

## CHAPTER 9

### AGRICULTURE SECTOR STRATEGIES

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#### Overview

Agricultural practices accounted for only 7%, or 9.53 megatons, of North Carolina's total GHG emissions in 1990 (Figure 9-1). While this is a small percentage, the sector is a significant contributor of methane (CH<sub>4</sub>) and nitrous oxide (47% and 39%, respectively). Overall land use changes, including conversion from and to farmland, also account for 2% of the state's nitrous oxide emissions. Such emissions can be reduced through improved agriculture and land management practices. This chapter outlines a number of strategies that target such improvements. If implemented, CH<sub>4</sub> management and recovery measures could help North Carolina achieve emissions reductions of at least 199,000 tons eCO<sub>2</sub>. When further combined with more fuel-efficient farming techniques and better fertilizer management practices, the eCO<sub>2</sub> reduction potential for agriculture is somewhat larger, but still relatively small in comparison to the other sectors.

Agriculture is a significant economic sector in North Carolina. In 1997, the state ranked 15<sup>th</sup> nationally in number of farms, with 2.7% of the nation's total. It also ranked 4<sup>th</sup> in generation of farm income, gleaning \$3.5 billion or 7.1% of the country's total farm gains. In terms of cash receipts for commodities, North Carolina was positioned 7<sup>th</sup> in the United States, bringing in \$8.3 billion or 4.0% of the nation's earnings that year. The state's leading farm commodities include broilers, hogs, tobacco, and greenhouse nursery crops (O'Leary Morgan et al 1999). Currently, North Carolina leads the nation in production of tobacco, turkeys, and sweetpotatoes.

These figures are significant because they indicate, first, the prevalence of farming in the state and, second, the mix of types of farming practiced. Such factors are important considerations in reducing GHG emissions since they influence variables, such as fertilizer and energy usage and CH<sub>4</sub> emissions from livestock.

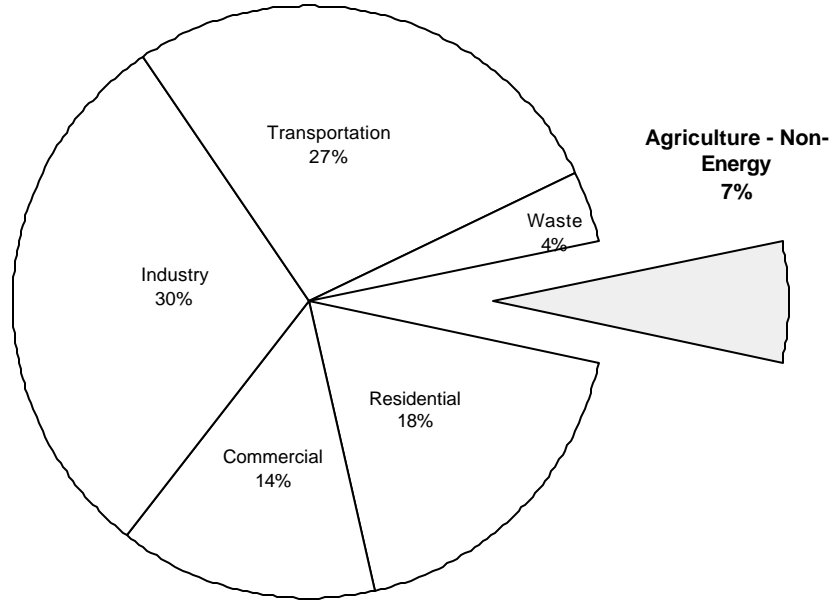
#### Assumptions

While recent trends show a decrease in number of farms and total farmland acreage, the average size of farms are increasing, as is the amount of planted and harvested land. From 1990-1997, the total number of farms in North Carolina decreased 8% (from 62,000 to 57,000) and total farmland acreage decreased 10% (from 10,000,000 to 9,000,000). Average farm size increased slightly from 156 to 158 acres during this same time period. From 1995-1997, planted acreage and acreage harvested also increased 6.0% (from 4.6 million to 4.9 million acres) and 7.4% (from 4.4 million to 4.8 million acres), respectively. If the trend towards increased farmland and acreage harvested

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continues to grow, and farming practices remain at a business as usual state, nitrous oxide and CH<sub>4</sub> emissions will likely rise considerably (O'Leary Morgan and Morgan 1999).

Figure 9-1: North Carolina Greenhouse Gas Emissions in 1990  
Total Emissions in 1990: 145 Megatons eCO<sub>2</sub>



Because farming is so widely practiced in North Carolina, the agricultural sector holds great potential for revision of practices effecting GHG emissions. Nitrous oxide (N<sub>2</sub>O) from fertilizer use and CH<sub>4</sub> from manure management dominate the state's agricultural emissions. Fertilizer use and agricultural liming account for 39% of nitrous oxide emissions, while animal manure management accounts for 47% of annual CH<sub>4</sub> emissions (Appalachian State University, 1996). CH<sub>4</sub> is one of the most potent GHGs, since each molecule of gas is estimated to have approximately 21 times the heat trapping effect of a carbon dioxide molecule (U.S. Department of Energy 1995.) Currently, the global atmospheric concentration of CH<sub>4</sub> is increasing at a rate of 1% annually and has more than doubled in the past two centuries.

CH<sub>4</sub> emissions from domestic animals were forecasted from 1987 statistics for the years 1990 and 2010 as a basis for weighing the effectiveness of reduction strategies (Table 9-1.) Changes in emissions from both enteric fermentation and manure management practices were projected. This was done by multiplying 1987 animal population statistics

by population growth coefficients to determine herd sizes for the two years in question. A default annual growth coefficient of 1.5% was applied all to populations except dairy cattle, which are estimated to decline at a rate of 1.5% annually. A growth rate of 0.0% was used for the swine population, to account for an ongoing moratorium on hog production. These projections were then multiplied by enteric CH<sub>4</sub> emissions/head/appropriate year to determine the amount of enteric manure emissions or manure management based emissions/head/appropriate year to determine manure-management-based emissions.

Annual emissions per head coefficients came from *The North Carolina Greenhouse Gas Emissions Inventory for 1990* (Appalachian State University 1996). These were derived using a detailed methodology developed by the USEPA (1993). Regional enteric emissions factors were then calculated and entered into the following equation to yield enteric emissions in tons of CH<sub>4</sub>.

$$\text{Methane emissions (tons)} = \text{animal population (head)} * \text{regional emissions factor (lbs CH}_4\text{/head)/2000 lbs CH}_4\text{/ton CH}_4$$

CH<sub>4</sub> emissions from animal manure were determined by first calculating the amount of volatile solids (VS) produced. Volatile solids are the organic portions of manure consumed by the microorganism methanogen, which produces CH<sub>4</sub> and carbon dioxide rich gas. Once annual volatile solids and typical animal mass (TAM) were identified, they were applied to the following equation:

$$\text{Total VS produced (lbs/yr)} = \text{animal population (head)} * \text{TAM (lbs/head)} * \text{VS (lbs VS/lb animal mass/yr)}$$

Forecast results are shown in Table 9-1. They indicate a 5,855-ton increase in methane produced by enteric fermentation and a 2,586-ton increase in methane attributed to manure management practices. These figures add up to a total estimated methane increase of 8,440 tons between 1990 and 2010. Changes in beef and dairy cattle emissions (influenced by changing herd sizes) have the greatest impact on the predicted growth of methane emissions. Table 9-1 shows that beef cattle are responsible for an estimated 7,333-ton increase in methane emissions, while dairy cattle are responsible for a 1,613 ton decrease in emissions from 1990-2010.

Based on CH<sub>4</sub> projections, several emissions reduction strategies were modeled using Torrie-Smith Associates software to better quantify their emissions reduction potential. These and the modeling assumptions behind them are outlined in the discussion of general strategies, as are measures that could not be modeled due to the nature of data.

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**Table 9-1: Agricultural Methane Emissions Forecast 1990-2010**

Animal Type	Enteric Fermentation (tons of methane)		Manure Management (tons of methane)		GRAND TOTAL	
	1990	2010	1990	2010	1990	2010
<b>Beef</b>						
Calves	4,292	4,981	170	197	4,462	5,179
Beef heifers	7,864	9,126	210	243	8,073	9,370
Steers	4,910	5,698	131	152	5,040	5,850
Beef Cows	25,817	29,962	921	1,068	26,738	31,030
Bulls	2,799	3,248	101	117	2,899	3,365
<b>Subtotal</b>	<b>45,682</b>	<b>53,015</b>	<b>1,532</b>	<b>1,778</b>	<b>47,213</b>	<b>54,793</b>
<b>Dairy</b>						
Dairy Heifers	2,717	2,336	2,550	2,193	5,268	4,529
Dairy Cattle	8,787	7,554	5,698	4,899	14,485	12,453
<b>Subtotal</b>	<b>11,504</b>	<b>9,891</b>	<b>8,249</b>	<b>7,092</b>	<b>19,753</b>	<b>16,982</b>
<b>Other</b>						
Sheep	146	169	8	9	153	178
Goats	49	57	5	6	55	63
Pigs	4,203	4,203	303,321	303,321	307,524	307,524
Horses	620	720	430	499	1,050	1,219
Mules and Asses	23	26	9	10	31	36
<b>Subtotal</b>	<b>5,041</b>	<b>5,175</b>	<b>303,773</b>	<b>303,845</b>	<b>308,813</b>	<b>309,020</b>
<b>Poultry</b>						
Layers	0	0	9,998	11,603	9,998	11,603
Broilers	0	0	7,239	8,401	7,239	8,401
Ducks	0	0	0	0	0	0
Turkeys	0	0	0	0	0	0
<b>Subtotal</b>	<b>0</b>	<b>0</b>	<b>21,331</b>	<b>24,755</b>	<b>21,331</b>	<b>24,755</b>
<b>TOTAL</b>	<b>62,226</b>	<b>68,081</b>	<b>334,884</b>	<b>337,470</b>	<b>397,111</b>	<b>405,550</b>
<b>Total As eCO<sub>2</sub></b>	<b>1,306,753</b>	<b>1,429,698</b>	<b>7,032,572</b>	<b>7,086,877</b>	<b>8,339,325</b>	<b>8,516,575</b>

To summarize, agriculture was responsible for 9.53 megatons of eCO<sub>2</sub> in 1990. The business-as-usual forecast to 2010 shows agriculture may be responsible for annual emissions of 10.99 megatons. With the strategies proposed below, this sector could be responsible for reducing total eCO<sub>2</sub> by 199,610 tons, a savings attributable mostly to the capture and combustion of CH<sub>4</sub> from animal waste.

**Emissions Reduction Strategies**

While there is room for emissions reduction in numerous agricultural practices, improvements in North Carolina’s farming energy efficiency, CH<sub>4</sub> management/recovery, and fertilizer management have the greatest potential for overall emissions reduction. This section will explore the effectiveness of these three main sets of strategies, with emphasis placed on CH<sub>4</sub> management and recovery. The research structure is as follows:

1. Strategy: Increase usage of energy efficient farming practices
2. Strategy: Increase usage of CH<sub>4</sub> management and recovery systems at swine and cattle production facilities
3. Strategy: Implement Best Farm Management Practices

***Strategy: Increase Usage of Energy Efficient Farming Practices***

The potential for reducing GHG emissions through increasing the energy efficiency of farms is one of the most difficult agricultural strategies to assess. This, in part, is due to a lack of state-level agricultural energy use data. Also, there is a long list of possible energy efficient adoptions that farmers might use, most of which individually involve relatively small amounts of GHG reductions. Many family farms operate with low fiscal margins and dated equipment. Such farms may find it very difficult to adopt new electric motor technology, for example. On the other hand, new farms and corporate farms are more likely to have the financial resources to implement the latest technologies.

In an effort to assess the potential impacts of this general strategy, the authors estimated that only about 3% of North Carolina's total farm energy use could realistically be saved by the adoption of new technologies before year 2010. It should be noted that this figure excludes the use of CH<sub>4</sub>-based biofuels, which are discussed in the CH<sub>4</sub> management and recovery section of this chapter. This reduction was not modeled using the Torrie-Smith Associates model. Without base estimates of agricultural energy use, an approximate 3% reduction has little specificity.

Two areas with strong potential for conservation of non-renewable energy sources include the substitution of gasoline and diesel fuels by fuel alcohol produced from agricultural crops or wastes and the substitution of solar energy for fuel oil and LP gas use in crop drying and tobacco curing. Ethanol production, especially from aflatoxin afflicted corn, has great potential to replace diesel and gasoline fuels. This substitution seems an attractive option for North Carolina since the state imports all of its fossil fuels and there is a sufficient amount of corn available for ethanol production. Other areas with strong potential for energy conservation include renewable energy based water heating and space heating of broiler houses, animal shelters, and greenhouses (Goswami 1975).

In North Carolina, the most commonly used forms of energy on farms include gasoline, diesel fuel, fuel oil, LP gas, electricity, natural gas, and coal. Farming practices with the greatest overall energy demands include farm machinery and automobiles utilizing gasoline and diesel fuels, and tobacco, grain, and peanut drying/curing. Fuel oil and LP gas are commonly used for drying/curing. Coal, natural gas and LP gas are used in broiler production, while livestock production operations requiring the greatest amount of energy (gasoline, diesel, and LP gas) include mechanical feed handling and waste disposal, automobiles, and space and water heating (Goswami 1975).

Modifications of existing crop drying equipment to utilize solar energy would in the long run cut farm energy costs and emissions. Costs of new equipment could be partially offset by the state's current tax credit program for the purchase of solar equipment. Farming machinery and automobiles could also be retrofitted to utilize ethanol gas, thus cutting fossil fuel based emissions and providing a productive use for crop wastes and spoiled crops. Corn, wheat, milo, barley and spoiled crops can be transformed into ethanol. It is estimated that only about 15-20 acres of corn are needed to produce enough of the fuel to meet liquid fuel demands for the average-sized farm (158 acres) in North Carolina (Goswami 1975). However, without government incentives, such as tax breaks, farmers may be less apt to implement this strategy, since the utilization of 10-15 acres for ethanol productions would take up approximately 10% of their lands. Use of crop wastes and spoiled crops to produce ethanol may help offset this figure proportionally.

***Strategy: Increase Usage of Methane Management and Recovery Systems***

Decomposing livestock manure produces numerous pollutants, including CH<sub>4</sub> emissions, ammonia, excess nutrients, and pathogens, as well as biochemical oxygen demand (BOD). In addition to emitting greenhouse gasses, they lead to pollution problems such as surface and ground water contamination, odor, dust, volatile organic acids, and ammonia. CH<sub>4</sub> recovery – also termed biogas – systems are becoming an increasingly attractive option for alleviating these problems (USDOE 1995).

Since it is estimated that less than 1% of North Carolina farms practice any form of CH<sub>4</sub> recovery, there is considerable room for expansion of agricultural waste management practices (Backman 1999). Most farmers have avoided implementing CH<sub>4</sub> recovery systems due to the high capital costs involved. However, government incentives, such as tax credits or subsidies, could help further encourage more efficient management of agricultural waste (Vignette 9-1).

Beef and dairy cattle are the state's leading CH<sub>4</sub> producers. In 1987, beef cattle produced an estimated 55.2% of North Carolina's CH<sub>4</sub> emissions, while dairy cattle emitted an estimated 31.85%. This figure represents emissions from both enteric fermentation and manure management. It is estimated that in the year 2010, dairy cattle will produce a total of 16,983 tons of CH<sub>4</sub>, while beef cows will emit 54,793 tons.

Pork production is the top agricultural economic enterprise in North Carolina. Among domesticated animals, hogs are the second largest producers of CH<sub>4</sub> emissions, next to cattle. In 1990, hogs accounted for 11.12% of North Carolina's agricultural CH<sub>4</sub> emissions (Appalachian State University 1996). Swine facilities are estimated to produce 20% of the state's total atmospheric nitrogen compounds, since in accordance with the design of lagoons and sprayfield systems, approximately two-thirds of the nitrogen in swine excretions can be emitted into the air (NCDENR 1999). North Carolina houses 2,400 major swine production facilities with 4,000 active and 650 inactive anaerobic lagoons (NCDENR 1999). While the number of swine farms fell from nearly 70,000 in

1970 to fewer than 5,000 in 1999, the State’s hog population tripled. Currently, North Carolina’s hog population is 9.9 million. An ongoing moratorium on hog production has kept swine populations capped at between 9.9 and 10.3 million head for several years. The moratorium, prompted by pollution concerns, will remain in effect until waste management issues are better addressed. It is estimated that in 2010 the annual amount of CH<sub>4</sub> produced by swine in North Carolina will be 307,524 tons.

<b>Vignette 9-1: Federal and State Methane Management Initiatives</b>
Currently, there are no formal federal regulations targeting CH <sub>4</sub> reductions. However, government agencies, such as the U. S. Environmental Protection Agency (USEPA), Department of Energy (USDOE), and Department of Agriculture (USDA) are researching a plethora of options for reducing CH <sub>4</sub> emissions, including capture and recovery systems. These agencies jointly sponsor the AgSTAR program, which encourages the use of CH <sub>4</sub> recovery (biogas) technologies at confined animal feeding facilities. The program provides farmers with the tools and guidance needed to determine the financial and environmental profitability of systems, based on choice of technology, operational characteristics, and finances (AgSTAR 1999)
CH <sub>4</sub> management is also becoming an important topic for North Carolina’s politicians and farmers, especially in regards to the state’s swine industry. Governor James Hunt is currently implementing an anaerobic swine lagoon conversion plan across the state for the purpose of converting sprayfields and inactive lagoons to new technologies. A technology panel created in July of 1999 will identify these. The group will work with other committees to write performance and technology standards for new swine waste management practices. Under the plan, all inactive lagoons will be tested and rated by the North Carolina Department of Environment and Natural Resources (NCDENR) to determine their risks to public health and the environment. This plan is one of the state’s first formal initiatives to manage swine waste.

**Background.** The term “CH<sub>4</sub> recovery” refers to the capture of CH<sub>4</sub> for conversion to CH<sub>4</sub>-rich biogas from the anaerobic digestion of animal manure. While conversion to biogas offers the added benefit of energy reduction through fuel substitution for electricity or liquid petroleum gas, simply capturing and flaring off CH<sub>4</sub> can also effectively reduce emissions. Digesters, which generally involve equipment such as generators, are used for the capture, recovery, and conversion of CH<sub>4</sub>. CH<sub>4</sub> digesters are airtight reactors in which biogas is produced from the anaerobic digestion of organic plant and animal materials by bacteria. They are usually designed to run in mesophilic temperature ranges (20°C to 45°C/68°F to 113°F), or thermophilic temperature ranges (45°C to 60°C/113°F to 140°F). Higher temperatures increase the potential loading rate of organic materials and speed the process. Also, higher temperatures help better destroy pathogens that exist in raw manure (U.S. Department of Energy 1995).

The use of enclosed digesters for manure management reduces odor and BOD levels, which can cause surface water contamination. The potential for ground and surface water

contamination is further reduced by the conversion of organic nitrogen to ammonium compounds through digestion. Several digester technologies exist, most of which differ in the solidity of the manure they handle (Vignette 9-2).

<b>Vignette 9-2: Comparison of Three Digester Technologies</b>
<p><b>Covered Lagoons.</b> Covered lagoons are used to treat liquid manure with less than 2% solids for conversion to biogas. Covers are used to keep manure under anaerobic conditions. This helps control odors and alleviates CH<sub>4</sub> emissions. Large lagoon volumes, preferably depths of at least 12 feet, are required for more effective for CH<sub>4</sub> recovery. A variety of materials can be used to cover lagoons, ranging from polyethylene to beer bottles or yard scraps (USEPA 1997a). Typical lagoon covers cost \$0.40-1.00 per square foot, or up to \$40,000 to install by themselves. They can be applied to any size of lagoon or even portions of a lagoon to help reduce CH<sub>4</sub> emissions and odor. Lagoon covers without generators are used to capture and flare off emissions. While this does not produce the added benefit of biogas production, it is an effective way to reduce emissions and control odor.</p>
<p>To produce biogas, lagoons must be equipped with engine generators. Capital costs for this type of system run, on the low end, around \$200,000. (Approximately \$1.00/square foot; \$50,000 for a typical lagoon, \$25,000 for piping instruments, and at least \$100,00 for a 100 kW engine/generator). After this initial investment, annual operating costs average less than 5% capital costs. The payback period for covered lagoons is approximately 5-10 years. As with all CH<sub>4</sub> recovery systems, on-farm use of the electricity generated from CH<sub>4</sub> recovery helps offset capital and maintenance costs. (USDOE 1995).</p>
<p><b>Complete Mix Digesters.</b> Complete mix digesters are used to treat slurry manure with 3-10% solids on swine and dairy farms. One benefit of these heated digesters is that they require less space than covered lagoons. Manure, which is mixed mechanically and kept at a constant volume, is collected in a mixing pit where % total solid is adjusted and, if necessary, heated. Manure travels from the mixing pit to the digester via a gravity-flow or pump system. An airtight digester cover traps CH<sub>4</sub> and keeps it under anaerobic conditions. Gas is collected through a pipe. Of the gas obtained, the quantity of CH<sub>4</sub> collected is about 5-8 ft<sup>3</sup>/lb volatile solids (or 8-11% of the total manure) (USEPA 1997a).</p>
<p>Most of the electricity needed to run a livestock farm can be produced by a complete mix digester equipped with an engine generator. Thus, these digesters are an effective way of offsetting farm energy costs. Capital costs for a complete mix digester start at about \$150,000, with maintenance costs running about 5-10% of capital costs.</p>
<p><b>Plug Flow Digesters.</b> Plug flow digesters are used to treat scraped dairy manure with 11-13% solids. Swine manure is not fibrous enough to be handled by these systems. These digesters are typically designed as long tanks. Tank volume is determined by multiplying</p>

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the volume of daily manure input (plug) by the manure retention time (15-20 days). Plug flow digesters also contain manure collection systems, mixing pit equipment, and effluent storage. Manure is collected daily in the mixing pit where the total solids concentration can be adjusted. It is then added to the tank, where new “plugs” push older manure down through tank (USEPA1997b).

Plug Flow digesters can cost about \$150,000-300,000, with annual operating expenses of up to at least \$15,000. An added benefit to these digesters is the ability to separate and compost digested solids for further treatment. Once composted, the byproducts can be mixed and sold off as soil additives (USEPA1997-2)

\*It should be noted that systems at larger facilities with greater energy loads are more cost effective for all CH<sub>4</sub> recovery systems, since they can generally better utilize the energy produced.

**Modeling methodology.** According to the North Carolina Energy Division, North Carolina swine and dairy farms can economically recover 1.5 trillion Btu of biogas annually. On these farms, it is estimated that owners could collectively recoup \$7 million in equivalent liquid petroleum gas (LPG) value. Torrie-Smith Associates software was used to model emissions reductions from: 1) The capture of CH<sub>4</sub> from digester usage and 2) The substitution of electricity for the amount of biogas produced. Substitution to electricity was Modeled rather than conversion to LPG, due to its greater emissions reduction potential.

One of the most efficient ways to utilize CH<sub>4</sub> is to capture it and combust it to generate electricity. During the modeling process for this scenario, it was assumed that 1 Btu of CH<sub>4</sub> is equivalent to 1 Btu of natural gas. We also assumed a 33% level of efficiency in converting biogas to electricity. Therefore, for the fuel switching measure, an emissions reduction of 500 billion Btu was converted to eCO<sub>2</sub>, so that we could evaluate this strategy's reduction of GHG.

**Results.** Modeling these measures indicates that CH<sub>4</sub> recovery and conversion to biofuels are extremely effective in reducing greenhouse gas emissions. The capture of CH<sub>4</sub> through digester technologies alone equates to an emissions reduction of 86,610 tons eCO<sub>2</sub> by the year 2010. Fuel switching to the 500 billion Btu's of electricity recovered prompts an additional savings of 113,000 tons eCO<sub>2</sub>. It should be kept in mind that the 1.5 trillion Btu CH<sub>4</sub> recovery potential reported by the Energy Division is a conservative estimate, as it is based on the amount of CH<sub>4</sub> farms can “economically recover” (North Carolina Energy Division circa 1990s). If government subsidies, tax credits, or other initiatives could be used to make implementation of such measures more economical for farmers, emissions reduction potentials could increase considerably.

***Strategy: Implement Best Farm Management Practices***

There are many very worthwhile measures that fit under this strategy, but their emissions reduction potentials are very difficult to model because adoption rates depend upon many unknowns, including cost, education, further technological development and others. Consequently, we list them here in order to call special attention to them and to acknowledge their increasing potentials.

**Compost wastes to reduce methane emissions.** It is common knowledge that most North Carolina farmers compost, but what materials and to what extent this is practiced is unknown. One recent and growing trend is the composting of dead animals. The North Carolina Veterinary Office currently issues permits for the composting of poultry and pigs. The animals are typically layered with a carbon source, such as wood shavings or peanut hulls, and turned after the first decomposition heat (about 10 days for poultry). Generally, by the end of the second heat, poultry are entirely decomposed except for bones. This composting process actually kills pathogens carried by the animals. The total decomposition process takes about 20 days for poultry, but can last a few months for pigs due to their greater body mass (Barker 1999).

North Carolina State University has patented a machine that grinds up carcasses of dead animals and adds both carbohydrates and bacteria or phosphoric acid to the resulting material during the process. These additives preserve the material, allowing for its storage. This substance may then be used as a fertilizer or as an ingredient in animal feeds. The university has licensed the technology to a firm that builds the machines and adds the necessary ingredients to the resulting substance. Plans are underway for the construction of a processing plant that would buy and process the material for use in animal feeds (Caldwell 1998.)

Another trend is the separation of swine and dairy waste solids from liquids for composting. These solids yield nutrient-rich fertilizers. Many farmers are taking advantage of the lucrative sale of such fertilizers. Approximately one-fourth to one-third of swine and dairy formers are moving to some form of solids separation (Barker 1999).

**Improve fertilizer and lime management techniques.** Farmers would be most apt to implement strategies to lower emissions if they would increase their bottom line profits. Government incentives/aid of some sort is needed to prompt such efforts.

Nitrogen applications to crops should be split applications to prevent the nutrient from leaching into soils. It should be noted that nitrogen is an essential nutrient for plants that cannot be stored in soils long-term due to leaching. According to Bollick (1999), North Carolina's farmers are proficient in using the necessary amount of nitrogen for their crops. The North Carolina Department of Agriculture currently regulates agronomic rates of manure applications and sets guidelines for nitrogen and lime applications. Such regulations and suggested standards depend on factors including land area and types of crops grown (Bollick 1999).

Soil tests are extremely beneficial to farmers since they quantify the types and amounts of nutrients present in soils and needed to support various crops. Only about 25 % of North Carolina farmers actually test their soils. Soil tests are done for free by the North Carolina Department of Agriculture in Raleigh. However, due to the backlog of soil samples, it can take up to two months for tests to be run. Private companies generally have faster turn-around rates. Commercial test sites generally charge \$8-18 per sample. A range of 8-20 samples is typical per 100 farm acres (Bollick 1999).

Another, newer, method of determining fertilizer needs is the use of combines suited with Global Positioning System (GPS) units. This instrument helps determine the spatial patterns of crop yields. When checked against photographs and infrared imagery gathered from aerial flyovers, fertilizer needs may be determined (Bollick 1999).

**Conservation tillage.** The term conservation tillage applies to environmentally friendly planting methods that help soils retain nutrients after completion of the planting process. Tillage systems that keep a minimum of 30% crop residue after planting are considered to be no-till (USEPA 1999). In this method, seeds are placed into an existing field coverage, such as a cut hay field or harvested corn field. Soils outside of seedbeds are not disturbed except for fertilizer applications.

While already widely practiced in North Carolina, conservation tillage should be noted as an important strategy for reducing on-farm energy use and labor, erosion, and nutrient loss in soils. It is estimated that no-till systems can minimize erosion by up to 93%, pesticide and water runoff by 70%, and phosphate runoff up to 81%. Currently, about 80% of North Carolina's farmers use conservation tillage practices. The fact that the same machinery (planter) can be used for both till/no-till applications makes these practices popular (Bollick 1999). Farmers benefit greatly from no-till planting because it greatly reduces their commercial fertilizer purchases and applications and thus lowers fuel usage. However, the extent to which farmers can benefit financially from conservation tillage practices has yet to be assessed.

Almost any crop can be grown no-till (ridge-till or mulch till) provided that seasonal crops are rotated with off-season crops. In eastern North Carolina, a popular practice is to rotate corn, wheat, and soybean crops (Bollick 1999). Crop residues must be maintained on the soil surface throughout all parts of the year to conserve soil and allow for maximum moisture entry and storage in crops. Because this coverage increases crop susceptibility to weeds, insects, and plant disease, precision planting and placement of fertilizer are essential (Agricultural Research Service 1982).

## **Conclusion**

The non-energy portion of the agriculture sector emitted 7% of North Carolina's GHG gases in 1990, or 9.53 megatons. By year 2010, under a business as usual scenario, this sector would be generating 10.99 megatons of eCO<sub>2</sub>. In order to meet its goal of 93% of its 1990 emissions by year 2010, this sector should achieve a reduction of 0.2 megatons.

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However, this goal may be very difficult for agriculture to achieve, based only on non-energy production of eCO<sub>2</sub>.

Table 9-2 shows the reductions of emissions possible from the three agriculture sector strategies selected. Of the possible strategies, these three held the greatest potential for reducing GHG emissions in this sector. The combustion of CH<sub>4</sub> from animal waste to substitute for fossil fuel-generated energy produced slightly more emissions savings (113,000 tons) than the capture of the CH<sub>4</sub> from animal waste lagoons (86,610 tons). Achievement of significant non-energy GHG reductions from the agriculture sector, compared to most other sectors, is difficult. For example, CH<sub>4</sub> produced directly by animals or that produced in waste lagoons is closely related to numbers of animals.

Reducing agricultural GHG emissions by increasing energy efficiencies of farms is, at best, a long-term process. Adoption of new, more efficient technologies before year 2010 may be able to save less than 3% of on-farm energy, a figure that is very difficult to model.

The non-energy agriculture sector contains several ways to reduce eCO<sub>2</sub> emissions. The capture of CH<sub>4</sub> from animal waste lagoons and combustion of the biogas for energy hold the greatest promise as a strategy, which could potentially meet more than 199,000 tons of reduction by 2010. Other important applications of improved farming practices, particularly in the applications of nitrogen fertilizer and lime, can also achieve significant results in this sector, but these are very difficult to model.

Small farmers' profit margins and numbers of animals, however, are not sufficient to afford new, energy efficient technology or the necessary CH<sub>4</sub> recovery technology. This "catch 22" situation means that GHG reduction technology adoption rates are relatively low in the agriculture sector.

**Table 9-2: Emissions Impacts from Mitigation Strategies - Agriculture**

Strategies	Reductions	
	eCO <sub>2</sub> (Megatons)	Percent of Total
Increase Energy Efficiencies	0.1	0.1
CH <sub>4</sub> Management and Recovery Systems	0.08	0.1
Best Farm Management Practices	Unknown	Unknown
<b>Total</b>	<b>0.18</b>	<b>0.2</b>

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