-22. WARM Output for the 25% Increase in Recycling Run**

<b>Material</b>	<b>Incremental Recycling (Tons)</b>	<b>Incremental GHG Emissions from Recycling (MtCO<sub>2</sub>E)</b>	<b>Incremental Landfilling (Tons)</b>	<b>Incremental GHG Emissions from Landfilling (MtCO<sub>2</sub>E)</b>	<b>Total Incremental GHG Emissions (MtCO<sub>2</sub>E)</b>
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)

<b>Material</b>	<b>Incremental Recycling (Tons)</b>	<b>Incremental GHG Emissions from Recycling (MtCO<sub>2</sub>E)</b>	<b>Incremental Landfilling (Tons)</b>	<b>Incremental GHG Emissions from Landfilling (MtCO<sub>2</sub>E)</b>	<b>Total Incremental GHG Emissions (MtCO<sub>2</sub>E)</b>
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
<b>Total</b>	<b>134,539</b>	<b>(496,379)</b>	<b>(134,539)</b>	<b>9,088</b>	<b>(487,291)</b>

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.<sup>67</sup>

- 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.

<sup>67</sup> Jim Hickman, NC Office of Pollution Prevention & Environmental Assistance, personal communication with S. Roe, CCS, January 2007.

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.

Resulting in 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<sub>2e</sub> 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

See “Key Assumptions” in the previous section

### Additional Benefits and Costs

Reduction in other air and water pollutant emissions associated with product manufacturing and transport.

### Feasibility Issues

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

### Status of Group Approval

Complete

### Level of Group Support

Unanimous

### Barriers to Consensus

None

## AFW–13. Urban Forestry Measures

### Mitigation Option Description

Urban forest cover protection and management offers a potentially cost effective mechanism to reduce energy use, to store/sequester carbon and mitigate land use change (conversion of forest and agricultural lands to residential sites). Strategic planting of trees to shade houses and AC units can yield energy savings of 15% to 50% on cooling costs.<sup>68</sup> Planting of shade trees can reduce summer heating costs, with only marginal increases in winter heating costs, particularly in mild climates. In addition, depending on local conditions, tree planting can reduce wind-speed and further reduce energy costs. The net direct impacts of tree planting are generally estimated to be positive, taking these factors into account.

### Mitigation Option Design

- **Goals:** Increase urban tree cover by planting three additional trees (i.e., three more than planned) on all new construction sites starting in 2008, and by planting three new trees on 25% of existing housing units in 2007 by 2020, with the aim of achieving a 25% reduction in annual heating and cooling costs.
- **Timing:** see above.
- **Parties Involved:** Local government planning agencies, developers, residential and commercial property owners, North Carolina Urban Forest Council, DENR Division of Forest Resources, electricity providers, NC Cooperative Extension Service.
- **Other:** Research on cost savings from urban tree planting indicates that planting three additional trees around a housing unit yields cost savings on the order of \$150/yr for the southeast (EPA Cooling our Communities). Annual residential energy expenditures on heating and cooling are estimated at \$585/yr per housing unit in NC (NC State Energy Plan 2003). Therefore, planting three additional trees amounts to about a 26% reduction in household heating and cooling costs.

### Implementation Mechanisms

- Use incentives to encourage developers to retain trees and green space on new construction sites. (Incentives could include density credits, priority during approval/permitting process, utility credits, etc.). Require developers to retain a minimum of 10% canopy cover and those that retain more than that receives increased credits and priority.
- Promote the creation of proper tree preservation and protection ordinances in communities across the state.

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<sup>68</sup> Cooling Our Cities, U.S. Environmental Protection Agency PM-221.

- Provide recognition to communities that increase their canopy cover percent (e.g., with CO<sub>2</sub> credits). Allow municipalities and or homeowners to direct benefits of CO<sub>2</sub> sequestration via trees to their budget or charity of their choice, respectively.
- Install green roofs on state buildings – green roofs reduce urban heat islands by providing shade and the cooling effects of evapotranspiration, absorb air pollution, collect airborne particulates, and store carbon, and insulate a building from extreme temperatures (reducing energy costs).
- Support the use of consulting arborists by developers/contractors in the planning and review process prior to building permit submission.
- Empower to NC Division of Forest Resources to increase seedling availability to Urban Tree planting on public lands. Expand the interaction with community groups and environmental organization
- Enhance existing programs (e.g., Neighborwoods, through the Alliance for Community Trees ACT) to educate and cost-share on encouraging seedlings for urban or residential plantings on private home ownerships
- Increase level of support/education to municipalities in order to ensure proper maintenance and care of increased urban forest.
- Designate an Urban Forestry Extension specialist to NCSU Forestry Extension staff

### Related Policies/Programs in Place

North Carolina Urban Forest Council  
 America the Beautiful Program  
 The Urban and Community Forestry Grant Program  
 Trees Across Raleigh  
 Trees Across Asheboro  
 Quality Forward

### Type(s) of GHG Reductions

- Increased carbon sequestration in urban trees
- Avoided emissions by reduced energy use in heating and cooling
- Improved retention of soil carbon (not quantified)
- Carbon sequestration in the form of durable wood products and fossil fuel offsets from forest based energy (not quantified)

### Estimated GHG Savings and Costs per MTCO<sub>2</sub>e

- **GHG reduction potential in 2010, 2020 (MMtCO<sub>2</sub>e):** 1.4, 4.3
- **Net Cost per MtCO<sub>2</sub>e:** -\$11
- **Data Sources:** Cooling Our Cities, U.S. Environmental Protection Agency PM-221; “Shade trees reduce building energy use and CO<sub>2</sub> emissions from power plants,” H. Akbari, Environmental Pollution, Vol. 116, p. S119-S126 March 2002; US Forest Service Effects of Urban Forests and their Management on Human Health and Environmental

Quality (<http://www.fs.fed.us/ne/syracuse/Data/data.htm>); US Census Bureau statistics on housing units in NC.

- Quantification Methods:** GHG reductions were quantified separately for (1) carbon sequestration in trees and (2) decreases in residential energy consumption. Trends in US Census Bureau data on housing stocks in North Carolina from 1939-2005 were used to model the NC housing stock from 2007-2020. Since 1938, there was positive growth in housing stock nearly all years, with growth rates ranging from 0.8%/yr during 1980-1989 to 11%/yr during 1995-1998. However, growth in housing stock decreased after 1998 and, on average, was -6.5%/yr during 2000-2005. Growth in annual housing stock from 2007-2020 was calculated by assuming 72,454 new housing units were constructed in 2006 (based on the average number constructed per year from 2000-2005) and a -6.5%/yr growth rate for 2007-2020.

Under the first goal, three additional trees beyond what would normally be planted around new construction in NC are planted on 100% of new housing units every year from 2007-2020. Carbon sequestration in urban trees was assumed at 6 kg C/tree/yr, which is the average for North Carolina in the USFS assessment of urban forest resources (Nowak et al., 2001). Total annual carbon sequestration was calculated each year, including sequestration in trees planted that year and trees planted prior to that year under the program. The results are shown in **Table H-23**.

**Table H-23. Carbon Sequestration in Trees Planted on New Housing Units, 2007–2020**

Year	New Housing Units	Number of trees planted	C sequestered in new trees (kg C)	C sequestered in trees planted since 2007 (kg C)	Total CO <sub>2</sub> e sequestered (MMtCO <sub>2</sub> e)
2007	67,751	203,253	1,219,515.93		0.004
2008	63,353	190,059	1,140,356.40	1,219,515.93	0.009
2009	59,241	177,723	1,066,335.16	2,359,872.32	0.013
2010	55,395	166,186	997,118.69	3,426,207.48	0.016
2011	51,800	155,399	932,395.10	4,423,326.17	0.020
2012	48,437	145,312	871,872.76	5,355,721.27	0.023
2013	45,293	135,880	815,278.96	6,227,594.02	0.026
2014	42,353	127,060	762,358.70	7,042,872.98	0.029
2015	39,604	118,812	712,873.53	7,805,231.68	0.031
2016	37,033	111,100	666,600.46	8,518,105.21	0.034
2017	34,630	103,889	623,331.02	9,184,705.67	0.036
2018	32,382	97,145	582,870.22	9,808,036.69	0.038
2019	30,280	90,839	545,035.75	10,390,906.91	0.040
2020	28,314	84,943	509,657.14	10,935,942.66	0.042

Under the second goal, three additional trees are planted on 25% of the 2007 housing stock over the course of 2007-2020. NC housing stock in 2007 was estimated at

4,080,759 units based on US Census Bureau data. The analysis assumed gradual implementation such that three trees were planted on 72,871 units each year. By 2020, three additional trees were planted on a total of 1,020,190 units (25% of 2007 housing stock). Total annual carbon sequestration in these trees was calculated each year, including sequestration in trees planted that year and trees planted prior to that year under the program. The results are shown in **Table H-24**.

**Table H-24. Carbon Sequestration in Trees Planted on Existing Housing Units, 2007–2020**

Year	# Units Planted	Number of trees planted	C sequestered in new trees (kg C)	C sequestered in trees planted since 2007 (kg C)	Total CO <sub>2</sub> e sequestered (MMtCO <sub>2</sub> e)
2007	72,871	218,612	1,311,672		0.005
2008	72,871	218,612	1,311,672	1,311,672	0.010
2009	72,871	218,612	1,311,672	2,623,345	0.014
2010	72,871	218,612	1,311,672	3,935,017	0.019
2011	72,871	218,612	1,311,672	5,246,690	0.024
2012	72,871	218,612	1,311,672	6,558,362	0.029
2013	72,871	218,612	1,311,672	7,870,035	0.034
2014	72,871	218,612	1,311,672	9,181,707	0.038
2015	72,871	218,612	1,311,672	10,493,380	0.043
2016	72,871	218,612	1,311,672	11,805,052	0.048
2017	72,871	218,612	1,311,672	13,116,725	0.053
2018	72,871	218,612	1,311,672	14,428,397	0.058
2019	72,871	218,612	1,311,672	15,740,070	0.063
2020	72,871	218,612	1,311,672	17,051,742	0.067

GHG reductions from avoided use of fossil fuels for heating and cooling were also estimated. Reductions in energy consumption were based on energy cost savings from tree planting. Research on cost savings from urban tree planting indicates that planting three additional trees around a housing unit yields cost savings on the order of \$150/yr/household for the southeast (EPA Cooling our Communities). Annual residential energy expenditures on heating and cooling are estimated at \$584.60/yr per housing unit in NC (NC State Energy Plan 2003). Therefore, planting three additional trees amounts to about a 26% reduction in household heating and cooling costs. It was assumed that at 26% reduction in costs translated into a 26% reduction in annual electricity and natural gas consumption for residential heating and cooling.

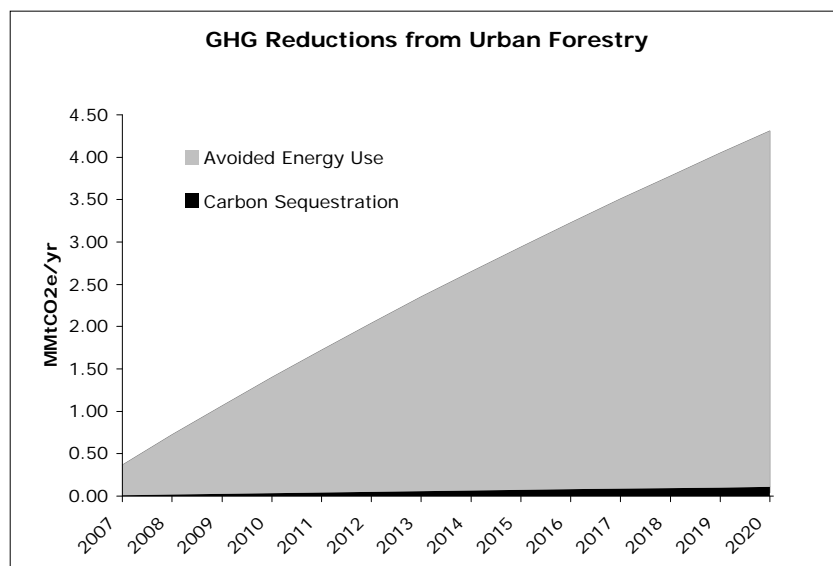
In NC, about 52.9 and 26.7 million BTU's (MMBTU) of electricity and natural gas, respectively, are used for heating and cooling per household (NC State Energy Plan 2003). It was assumed that housing units that planted trees under the program reduced electricity and natural gas consumption by 13.75 and 6.94 MMBTUs per year, respectively. Electricity and natural gas emission factors (0.1578 and 0.0528 tonnes CO<sub>2</sub>e/MMBTU, respectively) were calculated from the NC Inventory and Forecast (the electricity emission factor was modified based on additional data from the electricity

sector in NC, as documented in the ES Methods Memo). The resulting GHG emission reductions are shown in [Table H-25](#).

**Table H-25. GHG Reductions from Reduced Use of Fossil Fuels for Household Heating and Cooling**

Year	Housing units with additional trees	Energy Reductions- electricity (MMBTU)	Energy Reductions - natural gas (MMBTU)	CO <sub>2</sub> e reductions- electricity (MMtCO <sub>2</sub> e)	CO <sub>2</sub> e reductions- natural gas (MMtCO <sub>2</sub> e)	Total Reductions (MMtCO <sub>2</sub> e)
2007	140,622	1,934,109	976,195	0.31	0.05	0.36
2008	276,845	3,807,732	1,921,861	0.60	0.10	0.70
2009	408,957	5,624,794	2,838,979	0.89	0.15	1.04
2010	537,223	7,388,967	3,729,403	1.17	0.20	1.36
2011	661,894	9,103,684	4,594,865	1.44	0.24	1.68
2012	783,202	10,772,155	5,436,986	1.70	0.29	1.99
2013	901,366	12,397,382	6,257,280	1.96	0.33	2.29
2014	1,016,590	13,982,172	7,057,164	2.21	0.37	2.58
2015	1,129,064	15,529,150	7,837,964	2.45	0.41	2.86
2016	1,238,968	17,040,771	8,600,918	2.69	0.45	3.14
2017	1,346,469	18,519,328	9,347,185	2.92	0.49	3.42
2018	1,451,721	19,966,970	10,077,847	3.15	0.53	3.68
2019	1,554,871	21,385,701	10,793,917	3.38	0.57	3.95
2020	1,656,056	22,777,399	11,496,343	3.59	0.61	4.20

The relative contribution of tree carbon sequestration and reductions in energy consumption to overall GHG reductions is shown in [Figure H-6](#). Reductions in avoided use of fossil fuels for heating and cooling makes up most of the reductions over the time series.

**Figure H-6. GHG Reductions**

Urban tree planting has both costs and cost savings. The cost of planting and maintaining urban trees was estimated by multiplying the number of trees planted each year by \$250/tree. The cost is based on a reported range of \$10-500 per tree (Akbari 2002). The range reflects variation in program implementation and consideration of full life cycle costs (i.e., pruning/maintenance, liability, waste disposal, etc.). The value of \$250/tree is near the midpoint of this range. (The reported range does not consider potential uses of biomass waste for energy purposes, neither does this analysis.) In addition, cost savings was estimated by multiplying the cumulative number of households in the program each year by \$150/yr/household. Net annual costs (costs minus cost savings) are initially positive. However, starting in 2011, as more households see cost savings from reduced heating and cooling requirements, costs become increasingly negative. Annual discounted costs were estimated using a 5% interest rate. The cumulative costs effectiveness of the total program was calculated by summing the annual discounted costs and dividing by cumulative carbon sequestration, yielding -\$11/ton CO<sub>2</sub>e.

- **Key Assumptions:** Future growth of housing stocks is assumed at 6.5%/yr, starting with 4,080,759 existing units in 2007. Three additional trees per household will reduce heating and cooling costs by \$150/yr. Costs of planting and maintaining urban trees is \$250/tree. Average tree carbon sequestration in urban trees is 6 kg C/tree/yr.

### Key Uncertainties

The cost effectiveness of urban tree planting for carbon sequestration is not in doubt. The impact of hurricanes on shade trees is important, but uncertain in timing and spatial distribution. The biggest question is the administration of this program to reduce the cost of planted trees. The ability to implement these programs in smaller and newer communities<sup>69</sup> may be limited by administrative capacity in these communities.

<sup>69</sup> Predominantly in former agricultural lands without trees, although many new communities on former forest land completely clear all original trees.

### **Additional Benefits and Costs**

Additional benefits include an improved or maintained quality of life for people in improved urban forests as well as wildlife, recreation and watershed improvements.

### **Feasibility Issues**

Urban forestry is in general a known field with appreciable positive impacts.

### **Status of Group Approval**

Complete.

### **Level of Group Support**

Unanimous.

### **Barriers to Consensus**

None.