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Agriculture, Forestry, and Waste Management Technical Work Group

Summary List of Recommended Priority Policy Options for Analysis

Option No.	Policy Option			GHG Reductions (MMtCO$_2$e)			Net Present Value 2008–2020 (Million $)	Cost-Effective-ness ($/MtCO$_2$e)	Level of Support
				2012	2020	Total 2008–2020			
AFW-1	On-Farm Energy Efficiency								Pending
AFW-2	On-Farm Waste Energy Recovery	Swine and Dairy Manure		0.06	0.20	0.1	0.58	4.6	Pending
		Poultry Litter		0.01	0.03	0.2	3.2	15	
AFW-3	Expanded Use of Local Agricultural Products								Pending
AFW-4	In-State Liquid Biofuels Production	Biodiesel -based on in-state feedstock supply		0.12	0.13	1.5	25.7	17	Pending
		Ethanol -lower limit production goal		0.86	3.80	12.8	297	15	
AFW-5	Expanded Production of In-State Biomass for Electricity, Heat, or Steam Production			2.73	4.88	40.5	737	18	Pending
AFW-6	Terrestrial Carbon Sequestration	(a) Agriculture							Pending
		(b) Forestry	Forest Management	0.86	2.22	15.2	139	9	
			Afforestation / Reforestatoin	0.81	2.44	15.8	158	10	
			Urban Forestry						
AFW-7	Conservation and Restoration of Forest and Agriculture Lands for Enhanced Carbon Sequestration	(a) Agriculture		0.04	0.21	0.8	30	36	Pending
		(b) Forestry		0.80	5.78	24.9	159	6.39	Pending
AFW-8	Advanced Recycling and Composting			1.18	3.01	20.1	-44	-2	Pending
AFW-9	Organics Management for Energy Recovery			0.41	1.05	7.2	0	0	Pending
AFW-10	Water and Wastewater Energy Efficiency Improvements			0.16	0.19	1.6	-32	-20	Pending

	Sector Total After Adjusting for Overlaps						
	Reductions From Recent Actions						
	Sector Total Plus Recent Actions						

AFW-1. On-Farm Energy Efficiency

Policy Description

Renewable energy may be produced and used on-site at individual agricultural operations or regionally through farm cooperatives to achieve better economy of scale. For example, on-farm production and use of solar heating and biofuels will reduce carbon dioxide emissions by displacing the use of fossil based fuels.

Energy conservation for agricultural operations will result in increased efficiency. For example, improved irrigation systems save both water and energy, and expanded use of precision agriculture systems will also result in reduced fossil fuel usage.

GHG benefits can also be achieved indirectly through better use of organic fertilizers (manure) to offset commercial fertilizers, which require intensive energy inputs for production, transportation and application. These indirect (lifecycle) benefits are covered within option AFW-6a (soil carbon management).

Policy Design

Goals:

Fossil fuel reduction goal: 20% reduction in petro-diesel use by 2020, over 2007 baseline.

Electricity reduction goal: 30% reduction, including both electricity efficiency and on-site generation using renewable energy, over 2007 baseline.

Timing:

Fossil fuel reduction goal: Achieve 5% reduction by 2012. Achieve the full policy goal by 2020.

Electricity reduction goal: Achieve 10% reduction by 2012. Achieve the full policy goal by 2020.

Parties Involved: SC Department of Agriculture; SC DNR – Conservation Districts; SCDHEC; SC Energy Office; Clemson University – Cooperative Extension Service; USDA – Natural Resources Conservation Service; USDA – Rural Development; SC Farm Bureau; Businesses providing energy efficiency and renewable energy equipment and services.

Other: As needed, identify incentives that encourage the energy reductions through audits, maintenance, equipment modification, and developing feedstocks and availability of renewable energy.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

TBD – No recent policies or programs have been identified as of yet. The TWG and DHEC can work with CCS to identify existing or planned programs that address issues raised in this option.

Type(s) of GHG Reductions

Displacement of coal, natural gas, and other fossil fuels reduces emissions of fossil carbon. Increased energy efficiency decreases the amount of carbon emitted per unit of economic productivity. On-farm capture or production of renewable energy reduces the need for consumption of fossil energy, and displaces the associated fossil carbon emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources: Consumption of distillate fuel by the agriculture sector in South Carolina is projected from historical data provided by the Energy Information Administration (EIA).[1] The petro-diesel emissions factor used is consistent with the South Carolina I&F (10.07 $MtCO_2e$/1,000 gal). The agricultural sector electricity consumption was derived from the National Agriculture Statistics Service (NASS)[2] and historical electricity prices from the EIA.[3] The cost-effectiveness estimates are based on various sources throughout the literature. Data and case studies specific to South Carolina were used whenever possible.

Quantification Methods:

GHG Benefit

The quantification of the GHG benefits of this option will follow the following process:

- Establish the baseline on-farm petro-diesel and electricity usage. Data for diesel consumption are directly available from the EIA. Electricity usage is estimated based on expenditure and price data.
- Use lifecycle emission factors consistent with those used with the SC I&F for diesel and electricity to estimate the GHG reduction achieved through the goals set forth by this option.

Cost Effectiveness

The quantification of the cost effectiveness of this option will follow the following process:

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[1] Energy Information Administration. “South Carolina Total Distillate Sales/Deliveries to Farm Consumers.” 1984–2005. Accessed on January 18, 2007, at http://tonto.eia.doe.gov/dnav/pet/hist/kd0vfmssc1a.htm.

[2] National Agricultural Statistics Service. “Colorado Agriculture: A Profile.” 2005 data. Accessed on August 20, 2007. Not yet retrieved.

[3] Energy Information Administration. “Current and Historical Monthly Retail Sales, Revenues, and Average Retail Price by State and by Sector (Form EIA-826).” Not yet retrieved.

- Calculate cost savings realized from reduction in consumption of diesel fuel and electricity.
- Add cost of incentive and/or education program needed to implement goals (need TWG input).
- Add cost of agriculture energy audit (need TWG input).
- Add additional annual cost of new equipment and/or upgrades of current equipment. This will require a breakdown of how much energy is used on specific farm practices in SC (need TWG input).

Key Assumptions: [TBD, as needed on TWG approval]

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-2. On-Farm Waste Energy Recovery

Policy Description

Reduce the amount of methane emissions from livestock manure by installing manure digesters on livestock operation. Reduce the amount of excess nitrogen applied to crops from poultry litter by promoting gasification, pyrolysis and other thermochemical conversion methods for energy recovery. Energy from manure digesters is used to create heat or power, which offsets fossil fuel-based energy production and the associated GHG emissions. Thermochemical conversion and other methods of waste-to-energy may be more advantageous than anaerobic digestion. Energy from these processes will also reduce the GHG emissions and may be used to produce synthesis gas and hydrocarbon fuels. As with AFW-1, these energy recovery projects can be implemented at individual livestock operations or collectively at groups of operations in order to achieve better economies of scale.

Policy Design

Goals: Reduce 15% of the GHG emissions from animal feeding operations (AFOs) through methane capture (anaerobic digestion), thermochemical conversion, or other renewable energy means.

Timing: By 2012, implement projects to capture 5% of available methane energy at hog farms and dairies, and 5% of surplus litter at poultry and turkey farms. By 2020, implement projects to capture 15% of methane energy and 15% of litter.

Parties involved: SC Department of Agriculture; SC DNR – Conservation Districts; SCDHEC; SC Energy Office; Clemson University – Cooperative Extension Service; USDA – Natural Resources Conservation Service; USDA – Rural Development; USDA – Agricultural Research Service; SC Farm Bureau; hog, dairy, and poultry farmers; Businesses providing energy efficiency and renewable energy equipment.

Other: As needed, identify incentives that encourage the renewable energy production on all AFOs in SC. Determine the optimal technologies and management methods from perspective of on-farm economics and GHG mitigation/reduction. Digester economics may improve with additional feedstocks beyond manure, including spoiled or culled produce and other agricultural residues. Note the potential linkage to AFW-9, which addresses energy recovery from municipal solid waste.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

The USDA-Agricultural Research Service is conducting research on thermochemical waste-to-energy from animal manures for AFO waste streams. The State Energy Office has conducted analyses quantifying animal waste in South Carolina.

Type(s) of GHG Reductions

CH_4: methane is captured and typically combusted in an energy recovery system or flared. Small amounts of N_2O and CO_2 are emitted from the combustion process.

CO_2: carbon dioxide is reduced when the methane is converted to energy and that energy is used to offset fossil-based energy (e.g., coal-fired electricity, natural gas, etc.). Small amounts of N_2O and CH_4 are also reduced from the fossil-based energy that is offset.

N_2O: By avoiding land-application of surplus litter, nitrous oxide emissions are reduced by poultry-litter-to-energy installations. (Under wet conditions, excess nitrogen in soils increases the microbial reactions that release N_2O.)

Also, displacement of coal, natural gas, and other fossil fuels reduces emissions of fossil carbon. Increased energy efficiency decreases the amount of carbon emitted per unit of economic productivity. On-farm capture or production of renewable energy reduces the need for consumption of fossil energy, and displaces the associated fossil carbon emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources:

Final Report on Availability of Poultry Litter as Biomass Energy, http://www.scbiomass.org/Publications/Poultry%20Litter%20Final%20Report.pdf (416 k PDF) “It is estimated that between 400,000 and 700,000 tons of poultry and turkey litter are produced per year.”

Beddoes, Bracmort, Burns and Lazarus (2007) *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*, NRCS, Technical Note No. 1, October 2007.

Additional data sources are cited in the quantification methodology below.

Quantification Methods:

GHG Benefits from Manure

Methane emissions (in MMt CO2-e) data from the South Carolina Agriculture Inventory and Forecast was used as the starting point to estimate the GHG benefits of capturing and controlling the volumes of methane targeted by the policy. The available methane was also used to calculated the additional benefit of electricity generation using this captured methane (through offsetting fossil-based generation). The first portion of GHG benefit was obtained through reduced methane emissions through the capture of emissions from manure. An assumed collection efficiency of

75%[4] was applied to methane emissions from animal manure which was then multiplied by the assumed policy target ramping up to achieve 15% collection by 2020.

The second portion of the GHG benefit is through the offsetting of fossil-based electricity generation. This was estimated by converting the captured methane in each year to its heat content (in BTUs) and then multiplying by an energy recovery factor of 17,100 BTU/kWh to estimate the electricity produced (assumes a 25% efficiency for conversion to electricity in an engine and generator set). The CO_2e associated with this amount of electricity in each year was estimated by multiplying the Megawatt hours (MWh) by the South Carolina-specific emission factor for electricity production from eGRID (0.415 Mt/MWh).

The total GHG benefit was estimated as the sum of both portions of the benefit described above and indicated in Table X.

Table X: GHG Benefits from Dairy and Swine

Year	Methane Emissions From Dairy, and Swine (MMt CO_2-e)	Policy Utilization objective	Methane Captured and Utilized under policy (MMt CO2-e)	Million Metric Tons of Methane	Methane (million BTUs)	CO2e Offset as Electricity(Metric Tons)	Total Emission Reductions (MMt CO2-e)
2008	0.152	1%	0.001	0.000	2,854	69	0.001
2009	0.154	2%	0.002	0.000	5,790	141	0.002
2010	0.156	3%	0.004	0.000	8,808	214	0.004
2011	0.157	4%	0.005	0.000	11,792	286	0.005
2012	0.157	5%	0.006	0.000	14,800	359	0.006
2013	0.158	6%	0.007	0.000	18,575	451	0.008
2014	0.159	8%	0.009	0.000	22,379	543	0.009
2015	0.159	9%	0.010	0.000	26,213	636	0.011
2016	0.160	10%	0.012	0.001	30,118	731	0.013
2017	0.161	11%	0.014	0.001	34,064	827	0.014
2018	0.162	13%	0.015	0.001	38,049	923	0.016
2019	0.163	14%	0.017	0.001	42,075	1,021	0.018
2020	0.163	15%	0.018	0.001	46,141	1,120	0.020

Costs for Manure

The costs for this component were estimated using an analysis by Natural Resources Conservation Service (NRCS), *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*[5]. The production costs were assumed to be $0.11 per kWh for swine anaerobic digesters and $0.05 for dairy anaerobic digesters[6]. These costs are in 2006 dollars

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[4] 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).

[5] Beddoes, Bracmort, Burns and Lazarus (2007) *An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities*, NRCS, Technical Note No. 1, October 2007.

[6] It was assumed that the technology employed for both swine and dairy anaerobic digesters was covered anaerobic lagoon. Cost were obtained from table 1 of the NRCS paper sited above.

and assume a 30% thermal efficiency. The costs include annualized capital costs for the digester, generator, and Operation and Maintenance costs[7]. The value of electricity produced was taken from the all sector average projected electricity price for the Southeastern Electric Reliability Council from the EIA Annual Energy Outlook (see http://www.eia.doe.gov/oiaf/aeo/supplement/index.html). This price represents the value to the farmer for the electricity produced (as an offset of on-farm use) and is netted out from the production costs to estimate net costs.

Table X: Total GHG reductions and Net costs from dairy and swine manure

Year	Policy Utilization objective	Total Emission Reductions (MMt CO2-e)	Net Costs (2005$)
2008	1%	0.001	$ 4,792
2009	2%	0.002	$ 9,619
2010	3%	0.004	$ 14,459
2011	4%	0.005	$ 20,426
2012	5%	0.006	$ 27,209
2013	6%	0.008	$ 35,600
2014	8%	0.009	$ 43,980
2015	9%	0.011	$ 52,485
2016	10%	0.013	$ 59,994
2017	11%	0.014	$ 67,155
2018	13%	0.016	$ 74,367
2019	14%	0.018	$ 82,855
2020	15%	0.020	$ 91,217

Poultry Litter GHG Benefits

Similar to the use of swine and dairy manure, the poultry litter option has the potential to provide emission savings through two mechanisms: through the reduction of methane and through offsetting of fossil-based energy through the utilization of the poultry litter.

The reduction in methane emissions component was estimated through quantifying the reduced methane emissions (estimated from the SC inventory and forecast) from litter management of the poultry litter. An assumed reduction efficiency of 75%[8] was applied to methane emissions from poultry litter which was then multiplied by the assumed policy target ramping up to achieve 15% collection by 2020.

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[7] The economic analysis conducted for this publication does not include feedstock and digester effluent transportation costs. The technical note does not address the economics of centralized digesters where biomass is collected from several farms and then processed in a single unit.

[8] 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).

For the second component, it was assumed that the use of poultry litter for energy production at on-farm sites would occur through gasification rather than through direct combustion (including co-firing) or anaerobic digestion. This is based on *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production*[9] which indicated that anaerobic digestion "would be more difficult to implement on a small (on-site) scale" and "gasification at a small scale (100 kW) and medium scale (1 MW) is potentially economically viable compared to anaerobic digestion and combustion".

The assumed energy content of poultry litter is 4,600 BTU/lb and the assumed heat rate is 18,000 BTU/kWh[10]. A capacity factor of 80% was assumed to approximate the installed electrical capacity required. It was assumed that a litter capacity of 1000 tons/year was representative of large chicken broiler farms in South Carolina, which should be sufficient feedstock to supply an on-site 73 kW gasification electricity facility, assuming a capacity factor of 80%.

It was assumed that the energy produced would be offsetting emissions that would have otherwise been generated through the generation of electricity. The CO$_2$e associated with this amount of electricity in each year was estimated by multiplying the MWh by the South Carolina-specific emission factor for electricity production from eGRID (0.415 Mt/MWh). The resulting GHG emission savings is represented in table X below.

Table X: GHG Benefits from Poultry Litter

Year	Policy Utilization objective	Methane Reduced under policy (MMt CO2-e)	Tons of litter available for energy use	Energy Available (million BTUs)	Annual kW-hr Produced	CO2e Offset as Electricity (Metric Tons)	Total Emission Reductions (MMt CO2-e)
2008	1%	0.001	5551	51073	2,837,415	1,177	0.002
2009	2%	0.002	11103	102147	5,674,831	2,355	0.004
2010	3%	0.002	16654	153220	8,512,246	3,532	0.006
2011	4%	0.003	22206	204294	11,349,662	4,710	0.008
2012	5%	0.004	27757	255367	14,187,077	5,887	0.010
2013	6%	0.006	34697	319209	17,733,847	7,359	0.013
2014	8%	0.007	41636	383051	21,280,616	8,831	0.016
2015	9%	0.008	48575	446893	24,827,385	10,302	0.019
2016	10%	0.010	55515	510735	28,374,154	11,774	0.022
2017	11%	0.011	62454	574577	31,920,924	13,246	0.025
2018	13%	0.013	69393	638418	35,467,693	14,718	0.028
2019	14%	0.015	76333	702260	39,014,462	16,189	0.031
2020	15%	0.017	83272	766102	42,561,232	17,661	0.034

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[9] Flora and Riahi-Nezhad (2006) *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production*, Department of Civil and Environmental Engineering University of South Carolina, August 2006.

[10] The assumed energy content and heat rate were based on Flora and Riahi-Nezhad (2006) based on the gasification of poultry litter which is suggested to have the .

Poultry Litter Costs

The cost of production was assumed to be $0.0577 per kWh (in 2005 dollars). This was based on the gasification facility information in *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production* which provided a levelized cost of production in 2005 dollars (assumes 10 year timeframe and 10% rate of return). This production cost includes capital costs, operation and maintenance and litter cleanout. Also included in the cost analysis is the value of potential recovered ash. Transportation costs were excluded from the on-site system analysis.

The value of electricity produced was taken from the all sector average projected electricity price for the Southeastern Electric Reliability Council from the EIA Annual Energy Outlook (see http://www.eia.doe.gov/oiaf/aeo/supplement/index.html). This price represents the value to the farmer for the electricity produced (i.e. offsetting on-farm use) and is netted out from the production costs to estimate net costs.

The net cost of production was estimated by subtracting the price of electricity from the cost of production, illustrated in table X below.

Table X: Total GHG reductions and Net costs from Poultry Litter

Year	Policy Utilization objective	Annual kW-hr Produced	Total Emission Reductions (MMt CO2-e)	Net cost (production costs less retail price) (2005$)
2008	1%	2,837,415	0.002	$ (38,020)
2009	2%	5,674,831	0.004	$ (78,367)
2010	3%	8,512,246	0.006	$ (121,307)
2011	4%	11,349,662	0.008	$ (148,912)
2012	5%	14,187,077	0.010	$ (166,285)
2013	6%	17,733,847	0.013	$ (191,490)
2014	8%	21,280,616	0.016	$ (220,806)
2015	9%	24,827,385	0.019	$ (252,015)
2016	10%	28,374,154	0.022	$ (297,408)
2017	11%	31,920,924	0.025	$ (350,644)
2018	13%	35,467,693	0.028	$ (405,258)
2019	14%	39,014,462	0.031	$ (441,807)
2020	15%	42,561,232	0.034	$ (482,680)

Key Assumptions:

The assumed electricity price is the assumed value to the farmer for the electricity produced (to offset on-farm use).

It is assumed that the gas produced can be utilized on site. While the gas cannot be stored, it is assumed that sufficient opportunities exist to utilize the gas immediately.

Key Uncertainties

It is uncertain how willing and able farmers will be to develop on site projects (i.e. the technical expertise of farmers in energy utilization or electricity production). Flora and Riahi-Nezhad (2006) highlight that "in discussions within the Gaseous Fuels Committee within the South Carolina Biomass Council, it is anticipated that it would be difficult to convince poultry farmers to adapt energy generation on-site. Off-site cooperative and regional energy generating facilities may be more viable."[11]

In *Poultry Litter to Energy: Technical And Economic Feasibility*[12], Bock notes that poultry litter is a more challenging fuel than wood for several reasons including "that the nitrogen content is about 10 times higher in poultry litter than wood. This increases the potential for fuel NOx emissions and requires special measures to reduce these emissions. The sulfur content of poultry litter is more than 10 times higher than that of wood. High chloride levels, in conjunction to high alkali levels, increase the potential for particulate emissions, corrosion problems, and acid gas emissions, and requires special measures. Ash levels are much higher in poultry litter than in wood, requiring higher-volume ash-handling equipment and more attention to particulate removal, slagging, and fouling." These indicate that emission control measures may be more elaborate and more expensive on systems utilizing poultry litter compared to other feedstocks.

The future price of electricity will affect the analysis.

Additional Benefits and Costs

- If land application of poultry litter is not allowed, this technology will be a viable means to dispose of poultry litter.
- Possibilities of ash usage.

Feasibility Issues

- The public response to a perceived incinerator.
- The potential need for air pollution control devices.

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

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[11] Flora and Riahi-Nezhad (2006)

[12] Poultry Litter to Energy: Technical And Economic Feasibility, B. R. Bock, Ph.D. Principal Scientist TVA Public Power Institute

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-3. Expanded Use of Local Agricultural Products

Policy Description

Promote the production and consumption of locally produced agricultural commodities, which displace the consumption of commodities transported from other states or countries. Greenhouse gas (GHG) reductions occur from reduced transportation-related emissions and from local farms that institute GHG reduction practices that may not be instituted in other states or countries.

Policy Design

Goals: To increase the production, storage, and processing of locally grown animal products, grains, vegetables, and fruits and their consumption in South Carolina such that at least 25% of these products purchased in South Carolina are produced by South Carolina farmers and ranchers. Begin tracking this information so it is readily available for planning purposes.

Timing: To increase sales and consumption of local farm products by 50% and increase storage and processing capacity of locally grown farm products by 100% above current levels by 2012. Increase purchasing of South Carolina-produced agriculture products to 25% of total purchased agriculture products in SC by 2020.

Parties Involved: SC Department of Agriculture (SCDA); SC Farm Bureau (SCFB); Palmetto Agri-Business Council; Clemson University – Cooperative Extension Service; US Department of Agriculture (USDA); Carolina Farm Stewardship Association; SC Food Policy Council.

Other: State current baseline information here.

Implementation Mechanisms

Continue funding for the South Carolina Department of Agriculture's marketing and branding program for South Carolina grown commodities. Furthermore, identify incentives that encourage retail chains in SC to sell locally grown products. The SCDA also needs to increase or facilitate development of, and support for, more local farmers markets which both increase the financial return for small producers and encourage more small producers. **NOTE TO TWG: Text moved from "Other" to Implementation Mechanisms by B. Strode on 1/18/08.**

Related Policies/Programs in Place

Seeds of Hope, a local farmers' market program in Columbia, has weekly markets at 12+ sites during the growing season. The USDA lists 63 farmers markets in the state.

The SC Agribusiness Development Program is responsible for the development of new products (both traditional and non-traditional) that add value to the state's agricultural products. Since 1994, the "South Carolina Quality" marketing program has worked with supermarket chains to purchase and sell fresh produce grown in South Carolina, specifically encouraging customers to buy local produce in supermarkets. DOA also has the "Certified SC Grown" program to promote SC agricultural products.

Type(s) of GHG Reductions

CO_2: Reduction in CO_2 emissions due to a reduction in ton-miles required to bring out-of-state agriculture products to markets in South Carolina. Although not quantified in this analysis, it is possible that processing of products in-state may yield additional GHG benefits not related to the averted long-range transport of produce and other agricultural products.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources: U.S. per capita food consumption was taken from the USDA Economic Research Service (ERS) Food Availability (Per Capita) Data System.[13] South Carolina production and export data is available by product-type through the USDA National Agriculture Statistics Service (NASS).[14] The average travel distances of imported foods are taken from an Iowa study of food miles.[15]

Quantification Methods:

GHG Benefits

The quantification of the GHG benefits of this option will follow the following process:

- Use US per-capita food consumption to estimate SC food consumption by product type.

Table 3-1. Per capita consumption of food types, by category

Food Category	US per capita consumption (lbs)
Red meat	116
Chicken	86
Turkey	17
Fish	12
Eggs	33
All dairy	601
Fats and oils	87
Peanuts	7
Tree nuts	3
Coconut	1
Fresh fruit	122
Canned fruit	15
Dried fruit	2
Frozen fruit	5

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[13] http://www.ers.usda.gov/Data/FoodConsumption/FoodAvailSpreadsheets.htm

[14] Yet to be retrieved.

[15] Food, Fuel, and Freeways: An Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions. Leopold Center for Sustainable Agriculture. 209 Curtis Hall Iowa State University Ames, Iowa 50011-1050 Website: http://www.leopold.iastate.edu/

Food Category	**US per capita consumption (lbs)**
Fruit juice	72
Fresh vegetables	184
Canned vegetables	108
Frozen vegetables	75
Legumes	6
Dehydrated vegetables	14
Potatoes for chips, shoestrings	16
Grains	192
Coffee, tea, cocoa	20
Spices	3
Beverages	116
Total	**1,911**

- For agricultural products produced in SC, subtract the quantity produced from the quantity exported to determine the baseline in-state consumption of SC agricultural products.

- Use Iowa farm study to estimate the food miles of imported and locally grown food. Apply fuel consumption assumptions to estimate CO_2 emissions reduction for incremental increase in consumption of locally-grown food.

Cost Effectiveness

The quantification of the cost effectiveness of this option will follow the following process:

- Make contact with industry expert to establish the cost of increased in-state storage and processing.

- Add the net change in cost of food paid by consumers for locally grown food (source TBD).

- Add the net change in price received by farmers for in-state markets (source TBD).

- Subtract the cost savings yielded by reduced fuel consumption derived from the reduced number of food miles.

Key Assumptions: [TBD, as needed on TWG approval]

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-4. In-State Liquid Biofuels Production

Policy Description

The ultimate goal of South Carolina is to take full advantage of resources available in the state through agriculture, forestry, or other biomass feedstocks to displace the use of fossil fuels. South Carolina is in an excellent position to develop an in-state alternative fuels industry that will provide economic opportunities for rural communities looking for alternatives to a fading tobacco and cotton industry. Policies must be developed in South Carolina that will attract investors, retailers, and purchasers to produce and use the fuels in the state (Note the linkage of this option covering in-state production of biofuels with the TLU option covering consumption of biofuels through a low carbon fuel standard). The focus of this policy should be in-state biofuels production based on in-state feedstocks.

In 2006 and 2007, South Carolina passed attractive incentives that have been able to promote and expand this industry. To date, the incentives have been effective and a great deal of interest within the alternative fuels industry has been generated. Other potential incentives for alternative fuel producers include expanding existing tax credits for biodiesel and ethanol to include other low-GHG future fuels such as butanol and hydrogen.

NEED TO CHECK WITH TLU Note: This option is linked with TLU-12 on a Low GHG Fuel Standard and TLU-6 on Alternative Fuel Infrastructurs. This AFW option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biofuels using feedstocks with greater GHG benefits than the likely BAU national production methods.

Policy Design

Goals:

South Carolina's numerical targets for biodiesel and ethanol production by 2020 include:

Lower Limit Targets
* based on estimated growth of 25% every five years for biodiesel and an expansion of 50 MGY for ethanol facilities every five years.

Phase	Year	Gallons of biodiesel produced in South Carolina	Represents percentage of total diesel used in state (based on projected use)[16]	Gallons of ethanol produced in South Carolina	Represents percentage of total gasoline used in state (based on projected use)[17]
1	2010	81,000,000	10.4 %	100,000,000	3.7%
2	2015	100,000,000	11.4%	150,000,000	5%

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[16] Based on data collected by the SC Energy Office and Global Insights in *SC Energy Outlook*, January 2008.

[17] Based on data collected by the SC Energy Office and Global Insights in *SC Energy Outlook*, January 2008.

3	2020	125,000,000	12.5%	200,000,000	6.5%

Upper Limit Targets (contingent on current or increased price of crude oil, availability of technology advancements and development of cheaper feedstocks, and maintenance of federal government incentives):
* based on estimated growth of 50% every five years for biodiesel and an expansion of 200 million gallons of ethanol every five years.

Phase	Year	Gallons of biodiesel produced in South Carolina	Represents percentage of total diesel used in state (in FY 2007)	Gallons of ethanol produced in South Carolina	Represents percentage of total gasoline used in state (in 2006)
1	2010	100,000,000	12.9 %	100,000,000	4%
2	2015	150,000,000	17%	300,000,000	10.2%
3	2020	225,000,000	22.5%	500,000,000	16.3%

Timing: See table above.

Parties Involved: State of South Carolina, farmers, biofuels producers, distributors, fuel retailers, fuel wholesalers, business owners, and relevant agriculture and trade associations.

Other: Note to TWG: CECAC requests that the costs and benefits be assessed at two different levels of implementation – one based on the goals in the table above; and the other at the level that the TWG feels is the upper bound of potential feedstock availability.

Currently there are no commercial cellulosic ethanol plants in the United States. One large plant is under construction in Georgia, one has just broken ground in Montana and a few others are being planned across the country. There are no ethanol plants in South Carolina. There are two biodiesel plants in production and three more planned.

Implementation Mechanisms

The state could provide additional economic benefits such as:

- No state property tax for alternative fuel production facilities and a tax exemption on the purchase of equipment.
- A special exception for alternative fuel producers related to the Jobs Creation Tax Credit
- Higher state-owned pump alternative fuel requirements from B5 to B20 and provide greater state facility access to E85.
- Continue state funding for alternative fuel marketing and education programs.

- Maintain and enhance the current state tax rebates and state income tax credits for low-GHG emission alternative fuel production. Among the improvements needed in state legislation are presented in Act No. 83, 2007 include:

  1. SC Code 12-6-3600 – Remove the six month requirement prior to claiming tax credit.

  2. SC Code 12-6-3631 – Tax credit for R&D on alternative fuel feedstocks - remove the $100,000/year cap. Additionally, remove the limitation that each company can only claim $100,000 over all years.

  3. SC Code 12-6-3600 – Tax credit for ethanol and biodiesel production – remove $800,000/year cap.

  4. SC Code 12-6-3610 – Tax credit for ethanol and biodiesel dispensing equipment and amendment to include production equipment for intermediate steps of alternative fuel production (ex: crushing facilities) - remove $150,000/year cap.

  5. SC Code 46-3-260 - Secure funding for the SC Renewable Energy Grants and Loans program in subsequent years.

Related Policies/Programs in Place

South Carolina currently provides Biodiesel Production Tax Credits in the amount of $0.20 per gallon of biodiesel or ethanol produced from soybean oil or corn feedstocks and $0.30 per gallon of biodiesel or ethanol from feedstocks other than soybean oil and corn. There is also a 25% tax credit for the purchase and installation of equipment directly related to the production of ethanol and biodiesel.

Several on-going alternative fuel production facilities include:

- Carolina Biofuels - a new division of the Taylors, South Carolina-based company Carolina Polymers, rolled out their first load of biodiesel fuel on March 14, 2006. Carolina Biofuels manufacturing facilities are currently in full operation, and though starting at 10 million gallons of biodiesel fuel expect to grow to over 30 million gallons annually. A large percentage of the fuel produced at Carolina Biofuels is sold to World Energy Alternatives, LLC which is leading global supplier of biodiesel located out of Massachusetts. Carolina Biofuels supports South Carolina industry by using locally-grown soybeans to make their fuel, and as production ramps up, they will create between 20 and 30 jobs in the Taylors area.
- Southeast Biodiesel - In May 2007 the facility begin commercially selling biodiesel made from poultry fat in North Charleston. The company’s grand opening was October 27, 2006. Southeast Biodiesel expects to begin by producing six million gallons and eventually increase production once there is more demand in the Charleston area. The company is currently selling biodiesel fuel to local shrimpers.
- Ecogy Biofuels, LLC – the company will build a biodiesel plant across the street from an existing soy oil crusher, Carolina Soya. Construction of the Ecogy Biofuels, LLC plant is expected to be completed and producing biodiesel at the close of 2007. The plant is being

constructed to produce 30 million gallons of fuel annually. Ecogy Biofuels has begun research and development of alternative oils, including oils derived from algae.

- Aiken Biofuels – formerly known as Farmers and Truckers Biodiesel, this facility has converted a Warrenville clay warehouse in Aiken County to a 5 million gallon/year facility at a cost of approximately $1.4 million. The facility has the potential to expand to 20 million gallons/year and will use feedstocks such as soy oil, cotton seed oil, and animal fats to produce the biodiesel.
- Greenlight Biofuels - The Virginia based company plans to expand operations into South Carolina in 2008 with a 10 million gallon per year plant in Laurens. The $8.5 million facility will generate 15 jobs. Greenlight Biofuels will use vegetable oils, animals fats, and recycled restaurant grease to make the biodiesel which will be sold to local retail stations and also used for home heating oil and off-road motors.

Clemson University, the University of South Carolina, and other research institutions are working vigorously to develop a viable cellulosic ethanol industry. South Carolina has also formed an algae-to-biodiesel collaborative among state businesses to develop indigenous oil feedstocks. In-state retailers have also embraced alternative fuels and to-date South Carolina has 49 publicly-accessible E85 and 49 publicly-accessible biodiesel pumps. Additionally, beginning July 1, 2008 there will be in-state incentives for consumers to purchase vehicles that operate on E85. Despite the good intent of some of the in-state incentives there is an immediate need to clarify and correct legislation for alternative fuel producers in Act No. 83, 2007.

Additional recent programs and/or policies related to alternative fuel production in South Carolina are available through Act No. 83, 2007, Act. No.116, 2007, and the FY08 Budget Appropriations. These programs include:

- Tax credits for R&D into cellulosic ethanol and algae-derived biodiesel.
- Tax credit for equipment to produce renewable fuel.
- Low-interest loans for the production of transportation fuels from biomass (SC Renewable Energy Revolving Loan Program).
- One-time funding for the Dept. of Ag. Biofuels Marketing Program.
- One-time funding to purchase biodiesel and ethanol testing equipment to offer free ASTM testing for in-state producers as well as recurring funding for additional staff.

Type(s) of GHG Reductions

CO_2: Lifecycle emissions are reduced to the extent that biodiesel and ethanol is produced with lower embedded fossil-based carbon than conventional (fossil) fuel. Feedstocks used for producing biodiesel and ethanol can be made from crops or other biomass, which contain carbon sequestered during photosynthesis (e.g., biogenic or short-term carbon).

The primary feedstocks for biodiesel are vegetable oils (soy, canola, sunflower, algal, etc.) and alcohols (either methanol or ethanol). From a recent report (Hill et al., 2006),[18] 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_2e of biodiesel compared to importation of out of state vegetable oil supplies.

There are two different methods for producing ethanol based on two different feedstocks. Starch-based ethanol is derived from corn or other starch/sugar crops. Cellulosic ethanol is made from the cellulose contained in a wide variety of biomass feedstocks, including agricultural residue (e.g., corn stover), forestry waste, purpose grown crops (e.g., switchgrass), and municipal solid waste. Local production of ethanol also decreases the embedded CO_2e of ethanol compared to importation from the current U.S. primary ethanol producing regions. Current research indicates 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 Net Costs or Cost Savings

Biodiesel

Scenario A – Based on lower limit TWG production goals

- GHG reduction potential in 2012, 2020 ($MMtCO_2e$) **based on TWG goals**: 0.19, 0.32
- Net Cost per $MtCO_2e$: $16.86

Scenario B – Based on upper bound limits of in-state feedstock supply

- GHG reduction potential in 2012, 2020 ($MMtCO_2e$) **based on upper bound of potential feedstock availability**: 0.12, 0.13
- Net Cost per $MtCO_2e$: $17.42

Scenario C – Based on lower limit TWG production goals with new technologies meeting in-state feedstock supply shortfalls

- GHG reduction potential in 2012, 2020 ($MMtCO_2e$) **based on TWG goals and new technology**: 0.58, 0.86
- Net Cost per $MtCO_2e$: $13.88

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[18] Hill et al., 2006, “Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels,” *Proceedings of the National Academy of Sciences*, 103:11206–11210, July 25, 2006.

Ethanol

<u>Scenario A</u> – Based on TWG lower limit production goals

- GHG reduction potential in 2012, 2020 (MMtCO_2e): 0.86, 1.48
- Net Cost per MtCO_2e: $22.01

<u>Scenario B</u> – Based on TWG upper limit production goals

- GHG reduction potential in 2012, 2020 (MMtCO_2e) 0.86, 3.80
- Net Cost per MtCO_2e: $14.61

Biodiesel

Data Sources:

Data from the SC Draft Inventory & Forecast were the starting point for quantifying the benefits of offsetting fossil diesel with biodiesel produced within the state (these do not incorporate future reductions in consumption due to TLU options).

Fossil diesel consumption estimates are (under business as usual):

BAU Diesel Consumption

Year	Diesel consumption (Mmgal/year)
2012	929
2020	1,148

The lower limit policy design calls for production of 81 MMgal/year, 100 MMgal/year, and 125 MMgal/year biodiesel by 2010, 2015, and 2020, respectively, with a focus on in-state production based on in-state feedstock. The upper limit policy design calls for production of 100 MMgal/year, 150 MMgal/year, and 225 MMgal/year biodiesel by 2010, 2015, and 2020, respectively

The BAU biodiesel production is based upon the current and planned biodiesel capacity of SC. A capacity factor of 50% is assumed. See the table below for the existing and planned facilities in SC:

Current and planned biodiesel production facilities in South Carolina

Facility Name	Status	Capacity (1000 gal)	Feedstock	Misc.
Carolina Biofuels	In-production	10,000	Soy (In-state)	Potential to expand to 30,000
Southeast	In-production	6,000	Poultry fat	

Biodiesel				
Ecogy Biofuels, LLC	Planned 2008	30,000	Soy	
Aiken Biofuels	Planned 2008	5,000	Soy, Cottonseed, Animal Fat	Potential to expand to 20,000
Greenlight Biofuels	Planned 2009	10,000	Veg Oil, Animal Fat, Yellow Grease	

The CO_2e emission factor for fossil diesel used in the inventory and forecast is 10.07 Mt/1,000 gallons. The lifecycle fossil diesel emission factor is 12.3 Mt/1,000 gallons.[19]

Quantification Methods:

GHG Reductions

For biodiesel production a new study on lifecycle GHG benefits for biodiesel production and use was used to estimate the CO_2e reductions for this option.[20] 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 feedstock of biodiesel production in SC). Lifecycle CO_2e reductions (via displacement of fossil diesel with soybean-derived biodiesel) were estimated by Hill et al. to be 41%. This value is being used by the TLU TWG to estimate the benefit of the biodiesel component of the TLU biofuels option. Hence, this analysis focuses on incremental benefits of in-state feedstocks.

For this option, the incremental benefit of in-state production is derived from the carbon avoided from having to transport the feedstocks from their likely source region. For this assessment, the likely source region for soybean is the U.S. mid-west. Using the Iowa/Illinois border as a potential source region, rail transport would require shipments to central South Carolina of about 950 miles.[21] Rail fuel consumption is about 423 ton-miles/gallon.[22] From these inputs, a GHG emission rate of 507 $MtCO_2$/MMgal biodiesel produced was calculated.

In addition to soybean oil, other oil feedstocks included in this analysis include animal oils (yellow grease, poultry fat, lard, and tallow), cottonseed, peanut oil, sunflower oil, and algal oils. 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 approximately 5% of biodiesel production by 2020. 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 $MtCO_2e$/MMgal from the

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[19] From: Hill, J., et. al., Proceedings of the National Academy of Sciences, vol. 103, no. 30, 11206-11210. U.S. soybean-based biodiesel.

[20] Ibid.

[21] Google Maps directions, Davenport, Iowa to South Carolina; www.maps.google.com.

[22] Association of American Railroads, http://www.aar.org/getFile.asp?File_id=466.

Hill et al. study). As mentioned previously, the benefits of the biodiesel component of the TLU biofuels option is based on displacement with soybean-based biodiesel. Hence, this analysis was designed to only account for the incremental benefit of in-state feedstock (oil) production using GHG preferential feedstocks. These include vegetable oils that produce greater volumes of oil per unit of energy input, animal fats, yellow grease, 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 $MtCO_2e$/MMgal. So the incremental benefit of canola over soy is 7,261–2,744 = 4,517 $MtCO_2e$/MMgal. However, South Carolina produces essentially no canola (rapeseed) so current canola feedstock is assumed to be imported from the U.S. northern plains. Using North Dakota as a potential source region, rail transport would require shipments to central South Carolina of about 1700 miles, reducing the incremental benefit of canola over soy by 907 MtCO2e/MMgal biodiesel to 3607 MtCO2e/MMgal.[23]

Cottonseed produces less oil than soy - 35 gallons/acre compared to soybeans at 48 gallons/acre.[24] Assuming cottonseed production energy inputs are not significantly greater than soy, the lifecycle emission rate would be 7,261 x 48/35 or 9,957.3 MtCO2e/MMgal. So the incremental "benefit" of cottonseed over soy is 7,261 - 9,957.3 or a net loss of (2696.8) MtCO2e/MMgal biodiesel.

Sunflower seed produce102 gallons/acre compared to soybeans at 48 gallons/acre.[25] Assuming cottonseed production energy inputs are not significantly greater than soy, the lifecycle emission rate would be 7261 x 48/102 = 3416.9 MtCO2e/MMgal. The incremental benefit of sunflower over soy is 7261 - 3416.9 = 3844.1 MtCO2e/MMgal biodiesel.

Peanuts yield 113 gallons/acre compared to soybeans at 48 gallons/acre.[26] Assuming peanut production energy inputs are not significantly greater than soy, the lifecycle emission rate would be 7261 x 48/113 = 3048.3 MtCO2e/MMgal. The incremental benefit of peanut over soy is 7261 - 3048.3 = 4176.7 MtCO2e/MMgal biodiesel.

For animal fats, algal oils, and yellow grease CCS assumes that these have negligible embedded energy. So the incremental benefit over soy equals the soybean based EF (7,261 $MtCO_2e$/MMgal) minus transportation costs, which are assumed to average 100 miles[27], yielding a benefit of 7,207 MtCO2e/MMgal biodiesel over soy-based.

Scenario A

To meet the in-state production goals the table below provides the mix of oil feedstocks assumed in this analysis based on transitioning from the current and planned production mix of feedstocks used to all-in-state feedstocks.

Assumed mix of oil feedstocks

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[23] Google Maps directions, North Dakota to South Carolina; www.maps.google.com.

[24] http://journeytoforever.org/biodiesel_yield.html, accessed January 8, 2008.

[25] http://journeytoforever.org/biodiesel_yield.html, accessed January 8, 2008.

[26] http://journeytoforever.org/biodiesel_yield.html, accessed January 8, 2008.

[27] Average max dimension of SC is 200 miles, 100 miles is average distance from center of the state to border.

Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2012	Soy (out-of-state)	0.19	17
2012	Soy	0.50	45
2012	Other Veg oil	0.10	9
2012	Animal fats	0.17	15
2012	Algal	0.00	0
2012	Yellow grease	0.03	3
2012 Total			89
2020	Soy (out-of-state)	0.00	0
2020	Soy	0.64	81
2020	Other Veg oil	0.10	13
2020	Animal fats	0.17	21
2020	Algal	0.05	6
2020	Yellow grease	0.03	4
2020 Total			125

Excludes planned production capacity of 48 Mmgal/year.

GHG reductions were estimated by multiplying the new production above BAU for 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.

Scenario B

In-state oilseed feedstock supplies were estimated by measuring the average 2004-2006 South Carolina production yields of soybean, cottonseed, peanut, and sunflower and assuming that ***20%*** of production would go towards biodiesel instead of food. Animal fats available were estimated based on the ratio of South Carolina livestock/poultry slaughter/production to that of Minnesota, given that detailed amounts of grease, lard, poultry fat, and tallow available in Minnesota are known from their Bio-Power Evaluation Tool (BioPET) that identifies locations, types, and volumes of biomass fuels.[28] Yellow grease was projected based on industry estimates of 14 pounds restaurant grease per capita and 7.6 pounds of grease per gallon using US Census projections for South Carolina.[29] It was assumed that by 2020 algal biodiesel technology will have progressed enough to be available to provide 5% of biodiesel needs.

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[28] http://www.mncee.org/pdf/biomassreport.pdf, accessed January 8, 2008.

[29] http://media.cleantech.com/node/376, accessed January 8, 2008; http://www.cgfa.org/news.html, under Evaluate The Cost And Usage Of Various Fuels, accessed January 8, 2008; http://www.census.gov/population/www/projections/projectionsagesex.html, table 6, accessed December 28, 2007.

SC available biodiesel feedstock potential

Feedstock	Biodiesel equivalent (1000 gal)
Soybean oil	3,056
Cottonseed oil	7
Peanut oil	1,316
Sunflower oil	59
Animal fats	7,347
yellow grease 2012	8,586
yellow grease 2020	9,151
Algal 2020 - estimated at 5% of feedstock	1,047
total 2012	**20,370**
total 2020	**21,982**

Note: Only 20% of food production is assumed to be diverted to fuel production.

The mix of feedstocks assumed was based on respective proportion of each feedstock of the upper-bound of in-state supply.

Assumed mix for in-state feedstocks alone

Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2012	Soy (out-of-state)	0.00	0
2012	Soy	0.16	3
2012	Other Veg oil	0.00	0
2012	Animal fats	0.39	8
2012	Algal	0.00	0
2012	Yellow grease	0.45	9
2012 Total			20
2020	Soy (out-of-state)	0	0
2020	Soy	0.38	8
2020	Other Veg oil	0.17	4
2020	Animal fats	0.18	4
2020	Algal	0.04	1
2020	Yellow grease	0.23	5
2020 Total			22

The BAU current and planned production outpaces the upper bound of in-state potential feedstock by 2008. GHG estimates for this scenario were calculated by multiplying total production of each oil feedstock by the applicable incremental benefit without subtracting BAU production. After 2008, production is assumed to be capped based on the upper bound of potential feedstock supply. Total reductions in each year were estimated by summing the incremental benefit for each oil type.

Scenario C

To meet the lower limit in-state production goals the table below provides the mix of oil feedstocks assumed in this analysis based on transitioning from the current and planned production mix of feedstocks used to all-in-state feedstocks. New algal technology was assumed to make up the shortfall between the upper bound of potential in-state feedstock supply and the TWG in-state production goals.

Assumed mix of feedstocks with new technology meeting goal shortfall

Year	Oil Feedstock	Fraction of New Production	MMgal/yr Needed
2012	Soy (out-of-state)	0.00	0
2012	Soy	0.08	7
2012	Other Veg oil	0.03	3
2012	Animal fats	0.18	16
2012	Algal	0.50	45
2012	Yellow grease	0.21	19
2012 Total			89
2020	Soy (out-of-state)	0.00	0
2020	Soy	0.04	5
2020	Other Veg oil	0.02	3
2020	Animal fats	0.10	13
2020	Algal	0.73	91
2020	Yellow grease	0.12	15
2020 Total			125

Excludes planned production capacity of 48 Mmgal/year.
May not sum due to rounding.

GHG reductions were estimated by multiplying the new production above BAU for each oil feedstock by the applicable incremental benefit. Total reductions in each year were estimated by summing the incremental benefit for each oil type.

GHG emissions were not calculated for upper limit TWG goals because they far exceeded feedstock supply.

Costs

Costs were estimated using information from an analysis of biodiesel production costs from the US DOE.[30] The value of incentives needed is assumed to be $0.30/gallon - the value of incentives offered in a State of Missouri incentives program.[31] In Oct 2004 when the $0.30 Missouri biodiesel incentive passed, there was only 1 biodiesel plant under construction in Missouri; by the end of 2007, Biodiesel magazine lists 8 plants in operation or under construction in the state.[32] This program offers production incentives to producers up to 15 million gallons of production/yr. The incentive grants last for five years. Hence, CCS only applied the incentives costs to the first five years of the policy period, except in Scenario C where continued incentives are assumed to be needed to spur new technology.

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 above BAU 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, except in Scenario C where it continues for ten years.

Ethanol

Data Sources:

Data from the SC Draft Inventory & Forecast were the starting point for quantifying the benefits of offsetting gasoline consumption with ethanol produced within the state (these do not incorporate future reductions in consumption due to TLU options). Gasoline consumption estimates are (under business as usual):

Year	Gasoline consumption (Mmgal/year)
2012	2,013
2020	2,145

The lower limit policy design calls for 100 MMgal/year production, 150 MMgal/y, and 200 MMgal/y by 2010, 2015, and 2020, respectively. The upper limit policy design calls for 100 MMgal/year production, 300 MMgal/y, and 500 MMgal/y by 2010, 2015, and 2020, respectively Ethanol has approximately 67% the heat content of gasoline.[33] Emission factors from gasoline,

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[30] See www.eia.doe.gov/oiaf/analysispaper/biodiesel/index.html; accessed January 2007.

[31] Information on the Missouri Program from www.newrules.org/agri/mobiofuels.html#biodiesel,accessed January 2007.

[32] http://www.renewableenergyaccess.com/rea/news/story?id=21253, accessed January 9, 2008; http://www.biodieselmagazine.com/plant-list.jsp?view=production&sort=state&sortdir=asc&country=USA, accessed January 9, 2008.

[33] DOE/EIA, http://www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed January 9, 2008

starch-based ethanol and cellulosic ethanol are based on the ANL Greet Model.[34] The lifecycle CO_2e emission factor used for gasoline used is 11.74 Mt/1,000 gallons, for starch-based ethanol is 9.60 Mt/1,000 gallons, and for cellulosic ethanol is 3.28 Mt/1,000 gallons.[35] The production cost differential for cellulosic versus starch-based ethanol was obtained from the National Renewable Energy Laboratory (NREL).[36]

Quantification Methods:

GHG Reductions

For ethanol the benefits for this option are dependent on developing in-state production capacity that achieves benefits above the levels of using ethanol from starch-based production, which may already be accounted for under the Transportation and Land Use low GHG Fuel Standard policy recommendations.

Based on the emission factors listed above, the incremental benefit of the production targeted by this policy over conventional starch-based ethanol is 6.32 Mt/1,000 gallons, or a 66%. This value was used along with the production in each year to estimate GHG reductions.[37] This analysis does not take into account the benefits from transitioning from gasoline to corn-based ethanol.

Scenario A

In Scenario A the GHG emissions benefits and cost were calculated for the lower limit TWG goals. Ethanol production needed was assumed to ramp up from replacing 0% of BAU gasoline consumption in 2007 to 5% in 2010. GHG reductions were estimated by multiplying the cellulosic ethanol production requirement by the incremental benefit of using cellulose over corn.

In-state cellulose supply was estimated from non-harvested cropland and residual biomass residues. The South Carolina non-harvested cropland from 2002 was estimated by subtracting harvested cropland from total cropland. [38] The conversion factors below were used to estimate dry mass from cropland and ethanol from cellulose based on DOE and NREL data.[39]

Cellulose feedstock conversion factors

Year	Cellulose yield per acre (tons)	Ethanol yield from cellulose (gal/ton biomass)
2008	5	70
2012	7.5	90
2020	10	100

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[34] Ibid.

[35] ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

[36] http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

[37] ANLGreet model emission factor in g/mi x GREET model average fuel economy (100 mi/4.7 gal).

[38] 2002 production, http://www.nass.usda.gov/census/census02/volume1/sc/st45_1_001_001.pdf, Table 1

[39] http://genomicsgtl.energy.gov/biofuels/2005workshop/2005low_intro.pdf, accessed December 28, 2008; J. Ashworth, NREL, personal communication, 4/06/07.

Additional estimates of biomass from crop residues, switchgrass on Conservation Reserve Program (CRP) land, forest residues, primary and secondary mill residues, and urban wood were obtained from an NREL study.[40] The following table shows calculated cellulosic ethanol annual production maxima based on the upper bound of feedstock supplies.

Cellulosic ethanol annual production based on upper bound of feedstock supplies

Year	Cellulosic ethanol (1,000 gal)
2008	1,200
2009	314,985
2010	314,985
2011	314,985
2012	404,981
2013	566,973
2014	566,972
2015	566,972
2016	566,972
2017	809,961
2018	809,961
2019	809,961
2020	899,957

Sweet potato and sweet sorghum feedstock potential were also calculated based on USDA crop data[41] with yields of 2000 and 500 gallons ethanol per acre, respectively.[42] However, as these crops contribute a much smaller fraction of potential feedstock supply than cellulose, it was assumed that they would not be needed for production and all calculations were based on using cellulose to meet TWG goals.

Crop	Cellulosic ethanol potential (1,000 gal)
Sweet Potato	1,533
Sweet Sorghum	4,666

Scenario B

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[40] A Geographic Perspective on the Current Biomass Resource Availability in the United States,

A. Milbrandt, NREL, December 2005

[41] http://www.nass.usda.gov/Publications/Ag_Statistics/2007/index.asp

[42] E. Hartwig, SC Energy Office, personal communication, Jan 2008; http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=195472, accessed January 14, 2008.

In Scenario B the GHG emissions benefits and cost were calculated for the upper limit TWG goals.

Costs

For ethanol, 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. Estimates taken from an NREL-sponsored industry forum estimate a production cost of $1.31 per gallon for corn-based ethanol and $1.97 per gallon for cellulose-based, resulting in a differential of $0.66 per gallon.[43] These estimates include capitals costs so additional incentives for capital and R&D are not included in this analysis. These incentives are considered necessary in the near term to help commercialize technologies that produce ethanol from cellulose. 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, although this may also be covered in the TLU Alternative Fuel Infrastructure policy option.

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 federal legislation has been proposed to offer cellulose an incentive of $0.765/gallon compared to the $0.51/gallon currently offered for ethanol production.[44] If enacted, this $0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of South Carolina. Obviously, the federal incentives do not assure that production facilities would locate in SC, hence these federal incentives have not been factored into the cost estimates for this option.

Key Assumptions: Upper bound feedstock potential is based on the assumption that 100% of cellulose feedstocks identified go towards fuel and not other uses. New technologies such as algal biodiesel and rigorous cellulosic production that can use a variety of feedstock types are assumed to progress quickly enough to be implemented within the policy period.

Total SC biodiesel potential – assuming all feedstock goes toward fuel rather than food – is summarized in the chart below. However, only 20% of non-corn food feedstocks were assumed could be used for fuel.

SC annual biodiesel production potential based on upper bound of feedstock supplies

Feedstock	Biodiesel equivalent (1000 gal)

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[43] http://www.nrel.gov/technologytransfer/entrepreneurs/pdfs/19_forum/braemar_cellulosic.pdf, slide 21, accessed December 2007

[44] 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, accessed January 2007.

Soybean oil	15,278
Cottonseed oil	33
Peanut oil	6,579
Sunflower oil	295
Animal fats	7,347
yellow grease 2012	8,586
yellow grease 2020	9,151
total 2012	**38,117**
total 2020	**38,682**

Key Uncertainties

Cost competitiveness of biofuels will depend on cost of oil.

The Energy Information Administration (EIA) has stated “Capital costs for a first-of-a-kind cellulosic ethanol plant with a capacity of 50 million gallon per year are estimated by one leading producer to be $375 million (2005 dollars), as compared with $67 million for a corn-based plant of similar size, and investment risk is high for a large-scale cellulosic ethanol production facility. Other studies have provided lower cost estimates. A detailed study by the National Renewable Energy Laboratory in 2002 estimated total capital costs for a cellulosic ethanol plant with a capacity of 69.3 million gallons per year at $200 million.”[45]

In June 2006, a U.S. Senate hearing was told that the current cost of producing cellulosic ethanol is US $2.25 per US gallon (US $0.59/litre). This is primarily due to the current poor conversion efficiency. At that price it would cost about $120 to substitute a barrel of oil (42 gallons), taking into account the lower energy content of ethanol. However, the Department of Energy is optimistic and has requested a doubling of research funding. The same Senate hearing was told that the research target was to reduce the cost of production to US $1.07 per US gallon (US $0.28/litre) by 2012.

Transitioning to large amounts of energy crop cultivation for biofuels has the potential for a negative impact on biodiversity.

Transitioning to large amounts of energy crop cultivation for biofuels has the potential for a negatively impact on biodiversity.

A key uncertainty with this option is in estimating the incremental benefit above what is achieved with the low carbon fuel standard. To estimate benefits for in-state production of ethanol using GHG-superior technologies and feedstocks, one must make critical assumptions about what types of fuels will supply the low carbon fuel standard within the policy period. For the purposes of this analysis, CCS has assumed that the primary low carbon fuel that will be used to lower the carbon content of gasoline-powered vehicles will be starch-based ethanol and Midwest-grown soy. The incremental benefit is based on the higher GHG benefits associated with producing ethanol in-state

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[45] http://www.eia.doe.gov/oiaf/analysispaper/biomass.html, accessed December 2007

using cellulosic ethanol technology and feedstocks and biodiesel from in-state feedstocks. To the extent that this technology is widely employed within the policy period and acts as a significant supplier of fuel to meet the low carbon standard, the incremental benefits estimated here could be overstated.

Additional Benefits and Costs

Potential for competition with the production of food; less impact by cellulosic ethanol than corn ethanol on water quality and could actually reduce nutrient loads in some circumstances; permanent new sources of income for farmers and foresters; using current waste streams to replace US fuel consumption; environmental benefits or costs; recycling money in local economies; stimulation of potential markets for other biomass feedstocks (forest treatment biomass, municipal solid waste fiber); increased transportation energy security with shorter transport distances and on-farm use of fuel produced; reduced reliance on imported petroleum.

Feasibility Issues

Implementation of this option requires additional research and development in cellulosic ethanol production methods, development of feedstock collection and delivery infrastructure, successful negotiations with cellulosic technology leaders to establish pilot and commercial-scale plants in the state. Sourcing of feedstocks and the size and location of facilities (both crushing and biodiesel production) must be addressed for optimization and planning. Trade-offs between food and fuel crops will be an important issue. Full implementation of biodiesel goals requires quick research advancement in algal oil harvesting.

There may be an overlap among agricultural options that seek to increase/maintain crop acreage in no-till production or in conservation management programs. This could be in conflict with the higher levels of crop production proposed in this option.

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-5. Expanded Production of In-State Biomass for Electricity, Heat, or Steam Production

Policy Description

Offset fossil fuel use with production of electricity, steam, and heat from biomass resources. Provide incentives for the development of new biomass production and collection infrastructure, as well as incentives for energy end users that are equitable throughout the economy. Local electricity, heat, or steam production yields greatest net energy payoff. According to a recent study by La Capra and the SC Electric Cooperatives, South Carolina currently has 360 MW of installed capacity for woody biomass. Based on available wood and agriculture residue inventories as well as energy crop production potential, South Carolina has the ability to more than double the current level of production.[46]

Table XX: Current and Potential Electricity Generation Capacity from Biomass Feestocks

	Current Installed Capacity (MW)	Technical Potential (MW)	Practical Potential (MW)[47]	Practical Generation (GWh)
Wood Biomass	360	1,599	423	3,148
Agricultural By-Products	0	362	68	504
Total	***360***	***1,961***	***491***	***3,652***

The focus of this policy is on programs needed to increase the availability of biomass feedstocks for use in-state. Policies to encourage use of this resource are addressed within the ES and RCI sectors.

Policy Design

Goals: Increase production of electricity, steam, and heat generation to utilize 25% of the available wood and agriculture residue biomass by 2020, equivalent to 122MW over the 2007 baseline of 360MW of installed biopower capacity. By 2030, expand electricity, steam, and heat generation from biomass resources to utilize 50% of the available biomass (246 MW over the 2007 baseline).

Timing: Increase biomass electricity, steam, and heat generation to utilize an additional 10% of available resource by 2010, equivalent to 49 MW of increased capacity. By 2012, increased capacity should reach 68 MW, utilizing 14% of practical and available resource. By 2020,

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[46] La Capra Associates and GDS Associates. 2007. “Analysis of Renewable Energy Potential in South Carolina.” Prepared for: Central Electric Power Cooperative Inc. September 12, 2007. Accessed on January 8, 2008 from: http://www.ecsc.org/newsroom/RenewablesStudy.ppt.

[47] The La Capra study defines “Practical Potential” as “the maximum potential that might reasonably be expected to be implemented.”

increased capacity should reach 122 MW, utilizing 25% of practical and available resource. By 2030, increased capacity should reach 246 MW, utilizing 50% of practical and available resource.

Coverage of Parties:

SC Department of Agriculture, South Carolina Forestry Commission, University of South Carolina, Clemson University and Extension agencies, SC State University, SC Energy Office, South Carolina Department of Health and Environmental Control – Air Quality Division, SC Biomass Council, SC Forestry Association and SC Forestry Commission, Palmetto Institute, SC Institute for Energy Studies, SC Public Service Commission, Office of Regulatory Staff, SC Department of Revenue, Electric Utilities and Rural Electric Cooperatives, Livestock & Poultry Producers, Crop Producers, and Timberland Owners.

Other: Explore biomass production for utilization in electricity, steam, and heat generation using 100% biomass and/or co-firing with other feedstocks. [NOTE: This policy has parallel policy options in ES and RCI covering utilization of biomass; the focus here is on production]. Note to TWG, the CECAC would also like the TWG to include utilization of woody energy crops along with residues.

Implementation Mechanisms

A broad range of policy mechanisms and programs should be used to foster development of the industry and associated economic markets, including voluntary, incentive-based programs and regulatory requirements. These could include:

- Establish a state-level renewable electric portfolio standard (REPS), requiring a specific percentage of in-state generation to be fueled by biomass.
- Establish an interconnection standard that allows utility-scale combined heat and power production, and distributed generation fueled by biomass.
- Establish net metering rates by utilities, electric cooperatives, and municipalities that allow biomass energy to be price competitive (i.e., rates should be greater than avoided cost).
- Establish output-based emissions regulations (OBR) that encourage energy efficiency and biomass energy as air pollution control measures.
- Increase state-level incentives, especially those for construction of new utility-scale generating capacity using biomass resources.
- Establish competitive cost-share grant funding for feasibility studies for new utility-scale generating capacity using biomass resources.
- Stream-lining the permitting process for biomass-to-energy projects and technical assistance for new producers.
- Incentives in the form of grants or tax breaks (sales and/or income) for incurred capital costs for feedstock producers.
- Expanded consumer and end-user education to drive demand.
- Expanded producer education to develop skilled workforce.
- Active state involvement in new projects.

- State rebates for equipment purchase (ex: a rebate for each kW or kW-equivalent of energy installed).
- Removing state tax on the purchase of renewable energy equipment.

Related Policies/Programs in Place

Legal Definition:

In South Carolina state law, biomass is defined as wood, wood waste, agricultural waste, animal waste, sewage, landfill gas, and other organic materials.

Incentives:

Incentive Payment:
Beginning July 1, 2008, a business is allowed an incentive payment for production of electricity or methane gas fuel in a facility not using biomass resources before June 30, 2008, or in a facility which produces at least twenty-five percent more electricity or methane from biomass resources than the greatest three-year average before June 30, 2008. This includes:

- 1 cent per kilowatt-hour (kWh) for electricity.
- 9 cents per therm for methane gas fuel.

Equipment Tax Credit:
Beginning July 1, 2007 there is a credit against the income tax for twenty-five percent of the costs incurred by a taxpayer for the purchase and installation of equipment used to create heat, power, steam, electricity, or another form of energy for commercial use from a fuel consisting of no less than ninety percent biomass resource. Costs incurred by a taxpayer and qualifying for the credit allowed by this section must be certified by the State Energy Office, in consultation with the Department of Agriculture and the South Carolina Institute for Energy Studies. A taxpayer’s credit utilization in any one year, for all expenditures allowed pursuant to this section, must not exceed six hundred fifty thousand dollars. Unused credits may be carried forward for fifteen years.

Conducive Policies:

In December 2006, the SC Public Service Commission (PSC) adopted a simplified interconnection standard for small distributed generation (DG). The standard addresses renewable-energy systems and other forms of DG up to 20 kilowatts (kW) in capacity for residential systems, and up to 100 kW in capacity for non-residential systems. The standard does not include provisions for three-phase generators, and limits the range of commercially viable interconnections.

Type(s) of GHG Reductions

Displacement of coal, natural gas, and other fossil fuels reduces emissions of GHGs. Increased energy efficiency of smaller-scale generating technologies decreases the amount of carbon emitted per unit of energy generated.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources:

The South Carolina Energy Office has quantified the following potential for taking advantage of biomass that is currently not being used for fueling a sustainable bioenergy industry:

- 14 million tons of green wood from forest thinnings.
- 621,000 tons of urban waste wood that currently goes into landfills.
- 1.2 million tons of agricultural residues from fields planted in corn, soybeans, and cotton.

There is a case study about cofiring biomass with coal at the DOE Savannah River Cofiring Project in South Carolina in 2004 on page 22 of a DOE Federal Energy Management Program document titled “Biomass Cofiring in Coal-Fired Boilers.”

The South Carolina Electric Cooperative Association commissioned an informative study of biopower resource potential. Here is a link to the report, written by consultants GDS Associates and LaCapra Associates. http://www.energy.sc.gov/news.aspx?id=52 This study found 9.8 m dry tons per year of woody biomass potential, determined to have a cost of less than $65 per dry ton or about $4.00 per MMBtu.

The South Carolina Forestry Commission performs annual inventories of wood residues: http://www.state.sc.us/forest/prod.htm

Quantification Methods:

Biomass GHG Benefits

This analysis focuses on the incremental GHG benefits associated with the utilization of additional biomass to offset the consumption of fossil fuels. The analysis assumes that biomass will replace 100% coal. This is based on the assumption that the majority of biomass will be used to replace coal through co-firing opportunities in the RCI and electricity sector (where coal represents a significant proportion of electricity generated[48]). The amount of biomass available is taken from La Capra Associates and GDS Associates. 2007. “Analysis of Renewable Energy Potential in South Carolina.” Prepared for: Central Electric Power Cooperative Inc. September 12, 2007. Accessed on January 17, 2008 from: **http://www.ecsc.org/newsroom/RenewablesStudy.ppt**.

Table X: Estimated Available Agriculture Biomass

Agricultural Resources	Approximate Dry Tons per year required[49]	Maximum Fuel (MMbtu)	Assumed Capacity Factor	Technical Potential (MW) [50]
Corn	906,928	7,480,346	85%	72
Wheat	408,683	3,370,815	85%	32

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[48] Based on eGRID data for SC: Nuclear 52%, Coal 40%, Natural Gas 3.9%, Biomass 1.7%, Hydro 1.3%, Oil 0.9%.

[49] Assumed heat content of Ag Byproducts of 8.25 MBtu/Ton, Sourced from EIA Average Heat Content of Selected Biomass Fuels http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html

[50] Based on the La Capra Associates and GDS Associates report, the technical potential MW calculation assumes direct-fired plants with 14,000 btu/kWh heat rate and a capacity factor of 85%.

Soybean	404,696	3,337,936	85%	32
Cotton	502,617	4,145,582	85%	40
Total crop Residue	2,222,924	18,334,679	85%	176
Switchgrass	2,035,756	16,790,918	85%	161
Crop Residue and Switchgrass	4,258,681	35,125,597	85%	337

Table X: Estimated Available Wood Biomass

Wood Biomass Options	Dry Tons per Year	Annual Heat Value3 (MMBtu)	Technical Potential (MW)[51]
Logging Residue	2,205,750	37,497,750	360
Pre-commercial Thinnings	4,277,898	72,724,266	698
Commercial Thinnings	2,668,000	45,356,000	435
Southern Scrub Oak1	24,396	414,732	4
Net Available Mill Residue	6,043	102,731	1
Urban Wood Waste	621,000	10,557,000	101
Total Wood Biomass	**9,803,087**	**166,652,479**	**1599**

Biomass is assumed to reduce emissions by 0.0940 tCO2e/MMBTU when replacing coal combustion, based on CCS standards used in the inventory and forecast.

Biomass Costs

There are two main components to the cost calculation, the fuel costs and capital costs. The fuel component is based on the difference in costs between supply of biomass fuel and the assumed fossil fuel that it is replacing (i.e. coal). The fuel component for this option is based on the difference in costs between supply of woody biomass fuel and the assumed fossil fuel that it is replacing. The assumed costs and the source of the costs are identified in table X below.

Table X: Assumed Costs of Feedstocks

Fuel Type	Cost $/ton delivered	Cost $/MmBtu delivered	Source
Agricultural Byproducts	$ 40.00	$ 4.85	"The Potential for Biomass Cofiring in Maryland" Maryland Power Plant Research Program, March 2006 DNR

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[51] Based on the La Capra Associates and GDS Associates report, the assumed heat content of wood biomass material is 8,500 btu/dry lb of biomass. Potential MW calculation assumes direct-fired plants with 14,000 btu/kWh heat rate and a capacity factor of 85%.

Wood Biomass	$ 65.00	$ 4.00	La Capra Associates and GDS Associates. 2007. "Analysis of Renewable Energy Potential in South Carolina." Prepared for: Central Electric Power Cooperative Inc. September 12, 2007. Accessed on January 8, 2008 from: http://www.ecsc.org/newsroom/RenewablesStudy.ppt.
SwitchGrassc	$ 47.00	$ 3.20	"The Potential for Biomass Cofiring in Maryland" Maryland Power Plant Research Program, March 2006 DNR
Bituminous Coal	$34.26	$ 1.53	Source: EIA Coal Prices Fact sheet http://www.eia.doe.gov/neic/infosheets/coalprice.html

The fuel component is calculated by assuming the replacement of coal with biomass as indicated in Table X in MBtu. The difference in cost of supply between biomass and coal is calculated using the costs above. The difference in costs ($/MBtu) is multiplied by the amount of coal energy (MBtu) being replaced by biomass. Note that the cost estimates do not include potential benefits received from the *Equipment Tax Credit* (Beginning July 1, 2007), which would provide a credit against the income tax for twenty-five percent of the costs of equipment used to create heat, power, steam, electricity, or another form of energy for commercial use from a fuel consisting of no less than ninety percent biomass resource. The cost estimates incorporate an incentive payment for production of electricity or methane gas fuel in a facility not using biomass resources before June 30, 2008, or in a facility which produces at least twenty-five percent more electricity or methane from biomass resources than the greatest three-year average before June 30, 2008 (1 cent per kWh).

The assumed incremental capital costs are based on the capital costs associated with the biomass component of a coal/biomass co-fired plant. A capital cost of $100 per kW was assumed, based on a pulverized coal plant co-fired with 3% biomass, from: Table 3, *Biomass Co-firing in Coal-Fired Boilers*, (June, 2004) DOE Federal Energy Management[52]. While use of biomass may be pursued through other technology types (e.g. gasification) or end uses (e.g. heat or steam), the capital costs of co-firing were used to provide an estimate of possible capital costs required to enable the utilization of biomass[53]. The lifespan was assumed to be 30 years, and the interest rate of was assumed to be 5%, giving a Capital Recovery Factor of 0.065 (i.e. $1 million plant is assumed to cost approximately $65,000 per year over the life of the project). For the purposes of this analysis, it is assumed that biomass plants do not require additional operating and maintenance costs (e.g. no additional emission control measures and ash disposal required).

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[52] *Biomass Co-firing in Coal-Fired Boilers*, (June, 2004) DOE Federal Energy Management Program document, Produced for the U.S. Department of Energy, Energy Efficiency and Renewable Energy, by the National Renewable Energy Laboratory, a DOE national laboratory. (available at http://www.nrel.gov/docs/fy04osti/33811.pdf)

[53] The capital costs associated with using biomass as an alternative to fossil-based generation are dependent on many factors, including the end use (i.e. electricity, heat or steam), the design and size of the systems, the technology employed, and the configuration specifications of the system. Each system implemented under this policy would require a detailed analysis (incorporating specific engineering design and costs aspects) to provide a more accurate cost estimate of the system.

A summary of avoided emissions and cost for each year for agriculture residue, switchgrass and wood biomass are presented in Tables X,Y and Z.

Table X: Summary of Agriculture Residue Biomass GHG Benefits and Costs

Year	Percent of Utilization	Ag Residue Biomass (MMBtu)	Approximate Electrical Capacity (MW)	Avoided Emissions Ag Residue (MtCO2-e)	Ag Residue Cost/Savings	Discounted Cost/Savings
2008	3%	611,156	6	0.057	$1,630,636	$1,408,605
2009	7%	1,222,312	12	0.115	$3,261,272	$2,683,056
2010	10%	1,833,468	18	0.172	$4,891,907	$3,832,938
2011	12%	2,200,161	21	0.207	$5,870,289	$4,380,500
2012	14%	2,566,855	25	0.241	$6,848,670	$4,867,222
2013	15%	2,818,957	27	0.265	$7,521,308	$5,090,717
2014	17%	3,071,059	29	0.289	$8,193,945	$5,281,890
2015	18%	3,323,161	32	0.312	$8,866,582	$5,443,312
2016	20%	3,575,262	34	0.336	$9,539,220	$5,577,384
2017	21%	3,827,364	37	0.360	$10,211,857	$5,686,344
2018	22%	4,079,466	39	0.384	$10,884,494	$5,772,280
2019	24%	4,331,568	42	0.407	$11,557,131	$5,837,137
2020	25%	4,583,670	44	0.431	$12,229,769	$5,882,728
			Cumulative	**3.03**		**$61,744,113**

Table Y: Summary of Switchgrass GHG Benefits and Costs

Year	Percent of Utilization	Total Energy Crops (MMBtu)	Approximate Electrical Capacity (MW)	Avoided Emissions, Energy Crops (MtCO2e)	Energy Crop Cost/ Savings	Discounted Cost/ Savings
2008	3%	559,697	5	0.053	$569,837	$492,247
2009	7%	1,119,395	11	0.105	$1,139,675	$937,613
2010	10%	1,679,092	16	0.158	$1,709,512	$1,339,448
2011	12%	2,014,910	19	0.189	$2,051,415	$1,530,797
2012	14%	2,350,729	23	0.221	$2,393,317	$1,700,886
2013	15%	2,581,604	25	0.243	$2,628,375	$1,778,988
2014	17%	2,812,479	27	0.264	$2,863,433	$1,845,795
2015	18%	3,043,354	29	0.286	$3,098,491	$1,902,205
2016	20%	3,274,229	31	0.308	$3,333,549	$1,949,057
2017	21%	3,505,104	34	0.329	$3,568,607	$1,987,134
2018	22%	3,735,979	36	0.351	$3,803,665	$2,017,165
2019	24%	3,966,854	38	0.373	$4,038,723	$2,039,830
2020	25%	4,197,730	40	0.394	$4,273,781	$2,055,762
			Cumulative	**3.27**		**$21,576,927**

Table Z: Summary of Wood Biomass GHG Benefits and Costs

Year	Percent of Utilization	Forest Residue Biomass (MMBTU)	Approximate Electrical Capacity (MW)	Avoided Emissions Forest Residue (MMtCO2-e)	Forest Residue Cost/ Savings	Discounted Cost/ Savings
2008	3%	5,555,083	53	0.522	$10,099,792	$8,724,580
2009	7%	11,110,165	107	1.04	$20,199,584	$16,618,248
2010	10%	16,665,248	160	1.57	$30,299,376	$23,740,354
2011	12%	19,998,297	192	1.88	$36,359,251	$27,131,833
2012	14%	23,331,347	224	2.19	$42,419,127	$30,146,481
2013	15%	25,622,819	246	2.41	$46,585,291	$31,530,758
2014	17%	27,914,290	268	2.62	$50,751,455	$32,714,840
2015	18%	30,205,762	290	2.84	$54,917,619	$33,714,654
2016	20%	32,497,233	312	3.05	$59,083,783	$34,545,064
2017	21%	34,788,705	334	3.27	$63,249,948	$35,219,938
2018	22%	37,080,177	356	3.48	$67,416,112	$35,752,203
2019	24%	39,371,648	378	3.70	$71,582,276	$36,153,914
2020	25%	41,663,120	400	3.92	$75,748,440	$36,436,295
			Cumulative	**32.5**		**$382,429,164**

Poultry Litter GHG Benefits

Similar to AFW-2, the poultry litter option has the potential to provide emission savings through two mechanisms: through the reduction of methane and through offsetting of fossil-based energy through the utilization of the poultry litter.

The reduction in methane emissions component was estimated through quantifying the reduced methane emissions (estimated from the SC inventory and forecast) from litter management of the poultry litter (after adjusting for the litter utilized under AFW-2). An assumed reduction efficiency of 75%[54] was applied to methane emissions from poultry litter which was then multiplied by the assumed policy target ramping up to achieve 25% collection by 2020.

For the second component it was assumed that the use of poultry litter for energy production larger sites would occur through a combination of gasification and direct combustion. The amount of available litter was taken from Flora and Riahi-Nezhad (2006) and was reduced by the amount utilized under AFW-2. The amount of poultry litter utilized is illustrated in Table X below and expressed in MMBtu.

The assumed energy content of poultry litter is 4,600 BTU/lb and the assumed heat rate is 18,000 BTU/kWh[55]. A capacity factor of 85% was assumed to approximate the installed electrical capacity required at large facilities.

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[54] 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).

[55] The assumed energy content and heat rate were based on Flora and Riahi-Nezhad (2006) based on the gasification of poultry litter which is suggested to have the .

It was assumed that the energy produced would be offsetting emissions that would have otherwise been generated from coal (i.e. is assumed to reduce emissions by 0.0940 tCO2e/MMBTU). The resulting GHG emission savings is represented in table X below.

Table X: GHG Benefits from Poultry Litter

Year	Policy Utilization objective	Poultry litter/Energy Utilized (MMBtu)	Approximate Electrical Capacity (MW)	Methane Reduced/utilized under policy (MMt CO2-e)	Emissions Offset Poultry Litter (MtCO2-e)	Total Emission Reductions (MMt CO2-e)
2008	3%	168,542	1.3	0.004	0.016	0.020
2009	7%	333,680	3.2	0.007	0.031	0.039
2010	10%	495,413	4.8	0.011	0.047	0.057
2011	12%	588,366	5.6	0.013	0.055	0.068
2012	14%	679,277	6.5	0.016	0.064	0.079
2013	15%	736,176	7.1	0.017	0.069	0.087
2014	17%	791,320	7.6	0.019	0.074	0.094
2015	18%	844,707	8.1	0.021	0.079	0.101
2016	20%	896,340	8.6	0.024	0.084	0.108
2017	21%	946,216	9.1	0.026	0.089	0.115
2018	22%	994,337	9.5	0.028	0.093	0.122
2019	24%	1,040,702	10.0	0.031	0.098	0.128
2020	25%	1,085,311	10.4	0.033	0.102	0.135

Poultry Litter Costs

The cost of production of poultry litter as a feed stock was assumed to be $38 per ton (or $4.08 per MMBtu, assuming 4,600 Btu per pound). This was based on an average between gasification and combustion provided in *Availability Of Poultry Manure As A Potential Bio-Fuel Feedstock For Energy Production* which provided a value of poultry litter as a co-firing feedstock and a gasification feedstock.

The assumed incremental capital costs are based on the capital costs associated with the biomass component of a coal/biomass (poultry litter) co-fired plant. A capital cost of $100 per kW was assumed, based on a pulverized coal plant co-fired with 3% biomass, from: Table 3, *Biomass Co-firing in Coal-Fired Boilers*, (June, 2004) DOE Federal Energy Management[56]. While use of poultry litter may be pursued through other technology types (e.g. gasification e.g. anaerobic digestion) or other end uses (e.g. heat or steam), the capital costs of co-firing were used to provide

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[56] *Biomass Co-firing in Coal-Fired Boilers*, (June, 2004) DOE Federal Energy Management Program document, Produced for the U.S. Department of Energy, Energy Efficiency and Renewable Energy, by the National Renewable Energy Laboratory, a DOE national laboratory. (available at http://www.nrel.gov/docs/fy04osti/33811.pdf)

an estimate of possible capital costs required to enable the utilization of biomass[57]. The lifespan was assumed to be 30 years, and the interest rate of was assumed to be 5%, giving a Capital Recovery Factor of 0.065 (i.e. $1 million plant is assumed to cost approximately $65,000 per year over the life of the project). For the purposes of this analysis, it is assumed that plants utilizing poultry litter do not require additional operating and maintenance costs (e.g. no additional emission control measures and ash disposal required). As noted in AFW-2, this may not be the case.

The cost estimates incorporate an incentive payment for production of electricity or methane gas fuel in a facility not using biomass resources before June 30, 2008, or in a facility which produces at least twenty-five percent more electricity or methane from biomass resources than the greatest three-year average before June 30, 2008 (1 cent per kWh).

The net cost of production was estimated by subtracting the price of electricity from the cost of production, illustrated in table X below.

Table X: Costs/Savings of Poultry Litter

Year	Poultry Litter Annualized capital costs Cost/Savings	Poultry Litter Cost/Savings (including annualized capital costs and fuel costs)	Discounted Cost/Savings
2008	$14,756	$343,669	$296,875
2009	$37,562	$632,058	$519,996
2010	$55,768	$938,413	$735,271
2011	$66,232	$1,114,486	$831,647
2012	$76,465	$1,286,690	$914,426
2013	$82,871	$1,394,468	$943,831
2014	$89,078	$1,498,921	$966,218
2015	$95,088	$1,600,048	$982,291
2016	$100,900	$1,697,850	$992,698
2017	$106,514	$1,792,326	$998,034
2018	$111,931	$1,883,477	$998,848
2019	$117,151	$1,971,302	$995,641
2020	$122,172	$2,055,802	$988,876

Key Assumptions:

Plants utilizing biomass (from agriculture, forestry or poultry litter) do not require additional operating and maintenance costs (e.g. no additional emission control measures and ash disposal required).

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[57] The capital costs associated with using biomass as an alternative to fossil-based generation are dependent on many factors, including the end use (i.e. electricity, heat or steam), the design and size of the systems, the technology employed, and the configuration specifications of the system. Each system implemented under this policy would require a detailed analysis (incorporating specific engineering design and costs aspects) to provide a more accurate cost estimate of the system.

Key Uncertainties

The future price of electricity will affect the analysis.

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC] Sample Draft Policy Option Template

AFW-6. Terrestrial Carbon Sequestration

AFW-6(a). Soil Carbon Management (Agriculture)

Policy Description

There are four components of soil carbon management considered in this option: alternative cultivation practices (conservation-till, no-till, bio-char application, compost application, cover crops, etc.), manure management practices, crop conversion to increase sequestration potential, and rotational grazing.

The amount of carbon stored in the soil can be increased by the adoption of practices such as conservation and no till cultivation, cover cropping, and application of biochar and compost. Reducing summer fallow and increasing winter cover crops are complimentary practices that reduce the need for conventional tillage. The application of biochar (i.e., charcoal) and compost increases soil carbon content, stabilizes soil carbon, enhances drought resistance, and may improve production by boosting soil dynamics. By reducing mechanical soil disturbance, these practices reduce the oxidation of soil carbon compounds and allow more stable aggregates to form. Other benefits include reduced wind and water erosion, reduced fuel consumption, and improved wildlife habitat.

Additionally, the implementation of manure management practices may reduce GHG emissions associated with manure handling and storage. Potential practices include but are not limited to composting of manure (to reduce methane emissions) and improved methods of field-application (for reduced nitrous oxide emissions). Application improvements include incorporation into soil, instead of surface spray/spreading, spreader calibration, and manure-management planning.

Convert marginal agricultural land used for annual crops to permanent cover such as grassland/rangeland, orchard, perennial bio-crops, or forest, where the soil carbon and/or carbon in biomass is higher under the new land use. This option includes opportunities to keep CRP lands covered in perpetuity. Increased demand for corn-based ethanol and biodiesel feedstocks can act as an incentive for converting grassland to cropland. Adopt incentives to reduce acreage returning to conventionally tilled production or to suburban/urban development.

Heavy grazing can cause significant soil disturbance and result in carbon losses from soils. Rotational grazing where animals are moved from field-to-field on a regular basis reduces soil disturbance and improves soil carbon levels. Rotational grazing also can improve plant vigor.

Policy Design

Goals: By 2020, apply improved soil carbon management practices on 50% of acres that currently do not use these practices (see definition of improved soil carbon management practices in “Policy Description,” above). Note to TWG: need to consider a separate goal for manure management, as this element does not fit into the existing goal structure.

Timing: By 2012, apply improved soil carbon management practices on 20% of acres that currently do not use these practices. Achieve an increase to 50% of these acres by 2020.

Parties involved: SC Department of Agriculture; SC DNR – Conservation Districts; Clemson University – Cooperative Extension Service; USDA – Natural Resources Conservation Service; SC Farm Bureau; Farmers.

Other: Note to TWG: CECAC would like to see information on baselines to better understand the goals (e.g. current acres that utilize the above practices). Studies in North Carolina have found the potential to sequester one ton of carbon per acre through conservation tillage / no-till practices over a six-year period[58] (equivalent to about 3.3 $MtCO_2e$/acre). Studies in California[59] and Pennsylvania[60] have shown that improved soil carbon management techniques (i.e., cover cropping and application of compost and manure) can sequester dramatically more carbon than no-till practices alone. Moreover, it appears that the sequestration benefits of no-till are limited, whereas the longitudinal study in Pennsylvania saw no less accumulation of soil carbon sequestration over the 25 year period. *Are we inferring that accumulations occur indefinitely?*

Different methods to increase soil carbon content have different effects on soil fertility, disease management, and actual sequestration. Also, certain soil carbon management techniques may require greater energy input than others. Additionally, crop production cycle GHG emissions have not been quantified for all these improved soil carbon management practices. For these reasons, in-state research studies are needed to determine the optimal soil carbon management techniques in South Carolina's various soils, with the greatest GHG benefits.

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

Many farmers are participating in the no-till program. Each farm is eligible for up to $40,000 per year (max. 3 years) in fixed-rate incentives for participating in no-till farming of low-residue crops such as tobacco, vegetable crops, peanuts, cotton, soybeans, and silage crops.

Comprehensive Nutrient Management Plans are required, and some have been submitted to the Department. Regulation mandates that manure is applied at agronomic rates and that spreaders are calibrated. Many farms have composters for dead bird disposal. Some manure is used in this

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

[59] 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. http://calag.ucop.edu/0603JAS/pdfs/ConservTillageTomato.pdf

[60] "The Rodale Institute Farming Systems Trial 1981 to 2005: Long Term Analysis of Organic and Conventional Maize and Soy-bean Cropping Systems," p15-30, in Long Term Field Experiments in Organic Farming, edited by J Rauppe, C Perkrun, M Oltmanns, U Kopke. ISOFAR International Society of Organic Agriculture Research, Verlaug Publishing, Berlin, 2006.

process. Composted material is applied at agronomic rate. Because of the high cost of commercial fertilizer, many farms are getting their land approved for manure applications.

Cost-sharing programs available for landowners to manage forestland. These include the Forest Renewal Program, Stewardship Incentives Program, Conservation Reserve Program, Forest Land Enhancement Program, Wildlife Habitat Incentive Program, Environmental Quality Incentive Program, and others. Through these programs landowners can receive advice from foresters, biologists, soil scientists, and other experts along with cost sharing that pays, on average, about 40% of the cost of site preparation, planting, soil stabilization, wildlife habitat improvement, and some intermediate management practices.

Type(s) of GHG Reductions

CO_2: Reducing tillage and soil disturbance slows the breakdown of plant material on the soil surface and in the root zone, accelerating the microbial processes that stabilize carbon and protecting carbon from oxidation, inhibiting the release of carbon back into the atmosphere. Depending on how the adoption of alternative cultivation methods affects the overall crop production cycle, additional CO_2 reductions can occur through lower fossil fuel consumption in farm equipment. The conversion of agricultural lands to grassland cover, as well as the implementation of rotational grazing will increase terrestrial carbon sequestration.

N_2O: To the extent that fossil fuel consumption is lowered through the cultivation methods implemented under this policy, N_2O emissions from fuel combustion will be lowered. It is important to note that research also indicates the potential for higher N_2O emissions as soil organic carbon levels increase.[61] Nutrient management programs that reduce the application of manure and fossil-derived fertilizers reduce emissions that occur as a result of nitrogen run-off and leaching.

CH_4: To the extent that fossil fuel consumption is lowered through the cultivation methods implemented under this policy, CH_4 emissions from fuel combustion will be lowered. More efficient applications of manure (or other organic fertilizers) have the potential to reduce methane emissions.

Also, full life-cycle analysis on crop inputs is needed: For examples, displacement of chemical inputs through the use of bio-char, compost, manure, cover-cropping, or mechanical weed control will reduce emissions of fossil CO2 associated with manufacture of these chemical inputs.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources: [TBD by CCS on TWG approval]

Quantification Methods:

GHG Benefits

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[61] 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.

The quantification of the GHG benefits of this option will follow the following process:

- Determine how many acres are currently using the practices designed as "improved soil carbon management practices." TWG will need to provide input as to which carbon management strategies are complementary and which strategies are to be used independently (i.e. can no-till and manure management apply to the same land?). This will likely take some off-line discussion with CCS and TWG members.

Cost Effectiveness

Pending resolution of above questions.

Key Assumptions: [TBD, as needed on TWG approval]

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW 6(b). Forest Management for Carbon Sequestration

Policy Description

Forest management has significant potential to sequester carbon dioxide. Southern forests are capable of sequestering more than one metric ton of CO2 per acre every year, and there are 12.7 million acres of forest land in SC. Since 73% of SC forest land is privately owned, the management decisions made by private landowners will ultimately determine carbon impacts.

Promoting Forest Management for Carbon Sequestration also confers many additional benefits such as wildlife habitat, clean air and water, recreational opportunities, and scenic quality. Timber is SC's highest valued agricultural crop, and forest industry is among the top manufacturing segments. Forest-based jobs, payroll, and capital investment are an important part of the state's economy.

This option includes a range of forest management activities that promote productivity and increase the rate of carbon dioxide sequestration in biomass, soils, and in harvested wood products. Practices may include: increased stocking of poorly stocked lands, age extension of managed stands, thinning and density management, fertilization and waste recycling, expanding short rotation woody crops (for fiber and energy), expanded use of genetically preferred species, modified biomass removal practices, fire management and risk reduction, pest and disease management.

Establish forests on land that has not historically been forested (e.g., agricultural land) ("afforestation"). Promote forest cover and associated carbon stocks by regenerating or establishing forests in areas with little or no present forest cover ("reforestation"). In addition, implement practices such as soil preparation, erosion control, and stand stocking to ensure conditions that support forest growth. These practices should also include urban forestry, including urban tree planting and enhanced maintenance programs.

Policy Design

Goals: By 2020, ensure reforestation of 1.4 million acres by 2020 by planting approximately 120,000 acres annually; increase the number of landowners with a forest management plan by 50%; double the number of Tree Cities USA to 80 in SC; and achieve 40% canopy cover in 50% of municipalities.

> *Forest Management:* By 2020, apply improved forest management practices on 50% more acres than currently use these practices (see definition of improved forest management practices in "Policy Description," above).
>
> *Reforestation:* Reforest 100% of Forestland identified as suitable for reforestation*;* ensure reforestation of 1.4 million acres by 2020 by planting approximately 120,000 acres annually*;*
>
> *Afforestation: TBD? [Added by CCS. CCS suggests an explicit afforestation goal if desired, as there is reference to afforestation opportunities in the Mitigation Option*

Description above, as well as in 7b. Alternatively, could add afforestation goal to 7b as it is a type of land use change]

Urban Forestry: Increase urban trees by X% by 2020; double the number of municipalities participating in the Tree City USA program by 2020.

Timing:

Forest Management: By 2012, apply improved forest management practices on 20% more acres than currently use these practices. Achieve an increase to 50% by 2020.

Reforestation: By 2008, complete survey of SC Forestland to identify lands suitable for reforestation. Complete 25% of reforestation efforts by 2012.

Afforestation: TBD?

Urban Forestry: Achieve 25% of goals by 2012.

Parties Involved: SC Forestry Commission, SC Forestry Association, SC Parks Recreation & Tourism, SC Department of Natural Resources, SC Conservation Bank, SC Department of Agriculture, Santee Cooper, SC Farm Bureau, US Fish & Wildlife Service, US Forest Service, US Park Service, Clemson University, NGOs (including but not limited to SC Forestry Association, Ducks Unlimited, The Nature Conservancy, Lowcountry Open Land Trust, Congaree Land Trust, etc.)

Other: Not Identified

Implementation Mechanisms

Emphasis of opportunities to voluntarily optimize forest productivity by increasing forest stand density thereby sequestering additional carbon; exploration of opportunities to reward forest landowners with tax credits for increasing carbon sequestration on privately owned forest lands [Note to TWG: this has been moved to AFW-6b under Forest Management program implementation from AFW-7b implementation mechanisms.]

Considerations include:

1) Increase productivity of forest land and encourage active management of of privately owned lands through increased availability of technical assistance, cost-sharing programs, and education/outreach for landowners.

2) Fully fund and expand existing reforestation programs such as the Forest Renewal Program and Grow Some Green in order to promote afforestation and reforestation.

3) Promote carbon markets to provide financial incentives for landowners to enhance carbon sequestration through forest management. Consider development of a state carbon registry and explore markets for trading carbon offsets.

4) Support a healthy forest industry in South Carolina to ensure strong markets for primary forest products grown in-state. Emphasize forest-based economic development in rural areas, and encourage consumers to purchase SC grown and manufactured wood and paper products. Establish preference for SC products in government procurement. Strong markets for forest products will ensure that forest management is a financially sustainable option for private landowners.

5) Provide services for forest protection to minimize losses to wildfire, insects, disease, and invasive species.

6) Promote urban and community forestry programs leading to increased energy savings. Increase grant funding available to municipalities through the SC Forestry Commission Urban and Community Forestry program.

Related Policies/Programs in Place

Assistance available to pay partial costs of prescribed burning, reforestation, stand improvement, and other practices. Some poultry litter and municipal sludge are utilized as forest fertilizer. 21,000 acres of forestland will be included in a program to restore the longleaf pine. SC will implement the use of improved seedlings for higher production. For example, Arborgen and Cellfor are developing tree varieties to capture more carbon. SC forestry commission offers assistance and guidance for those seeking to perform prescribed burns to mitigate wildfire risk. Programs such as "Firewise Communities" educate homeowners about wildfire prevention and provide wildfire hazard assessments. There is a current USFS program for reducing wildfire hazard and putting the biomass toward beneficial use.

SC Forestry Commission uses several state and federal cost-share programs and technical assistance for landowners.

Tree City USA is a program sponsored by the National Arbor Day Foundation that provides direction, technical assistance, and publicity for urban and community forestry programs. Currently, 40 SC cities are participating in the Tree City USA program.

Type(s) of GHG Reductions

CO_2: 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

Estimated GHG Reductions and Net Costs or Cost Savings

Forest Management

Data Sources: Forest carbon stocks, sequestration rates, and growing stock volume from Southeast US defaults in the 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 on distribution of forest types in SC from USFS Forest Inventory Analysis;

Assumptions about carbon removals during harvesting from Strong, T.F., 1997 "Harvesting Intensity Influences the Carbon Distribution in a Northern Hardwood Ecosystem," USFS Research Paper NC-329; costs of implementing forest management practices based on similar estimates for North Carolina; National Woodland Owner Survey (can I get a copy from G. Sabin?); harvest rates calculated from data published in South Carolina Forest Resources – 2000 Update (USFS Resource Bulleting SRS-65).

Quantification Methods:

Forestland Targeted for Improved Forest Management

Twenty-eight percent of private forest land owners in SC report receiving some form of assistance to improve their forest management (National Woodland Owner Survey, personal communication G. Sabin). The goal of this option is to increase the number of landowners (and the acres they manage) that receive such assistance. In 2006, SC had 4,750,214 acres of privately owned Loblolly-shortleaf pine forestland (FIA 2006). As noted below, the analysis is limited to Loblolly-shortleaf because this is a predominant forest type and the appropriate data are available for this type only. It is roughly estimated that about twenty-eight percent of these acres, or 1,330,060 acres, are under some form of active/improved management currently in SC. Thus, under the goals of this option, by 2012, an additional 266,012 acres would be under improved forest management and by 2020, an additional 665,030 acres would be under improved forest management. To achieve these cumulative levels, approximately 66,503 acres per year from 2009-2012 and 49,877 acres per year from 2013-2020 would need to move from average or below average conditions to improved management.

Impacts of Improved Management on Carbon Sequestration

Net changes in carbon stocks in forest biomass and soil are influenced by growth, mortality and decay processes, as well as the amount of carbon removed during harvest, all of which are influenced by forest management to some degree. A range of forest management activities can promote productivity and increase the rate of carbon sequestration in SC (see Policy Option Description for details). Increasing productivity involves increasing the rate at which forests accumulate biomass; i.e., a high productivity stand accumulates more carbon in biomass over the same amount of time as an otherwise equivalent low productivity stand. This leads to a relatively higher growing stock volume (i.e., the volume of living trees above the ground), some portion of which is harvested at periodic intervals (providing for potentially greater harvest volumes).

Data are available to estimate the carbon stock and growing stock volume changes associated with increasing productivity of Loblolly-shortleaf pine stands in SC. In addition, Loblolly-shortleaf pine forests are the most abundant type in SC, making up 41% of all classes of forest and 42% of all privately owned forests in SC (FIA 2006). An analysis of this forest group alone is believed to be a good approximation of the overall potential GHG benefits of forest management in SC. Thus, the analysis below is based on shifting productivity levels from average or below average to high levels in privately owned Loblolly-shortleaf stands.

The estimated changes are based on comparing carbon and growing stock volume yield tables for average and high productivity Loblolly-shortleaf pine stands in the Southeast published by the USFS. This type of comparison assumes that the newly treated stands will realize gains as if they were growing according to the yield table of a high producing forest from their beginning.

In reality, total gains will be influenced by the age of the stand at which time treatment is initiated.

The net impact of a shift from low to high productivity forests involves both forest carbon and HWP pools. From a carbon accounting perspective, harvested carbon represents a carbon stock loss to the forest and a carbon stock gain into the HWP pool, with only a portion of the carbon that is shifted into the HWP pool at harvest remaining stored for long periods of time. The change in carbon stocks in both forest and HWP pools are quantified below.

Estimated Increases in Carbon Sequestration Rates and Growing Stock Volumes

The USFS publishes carbon stock tables for forest types by region for the entire US. In some regions, for some forest types, the USFS provide tables for both average and high productivity stands. Such tables are available for Loblolly-shortleaf pine in the Southeast. Carbon stock and growing stock volume data in the USFS tables (see Tables 1a and 1b below) were used to calculate an annual carbon sequestration rate for average and high productivity Loblolly-shortleaf pine forests in SC (carbon stocks in 30 yr old stands were subtracted from carbon stocks in new stands and divided by 30). An average over 30 years is assumed to encompass the range of age classes for this forest type given that about 75% of all Loblolly-shortleaf pine stands in 2006 were 30 years or younger according to FIA data (in reality, sequestration rates vary by stand age). Note that soil carbon stocks are constant over time and between productivity classes, so carbon stock gains occur only in biomass pools. Comparing Tables 1a and 1b below shows that high productivity stands sequester approximately 0.9 tons more carbon per acre per year. Therefore, regardless of the initial carbon stock levels, a forest stand that moves to higher productivity status will gain roughly 0.9 more tons C per acre per year than it would if left as is.

Table. 1a Carbon stocks and mean growing stock volumes by selected age class for Loblolly-shortleaf pine in the Southeastern US (USFS GTR NE-343, Table A39)

Age	Mean volume (cf/ac)	Biomass (tC/ac)	Soils (tC/ac)	Total (tC/ac)
0	0	10.7	29.5	40.2
30	1554	32.7	29.5	62.2
Average annual sequestration (30 year average) (tC/ac/yr)				0.73

Table. 1b Carbon stocks and mean growing stock volumes by selected age class for high productivity sites (growth rates greater than 85 cubic feet/ac/yr), with high-intensity management (replanting with genetically improved stocks) (USFS GTR NE-343, Table A40)

Age	Mean volume (cf/ac)	Biomass (tC/ac)	Soils (tC/ac)	Total (tC/ac)
0	0	14.9	29.5	44.4
30	4963	64.6	29.5	94.1
Average annual sequestration (30 year average) (tC/ac/yr)				1.66

In addition, the growing stock volume is greater in all age classes of high productivity stands. Assuming that, on average, stands are harvested at 30 yrs, USFS HWP accounting methods were used to convert the 3,409 cubic feet per acre incremental increase in growing stock volume into the equivalent carbon volume of 35.6 tons C/ac (see Table A2 and Appendix below for explanation of this calculation). Note that this is the carbon stored in the incremental increase in growing stock, only a portion of which is removed during harvest (this analysis assumes 35% is removed, see below).

Calculation of Net Carbon Stock Change in Forests and HWP

The calculation of net forest carbon stock change takes into account that each year gains in biomass carbon stocks from higher accumulation rates are offset by the removal of larger volumes of carbon during harvest (Table 3). The incremental increase in biomass carbon stocks is calculated by multiplying the cumulative number of acres treated by 0.9 tons C/ac/yr (Table 3, Column A). Cumulative acres are used because once an area is treated it continues to sequester carbon at a higher rate in subsequent years.

The incremental increase in carbon removed during harvest is calculated by multiplying the number of acres harvested each year by 35% of the carbon increase in growing stock volume (i.e., 35% of 35.6 tons C/a = 12.5 tons C/ac) (Table 3, Column B). This assumes that 35% of the growing stock volume is removed during a harvest (based on a study of carbon removals at different harvest levels; 35% is roughly the proportion removed from moderate harvest levels, see Strong 1997 for details). The number of acres harvested is calculated by assuming 1.66% of the acres treated each year are harvested the following year. The harvest rate of 1.66% was calculated from data published in the South Carolina Forest Resources – 2000 Update (USFS Resource Bulleting SRS-65).

Carbon removed during harvest is subtracted from the carbon gains in biomass due to sequestration to yield a net change in forest carbon stocks each year (Table 3, Column C). If the calculation stopped here, then this would imply that all carbon removed is essentially emitted to the atmosphere. Therefore, a subsequent step is taken to account for the portion of carbon that remains stored in HWP for a total carbon stock balance.

Standard USFS HWP accounting methods were used to estimate the incremental increase in harvested carbon that remains stored in HWP indefinitely. The amount of carbon stored in HWP carbon stocks is time dependent relative to the year of harvest (carbon stocks are high initially and decrease over time as a result of disposal and decay), making carbon stock accounting for HWP complex. Therefore, an approach has been developed to standardize and simplify HWP carbon accounting, which applies the amount of carbon still stored in HWP 100-yrs after harvest as the estimated net increase in HWP carbon stocks; and, this gain is attributed to the year of harvest.

The USFS methods were applied to coefficients for Loblolly-shortleaf pine stands in the Southeast to estimate that approximately 21% of harvested carbon remains stored in HWP 100-yrs after harvest (see Table A5 and Appendix below for calculation details). Therefore, the long-term storage of carbon in HWP increases by approximately 2.6 tons C/ac when stands go from average to high productivity forests (i.e., an additional 12.5 tons C/ac is harvested, of which 21% remains stored indefinitely). The net carbon stock increase in HWP attributable to increased productivity was calculated by multiplying the number of acres harvested by 2.6 tons C/acre (Table 3, Column D). For standardization across all policy options, units are converted to million metric tons carbon dioxide equivalent (MMtCO2e) in Table 4.

Table 3. Summary of Calculated Net Changes in Forest and HWP Carbon Stocks (in units of tons C)

			Column A	**Column B**	**Column C (A minus B)**	**Column D**	**Column E (C plus D)**
Year	Acres/yr	Cumulative Acres	Increased C Stocks in Forest Biomass (tons C)	Increased C Stocks Removed at Harvest (tons C)	Net Change in Forest Carbon Stocks (tons C)	Net Increase in HWP C Stocks (tons C)	Total Increase in Forest and HWP Carbon (tons C)
2009	66,503	66,503	61,404	0	61,404	0	61,404
2010	66,503	133,006	122,809	13,752	109,057	2,872	111,928
2011	66,503	199,509	184,213	13,752	170,461	2,872	173,333
2012	66,503	266,012	245,618	13,752	231,866	2,872	234,737
2013	49,877	315,889	291,671	13,752	277,919	2,872	280,791
2014	49,877	365,766	337,724	10,314	327,410	2,154	329,564
2015	49,877	415,644	383,778	10,314	373,464	2,154	375,617
2016	49,877	465,521	429,831	10,314	419,517	2,154	421,671
2017	49,877	515,398	475,884	10,314	465,570	2,154	467,724
2018	49,877	565,275	521,938	10,314	511,624	2,154	513,777
2019	49,877	615,153	567,991	10,314	557,677	2,154	559,831
2020	49,877	665,030	614,044	10,314	603,730	2,154	605,884
Total	665,030				4,109,698	26,564	4,136,263

Table 4. Summary Table: Results in Million Metric Tons Carbon Dioxide Equivalent (MMtCO2e)

	Net Change in Forest Carbon Stocks (MMtCO2e)	Net Increase in HWP C Stocks (MMtCO2e)	Total Increase in Forest and HWP Carbon (MMtCO2e)
2009	0.23	0.00	0.23
2010	0.40	0.01	0.41
2011	0.63	0.01	0.64
2012	0.85	0.01	0.86
2013	1.02	0.01	1.03
2014	1.20	0.01	1.21
2015	1.37	0.01	1.38
2016	1.54	0.01	1.55
2017	1.71	0.01	1.71
2018	1.88	0.01	1.88
2019	2.04	0.01	2.05
2020	2.21	0.01	2.22
Total	15.07	0.10	15.17

The results suggest potential net carbon stock increases in forest biomass of 0.85 MMtCO2e in 2012, increasing to 2.21 MMtCO2e in 2020 as more acres are treated, with a cumulative gain in forest biomass carbon stocks of 15.07 MMtCO2e from 2009-2020. In addition, the analysis suggests a relatively small net carbon stock increase in HWP of 0.01 MMtCO2e each year starting in 2010, for a cumulative gain of 0.10 MMtCO2e from 2009-2020.

Costs Analysis

In this analysis costs are based on the average cost of implementing forest management practices on the ground that have the potential to increase productivity. These data are readily available from existing technical assistance programs.

An average lifetime cost to implement forest management practices was estimated to be $264/acre based on data used in a similar analysis for North Carolina (where it was assumed that forest management costs about $8.80 per acre for 30 years).

The average cost to implement forest management was multiplied by the number of acres treated each year to yield an average annual cost (Table 5). Annual discounted costs were estimated each year from 2009 to 2020 using a 5% discount rate. The sum of annual discounted costs from 2009 to 2020 provides an estimate of the Net Present Value (NPV) of this option, which amounts to $139 million. The cumulative cost effectiveness of the total program was calculated by dividing the NPV by cumulative carbon benefits of this option for, yielding $9/ton CO2e.

Table 5: Summary of Cost and Cost Effectiveness

	Acres	Total GHG Benefit (from Table 4)	Cost	Discounted Costs
2009	66,503	0.23	$17,556,791	$17,556,791
2010	66,503	0.41	$17,556,791	$16,720,754
2011	66,503	0.64	$17,556,791	$15,924,527
2012	66,503	0.86	$17,556,791	$15,166,217
2013	49,877	1.03	$13,167,594	$10,833,012
2014	49,877	1.21	$13,167,594	$10,317,154
2015	49,877	1.38	$13,167,594	$9,825,861
2016	49,877	1.55	$13,167,594	$9,357,963
2017	49,877	1.71	$13,167,594	$8,912,346
2018	49,877	1.88	$13,167,594	$8,487,948
2019	49,877	2.05	$13,167,594	$8,083,760
2020	49,877	2.22	$13,167,594	$7,698,819
Total	665,030	15.17		$138,885,152

The analysis does not account for potential increases in forest revenue as a result of greater harvest volumes and a strong forest products markets. If this were taken into account, the net costs of the option would be lower or possibly even negative.

Appendix: Calculations of HWP assumptions

Two key HWP coefficients were calculated using standard USFS methods:

- incremental increase in carbon in the growing stock volume of forests treated to improve productivity (35.6 tons C/ac, see Table A2)
- of this, the amount of that carbon that remains stored in products in use and landfills 100-years after harvests (7.4 tons C/ac, or 21% of 35.6 tons C/ac, see Table A5)

The USFS methodology uses growing stock volume in metric units as a starting point. The incremental increase in growing stock volume of high productivity stands was used as a starting point for this analysis: 3,409 cubic feet per acre converts to 235 cubic meters per hectare (m3/ha). Thus, all factors calculated below represent increases above baseline productivity levels.

A series of default coefficients for the Southeast region were applied to the increase of 235 m3/ha, to apportion the fraction of growing stock volume into classes of softwoods and hardwoods (Table A1). The specific gravity of hardwoods and softwoods are combined with the carbon content in biomass to calculate separate per-area carbon volumes for hardwood and softwood classes (Table A2).

Table A1. Softwood and Hardwood fractions in the growing stock volume, for Loblolly-shortleaf stands in the Southeast (US GTR NE-343 Table 4)

	Factor
Incremental increase in growing stock volume (m3/ha) (i.e., 3,409 cuft/ac converted to metric units)	235
Fraction of growing stock volume that is softwood	0.880
Fraction of softwood growing stock volume that is sawtimber-size	0.653
Fraction of hardwood growing stock volume that is sawtimber-size	0.358
Specific gravity of softwoods	0.470
Specific gravity of hardwoods	0.516
Carbon content in biomass	0.5

Table A2. Calculated Carbon Content of Softwood and Hardwoods Harvested from Loblolly-shortleaf stands in the Southeast

	Tons C/ha
Softwood saw log carbon in growing-stock volume	31.67
Softwood pulpwood carbon in growing-stock volume	48.50
Hardwood saw log carbon in growing-stock volume	2.60
Hardwood pulpwood carbon in growing-stock volume	4.66
Total (tons C/ha)	87.43
Total (tons C/ac)	35.58

The quantity of carbon in hardwoods and softwoods that is processed into primary wood products was calculated next (factoring out carbon in logging residue, fuelwood, and waste), using the ratios in Table A3 for the South. The results are approximate per-area carbon stocks (tons carbon per hectare) in industrial roundwood, excluding bark and fuelwood (Table A4).

Table A3. Ratios of Industrial Roundwood produced from Hardwood and Softwood classes in the Southern Region of the US (USFS GTR NE-343 Table 5)

	Ratio of industrial RW to growing stock volume removed as RW	Ratio of carbon in bark to carbon in wood	Fraction of growing stock volume removed as roundwood	Ratio of fuelwood to growing stock volume removed as RW
Softwood Saw log	0.99	0.182	0.891	0.019
Softwood Pulpwood	1.246	0.185	0.891	0.019

Hardwood Saw log	0.832	0.198	0.752	0.301
Hardwood Pulpwood	1.191	0.218	0.752	0.301

Table A4. Calculated Carbon Content of Harvested Wood that Produces Industrial Roundwood

	(tons C/ha)
Softwood saw log carbon in industrial roundwood	27.94
Softwood pulpwood carbon in industrial roundwood	53.84
Hardwood saw log carbon in industrial roundwood	1.63
Hardwood pulpwood carbon in industrial roundwood	4.17

The average disposition pattern of HWP over time in the Southeast is provided by the USFS methodology. The disposition pattern tracks the flow of softwood and hardwood classes of industrial roundwood through four "pools" over time: carbon in HWP in use, carbon in HWP in landfills, carbon in HWP emitted with energy capture, and carbon in HWP emitted without energy capture. Disposition patterns are provided separately for softwood and hardwood categories and are represented by the fraction of carbon remaining in each pool over time.

Table A5 shows the fraction remaining 100-years after harvest for the Southeast by softwood and hardwood classes. These fractions were multiplied by the corresponding initial carbon contents shows in Table A4 to yield the carbon content remaining 100-yrs post harvest in each pool. The net carbon stock change in HWP is calculated as the total amount of carbon remaining in HWP *in use* or *landfills* after 100-yrs (the other two pools represent carbon emissions).

Table A5. Fraction of Carbon in HWP Pools 100-yrs Post Harvest (USFS GTR NE-343 Table 6) and Corresponding Calculated Per-area Carbon Stock.

	Disposition Factor for 100-yrs	**Carbon Stock (tons C/ha)**
Softwoods-Sawlog		
in use	0.104	2.91
landfill	0.232	6.48
energy	0.386	10.78
emitted w/o energy	0.277	7.74
Softwoods-Pulpwood		
in use	0.036	1.94
landfill	0.105	5.65
energy	0.463	24.93
emitted w/o energy	0.396	21.32
Hardwoods-Sawlog		
in use	0.037	0.06
landfill	0.267	0.43
energy	0.361	0.59
emitted w/o energy	0.335	0.54
Hardwoods-Pulpwood		
in use	0.063	0.26
landfill	0.125	0.52
energy	0.385	1.61

emitted w/o energy	0.427	1.78
Total stored C 100 yrs post harvest (tons C/ha)		18.26
Total stored C 100 yrs post harvest (tons C/ac)		7.43

Key Assumptions: Pending

Reforestation

Data Sources: Forest carbon stocks from Southern region tables in the 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 on distribution of forest types in SC from USFS Forest Inventory Analysis 2006 inventory data published online. Cost are from a similar analysis for North Carolina.

Quantification Methods:

A weighted average annual rate of carbon sequestration for young-aged forests in SC was calculated as 1.1 tons C/ac/yr using data on carbon stocks by age class published by the USFS for the three most dominant forest groups, totaling 80% of private forestland in SC (Table 1). For each forest type group, annual carbon sequestration rates were calculated by subtracting carbon stocks in new stands (0 yrs) from carbon stocks in 15-yr old stands and dividing by 15 yrs. An average rate was calculated, weighted by area of each forest type to take into account variation in carbon sequestration across forest types. A fifteen-year rate was used to reflect the average age of forested stands during the timeframe of analysis. Young stands typically sequester carbon at faster rates than older stands.

Table 1. Data on carbon stocks, 15-yr annual average sequestration rates, and area by forest type, used to calculate a weighted average annual sequestration rate for forestation.

	Carbon Stocks at Age 0 yrs (tons C/ac)	Carbon Stocks at Age 15 yrs (tons C/ac)	Average Annual Sequestration (tC/ac/yr)	Area in 2006 (acres)
Loblolly-shortleaf pine				
Soils	22.1	22.8		
Biomass*	1.7	18.7		
Total	23.8	41.5	1.180	4,750,214
Oak Hickory				
Soils	13.7	14.1		
Biomass*	1.7	16.6		
Total	15.4	30.7	1.020	2,758,022
Oak-gum-cypress				
Soils	48	49.3		
Biomass*	0.7	15.1		
Total	48.7	64.4	1.047	1,684,321
Area weighted average				1.108

* Includes live trees, standing dead wood, understory, down dead wood, and litter/debris on the forest floor

Estimated annual acres of land to be refforested were derived from the policy goal, which is to plant a 120,000 acres per year until 2012 (for a total of 1.4 million acres). Approximately 70,000 acres per year are currently planted (G. Sabin, personal communication), thus the goal represents an increase of 50,000 acres planted per year (for a total of 600,000 acres). At this rate, 25% of the total additional acres will be planted by 2012,which is also articulated in the timing of the policy goals.

A forest continues to accumulate carbon each year after it is planted; thus, to calculate the carbon sequestration attributed to this policy option, the weighted average annual carbon sequestration rate was multiplied by the cumulative acres of additional forestland planted each year since 2009. Forested acres (annual and cumulative) and annual total carbon sequestration is shown in Table 2. Reductions are calculated in tons of carbon and converted to standard units of million metric tons of carbon dioxide equivalent (MMtCO2e).

Table 2. Calculation of annual carbon sequestration from and costs to implement refforestation from 2009 to 2020.

	Increase in Acres Planted	Cumulative Increase in Acres Planted	Carbon Sequestration (tons C/yr)	Carbon Sequestration (MMtCO2e/yr)	Cost ($)	Discounted cost ($)
2009	50,000	50,000	55,378	0.20	$17,000,000	$17,000,000
2010	50,000	100,000	110,757	0.41	$17,000,000	$16,190,476
2011	50,000	150,000	166,135	0.61	$17,000,000	$15,419,501
2012	50,000	200,000	221,513	0.81	$17,000,000	$14,685,239
2013	50,000	250,000	276,891	1.02	$17,000,000	$13,985,942
2014	50,000	300,000	332,270	1.22	$17,000,000	$13,319,945
2015	50,000	350,000	387,648	1.42	$17,000,000	$12,685,662
2016	50,000	400,000	443,026	1.62	$17,000,000	$12,081,583
2017	50,000	450,000	498,404	1.83	$17,000,000	$11,506,269
2018	50,000	500,000	553,783	2.03	$17,000,000	$10,958,352
2019	50,000	550,000	609,161	2.23	$17,000,000	$10,436,525
2020	50,000	600,000	664,539	2.44	$17,000,000	$9,939,548
Total	600,000			15.84		$158,209,042

The cost of of $340/acre was estimated based on average costs for tree planting through a typical cost share program, as reported for North Carolina in a similar policy option.[62] In reality, costs will vary depending on specific goals of the tree planting project, species planted, and site conditions. Potential future cost savings from forest products (e.g., merchantable timer or bioenergy feedstocks) is not taken into account. These cost savings would likely not be realized during the timeframe of this analysis.

Annual costs were calculated by multiplying the number of acres planted each year by $340/acre (Table 2). Annual costs were discounted using a 5% rate to convert future dollars to present values. The sum of annual discounted costs from 2009-2020 yields an estimate of the Net Present Value (NPV) of this option, which is on the order of $158 million. The cost

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[62] Note MN DNR reports similar costs ranging from $350-$400 per acre to plant trees in existing agricultural fields, including the cost of planting stock, herbicide treatments, equipment rental, labor, and upkeep for the first two years.

effectiveness is calculated by dividing the NPV by the cumulative GHG benefit of 15.84 MMtCO2e over the same time frame, yielding a cost effectiveness of $10 per ton of CO2e saved.

Key Assumptions: Pending

Urban Forestry

Quantification in Progress

Initial Data Gathered Shown Below

SC Urban Tree Cover and Carbon Sequestration
Source for urban tree cover and carbon sequestration:
http://www.ncrs.fs.fed.us/pubs/jrnl/2001/nc_2001_Nowak_001.pdf
Also published in Urban Tree and Tree Cover Data from: Nowak, David J.; Mary H. Noble, Susan M. Sisinni, and John F. Dwyer. (2001) Assessing the US Urban Forest Resource. Journal of Forestry; 99(3): 37-42 **.**

- Urban trees (#): 86,696,000
- Urban tree cover in SC = 39.8%
- Portion of state tree cover: 3.6%
- Urban area (km2): 4380
- Portion of state that is urban: 5.3%
- Carbon storage: 16,125,000 tonnes C
- Gross Carbon Sequestration: 523,000 tonnes C/yr
- (Note USEPA uses a ratio of 0.7 to convert gross to net carbon sequestration in urban trees)
- Urban = area occupied by the union of three census-defined urban designations: (1) urbanized areas (poop of 50,000 or more and a minimum pop density of 384 people per km2; (2) places (concentrations of people in incorporated or census-designated areas that have a name, are locally recognized, and are not partfo any other place) the contain some urbanized areas within their boundaries; and (3) urban places (places with at least 2,500 people and located outside of urban areas). Also includes areas totally surrounded by urbanized areas but no within an urbanized boundary.

  Data from USFS indicate that SC has already achieved the levels of urban forest cover recommended by American Forests Urban Tree Canopy Program).

Notes on Urban Tree goals:

- There are two types of GHG benefits associated with urban trees: carbon sequestration in tree biomass; and avoided energy-related emissions when trees are planted strategically for shading and wind reduction.

Data on growth in housing units in SC (may help determine how many trees planted under this program are designed for strategic planting around housing units)

- US Census Bureau reports a 12.7% increase in housing stock in SC from 2001-2006, with 1,753,670 housing units estimated in April 2001 and 1,975,638 estimated in 2006
- Approximately 37,000 housing units are built per year in SC.
- Three additional trees on all units would be 111,000 trees per year

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-7. Conservation and Restoration of Forest and Agriculture Lands for Enhanced Carbon Sequestration

AFW-7(a). Conservation and Restoration of Agricultural Lands for Enhanced Carbon Sequestration

Policy Description

In agricultural lands, soil carbon levels can be higher than those converted to developed use. By conserving agricultural lands, GHG emissions can also be reduced indirectly by influencing more efficient development patterns (leading to lower vehicle-miles traveled). Therefore, a suitable policy for carbon sequestration is to incorporate methodologies that reduce the rate at which the existing base of South Carolina agricultural acreages are cleared and converted to developed uses.

Policy Design

Goals: Reduce the rate at which agricultural lands are converted to developed use by 50% by 2020 from current levels.

Timing: By 2012, reduce the rate of conversion by 20% from current levels. By 2020, reduce the rate of conversion by 50%.

Parties Involved: SC Parks Recreation & Tourism, SC Department of Natural Resources, SC Conservation Bank, SC Department of Agriculture, Santee Cooper, SC Farm Bureau, US Fish & Wildlife Service, US Park Service, Clemson University, NGOs (including but not limited to SC Forestry Association, Ducks Unlimited, The Nature Conservancy, Lowcountry Open Land Trust, Congaree Land Trust, etc.)

Other: SC forest and agricultural land conversion 9th in US at 539,700 acres from 1992-97; rate of increased conversion of 30.2% increasing from 13.0% (1982-87) and 14.1% (1987-92).[63] Table XX below displays the total agricultural land lost to developed uses between 1982 and 1997.[64] This data shows an annual decrease in agricultural lands of 81,000 from 1992-1997, a 10.7% change in total area.

Table XX: South Carolina Agricultural Land lost to Developed Uses 1982-1997

Land lost to developed uses (1982-1997)	**1,000 acres**
Cultivated cropland	175.8

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[63] London, James B. and Nicole L. Hill. 2000. Land conversion in South Carolina: State makes top 10 list. Jim Self Center on the Future. Clemson University. 6 p.

[64] Natural Resources Conservation Service. SC NRI data provided by the NRCS national office. Provided to J Pryor on February 5, 2008 by Marjorie Harper via e-mail.

Pastureland	74.6
Minor land cover/uses	18.2
Total	268.6

Implementation Mechanisms

Policy design considerations include:

(1) Emphasis of grant and partnership opportunities to utilize fee title acquisition to acquire additional State Forest, State Park and Wildlife Management Area lands from willing sellers while incorporating sound forest management plans optimizing forest carbon sequestration on acquired acreage;

(2) Emphasis of opportunities to sequester additional carbon through voluntary private land conservation easements to decrease land conversion and protect agricultural acreage from development;

(3) Utilization of state income tax credit for donations or bargain sales of conservation easements including the potential increase of tax benefits to incentivize agricultural landowners.

Fee Title Acquisitions, Private land Conservation Easements, Landowner Incentives, Infusion of additional funds into the SC Conservation including earmarking some or all of the increase to go to projects that conserve lands where the proposed uses will increase carbon sequestration.

Related Policies/Programs in Place

A change in Federal tax law is in place for land put into conservation easement through 2007 allowing property owners to offset half of tax liability for 15 years. SC Conservation Bank.

Governor Mark Sanford has proposed a $50 million increase to the South Carolina conservation bank's land fund for 2008.[65]

Type(s) of GHG Reductions

CO2: Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass.

Estimated GHG Reductions and Net Costs or Cost Savings

TBD – [CCS should provide a worksheet and other reference material as needed for transparency]

Data Sources:

As indicated below.

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[65] "Sanford wants to add $50 million to land fund." *The State*. Posted on Tuesday, December 11, 2007. Accessed on January 4, 2008 from; http://www.thestate.com/politics/v-print/story/254330.html.

Quantification Methods:

GHG Benefit

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 estimating the annual rate of agricultural land lost to developed use (determined to be almost 18,000 acres per year from NRI South Carolina data) and assuming that agricultural land protected at an increasing rate up to 2020, where it is assumed loss of agricultural lands is reduced by 50%.
2. multiplying the soil carbon content (0.017 MMtC per 1000 acres[66]) 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 CO2 by multiplying by 44/12, to factor in the different relative weights of carbon and carbon dioxide.

Costs

To estimate program costs in each year, CCS multiplied the estimated agricultural acres protected from development by the conservation cost. The conservation costs were assumed to be $1,461 across the policy period, which is the average easement cost per acre for South Carolina in 2007FY (Financial Assistance Dollars Obligated was $1,189,345 and Number of Acres was 814) from Farm and Ranch Lands Protection Program (FRPP)[67]. It is assume that subsidies are available through the Farm and Ranch Land Protection Program (FRPP)[68] for a 50% cost share. Subsidies received through the FRPP are excluded from the program costs. The resulting cost effectiveness is approximately $36/MMtCO2-e. 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.

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[66] Franzluebbers, A.J., B. Grose, L.L. Hendrix, P.K. Wilkerson, B.G. Brock, "Surface-Soil Properties in Response to Silage Intensity under No-Tillage Management in the Piedmont of North Carolina", presented at the 25th Southern Conservation Tillage Conference for Sustainable Agriculture, Auburn, AL, June 24-26, 2002.

[67] See http://www.nrcs.usda.gov/programs/frpp/2007_Easements/2007FRPPEasements.html

[68] The FRPP provides matching funds (up to 50%) to keep productive farm and ranchland in agricultural uses. Working through existing programs, USDA partners with State, tribal, or local governments and non-governmental organizations to acquire conservation easements or other interests in land from landowners.

Table X: GHG Benefits and Costs from Reduced Agriculture Land Conversion

	Assumed percentage of goal achievement	Ag Acres Saved	MMtCO2e Saved	Costs	Discounted Costs
2008	4%	344	0.008	$503,147	$434,637
2009	8%	689	0.016	$1,006,294	$827,880
2010	12%	1,033	0.024	$1,509,441	$1,182,686
2011	15%	1,377	0.032	$2,012,588	$1,501,824
2012	19%	1,722	0.040	$2,515,735	$1,787,886
2013	23%	2,066	0.048	$3,018,882	$2,043,298
2014	27%	2,411	0.056	$3,522,029	$2,270,331
2015	31%	2,755	0.064	$4,025,176	$2,471,109
2016	35%	3,099	0.072	$4,528,323	$2,647,616
2017	38%	3,444	0.080	$5,031,470	$2,801,711
2018	42%	3,788	0.089	$5,534,617	$2,935,125
2019	46%	4,132	0.097	$6,037,764	$3,049,481
2020	50%	8,953	0.209	$13,081,821	$6,292,580

Key Assumptions:

Assume that the cost of easements remain constant (in nominal terms) over the policy period.

Key Uncertainties

Hurricanes, societal costs, tradeoffs, leakage

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-7(b). Conservation and Restoration of Forestlands for Enhanced Carbon Sequestration

Policy Description

Forests can play a substantial role in climate change by sequestering (or storing) carbon (by absorbing CO2) as trees grow and releasing it as they decay. Trees are powerful, relatively low cost concentrators of carbon. Young forests sequester carbon at a high rate, roughly proportional to forest growth in biomass. Old growth forests have a large balance of carbon stored over time in wood and soil.[69] Forests set aside to promote old growth result in long term carbon storage balance due to a negligible rate of additional carbon sequestration because of natural loss and decay at about the same rate as they are growing.[70] Land use changes resulting in forest conversion to other uses are generally believed to be a secondary source of net carbon release.[71] Much of the carbon stored in forest biomass and soils can be released as a result of such land use conversion in addition to the loss in future carbon sequestration. Therefore a suitable policy for carbon sequestration is to incorporate methodologies that promote long-term maintenance of the existing base of South Carolina (SC) forest acreages and support public policies that encourage and enhance carbon sequestration on those lands. Another appropriate policy to sequester carbon is to encourage the manufacture and use of durable wood products sequestering carbon over the life of the wooden product.

Conversion of cropland acreage to forest acreage can produce GHG benefits by adding above and below ground biomass (sequestering carbon) to the converted area. Also, the converted area is likely to sequester more carbon annually as forested area than cropland. This option also covers programs aimed at protecting forested areas that were previously converted (e.g., returned to active cultivation).

Policy Design

Goals: Reduce the rate of forest conversion to developed uses by 70% by 2020

Timing: Reduce the rate of forest conversion to developed uses by 10% by 2012, achieve a 70% reduction by 2020

Parties Involved: SC Forestry Commission, SC Forestry Association, SC Parks Recreation & Tourism, SC Department of Natural Resources, SC Conservation Bank, SC Department of Agriculture, Santee Cooper, SC Farm Bureau, US Fish & Wildlife Service, US Forest Service, US Park Service, Clemson University, NGOs (including but not limited to SC Forestry Association, Ducks Unlimited, The Nature Conservancy, Lowcountry Open Land Trust, Congaree Land Trust, etc.)

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[69] R.A. Sedjo. 2001. Forest carbon sequestration: Some issues for forest investments. Discussion Paper 01-34. 26 pp. Resources for the Future. Washington, DC. Available at: http://www.rff.org/Documents/RFF-DP-01-34.pdf

[70] B. Sohngen, R. Mendelsohn, and R. Sedjo. 1998. The Effectiveness of forest carbon sequestration strategies with system-wide adjustments. Available at: http://www-agecon.ag.ohio-state.edu/peole/sohngen.1/forests/effectc.pdf

[71] R.N. Stavins and K.R. Richards. 2005.The cost of US forest-based carbon sequestration. Pew Center for Global Climate Change. Available at: http://www.pewclimate.org/docUploads/sequest_Final.pdf

Other: Timberland area in SC in 1993 was 12,454,900 acres. SC timberlands declined by 142,000 acres from 1993 to 2000 (SRS-65)[72] and 263,600 acres from 1993-2001 (SRS-96)[73]. As can be seen in Table XX below, showing the specific land use changes involving timberlands, the largest category of timberland loss is from diversion to urban and other uses.

Table XX: Land Use Changes in South Carolina Timberlands; 1993-2000 & 1993-2001

Land Use Change	***1993-2000 Number of Acres***	***1993-2001 Number of Acres***
Timberland cleared for agriculture	-205,000	-182,400
Timberland diverted to urban and other uses	-392,000	-500,100
Timberland converted to lakes, ponds, or other impoundments	-51,000	-44,600
Timberland added through reforestation and natural regeneration	506,000	463,500
Total Change in Forestlands	-142,000	-263,600

The TWG notes that the most recent USFS FIA survey published for 2006 shows an increase in SC forest acreage from 12.4 million acres to 12.7 million acres. CCS is awaiting an updated report from Roger Conner including data from 2001-2006.

Implementation Mechanisms

Policy design considerations include:

(1) Placing land in protected status through the emphasis of grant and partnership opportunities to utilize fee title acquisition to acquire additional State Forest, State Park and Wildlife Management Area lands from willing sellers while incorporating sound forest management plans optimizing forest carbon sequestration on acquired acreage;

(2) Long-term protection of privately owned lands by seeking opportunities to sequester additional carbon through voluntary private land conservation easements to decrease land conversion and protect forest and agricultural acreage from development;

(3) Facilitate profitable management of existing forest and agricultural land uses by strengthening landowner technical assistance, cost-sharing such as the Forest Renewal Program, and education programs. Consider incentives to keep land in forest and

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[72] Conner, R.C., and R.M. Sheffield. 2001. "South Carolina's Forest Resources – 2000 Update." United States Department of Agriculture: Forest Service – Southern Research Station. Resources Bulletin SRS-65. Accessed on January 2, 2008 from: http://www.state.sc.us/forest/fia2000.pdf.

[73] Conner, R.C., et al 200?. "The State of South Carolina's Forests, 2001. USDA FS – Southern Research Station, Resources Bulletin SRS-96.

agricultural use through favorable tax treatment and protection from local regulation that impact land management activities. Encourage growth management efforts to recognize the value of maintaining forest and farm lands and discourage sprawl while respecting landowner rights.

(4) Provide additional funding for reforestation programs to convert idle agricultural acreage to forest land and more rapid reforestation of cut-over forest acreage, and

(5) Explore carbon markets as incentives for enhancing carbon sequestration on forest and farm lands. Consider opportunities for a state carbon registry and trading of carbon offsets.

Related Policies/Programs in Place

A change in Federal tax law is in place for land put into conservation easement through 2007 allowing property owners to offset half of tax liability for 15 years. SC Conservation Bank.

Governor Mark Sanford has proposed a $50 million increase to the South Carolina conservation bank's land fund for 2008.[74]

Type(s) of GHG Reductions

CO2: Avoided emissions of CO_2 from biomass and soils that would occur as a result of forest conversion to other uses; Protection of annual carbon sequestration capacity in forest biomass when conversion of forests is avoided.

Estimated GHG Reductions and Net Costs or Cost Savings

- **Estimated GHG Reductions in 2012, 2020 (MMtCO2e): 0.8, 5.78**
- **Estimated Cumulative GHG Reductions 2009-2020 (MMtCO2e): 24.9**
- **Estimate Cost Effectiveness: $6.39**

Data Sources: Forest carbon stocks from Southeast US defaults in the 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 on distribution of forest types in SC from USFS Forest Inventory Analysis data for 2006; data on forest conversion rates from "South Carolina's Forest Resources, 2000 and 2001 updates (USFS Resource Bulletins SRS-65 and SRS-96) and the Southern Forest Resource Assessment (2002) (http://www.srs.fs.usda.gov/sustain/report/index.htm); Assumptions about carbon losses from (a) Strong, T.F., 1997 "Harvesting Intensity Influences the Carbon Distribution in a Northern Hardwood Ecosystem," USFS Research Paper NC-329 and (b) "The Intersection of Land Use History and Exurban Development: Implications for Carbon Storage in the Northeast" Undergraduate Thesis, K. Austin, 2006; cost data from NC CAPAG Agriculture Forestry and Waste Policy Option, "Preservation of Working Lands-Forest Land".

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[74] "Sanford wants to add $50 million to land fund." *The State*. Posted on Tuesday, December 11, 2007. Accessed on January 4, 2008 from; http://www.thestate.com/politics/v-print/story/254330.html.

Quantification Methods:

GHG Benefits

This option maintains a certain area of forestland that would otherwise be converted to development, assuming historic rates of forest conversion continue out into the future. The carbon savings are estimated from two sources: the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., "avoided emissions"); and the amount of annual carbon sequestration in the forest area that is not converted to development under this option (i.e., "protection of carbon sequestration potential").

Baseline future rates of forest conversion were calculated from land use change data reported by the US Forest Service Forest Inventory Analysis (FIA) for 1993-2000 (Table 1). These data indicate a baseline forest conversion rate (timberland converted to urban or other uses, not including agriculture) of about 0.46% per year [NOTE: CCS is awaiting data from FIA for 2001-2006, which we will use to update the baseline forest conversion rate. FIA data for 1993-2001 indicate a conversion rate of 0.50% per year, which we will use if the more recent FIA data do not become available in time]. For comparison, the Southern Forest Resource Assessment (2002) projects forest conversation rates to urban uses ranging from 5-8% over the period of 1992-2020 for the entire southern region. This translates to annual forest conversion rates for the southern region on the order of 0.2-0.3%/year. Forest conversion is projected to be concentrated in a few key regions, including the Piedmont area of South Carolina, indicating South Carolina will tend toward the high end of the projected range for the southern region. Theses data suggest that the 0.46%/yr conversion rate calculated from FIA is a reasonable, though higher, approximation of future conversion trends.

The area of forestland converted to development each year starting in 2007 was estimated at 59,330 acres/yr, using the 0.46%/yr conversion rate and 2006 area of forestland reported by the FIA (12,894,218 acres).

Table 1. Timberland and Forestland Conversion Rates

	Value
Timberland in 1993 (acres)	12,170,500
Timberland converted to urban and other uses during 1993-2000 (acres)	392,000
Timberland conversion rate (ac/yr)	56,000
Timberland conversion rate (%/yr)	0.46%
Forestland area in 2006 (acres)	12,894,218
Projected Annual Forestland Conversion Rate 2009-2020 (ac/yr)	59,330

At the goal levels specified by this option, the baseline rate of forest conversion to development would be reduced by 10% by 2012 and 70% by 2020. This amounts to the avoided conversion of 5,933 acres/yr by 2012 and 41,531 acres/yr by 2020.

Loss of forests to developed uses typically results in the near complete removal of forest trees and other biomass, as well as significant soil disturbance, causing a substantial one-time loss of carbon stocks stored in forest biomass and soils. For this analysis, it was assumed that 53% of carbon stocks in biomass and 35% of carbon stocks in soils would be lost in the event of forest conversion, with no appreciable carbon sequestration in soils or biomass following development. The biomass loss assumption is based on research that shows heavy levels of individual tree removal results in the harvesting of 53% of carbon in aboveground biomass (Strong 1997). In this analysis, the potential long-term storage of carbon in durable wood products is not taken into account and all harvested carbon is considered a loss of carbon. The soil carbon loss assumption was based on a study that shows about a 35% loss of soil carbon when woodlots are converted to developed uses (Austin, 2006).

Weighted average forest carbon stocks (tons carbon per acre), weighted by forest group dominance, are multiplied by the anticipated percentage loss of carbon due to development (e.g., 53% for biomass and 35% for soils) to yield avoided emissions coefficients. Average forest carbon stocks are taken from carbon yield tables published by the USFS (USFS GTR NE-343). Because carbon stocks generally increase with stand age and vary by forest type, carbon stock values were chosen for the three dominant forest types in SC, at their mature age class. “Mature age class” is the oldest stand age at which at least 75% of the forests area is in this age class or younger (e.g. 75% of all Loblolly-shortleaf pine stands are 30 years or younger in SC, thus, the mature age class for Loblolly-shortleaf pine is 30 years). To estimate avoided emissions, the avoided emissions coefficients for biomass and soils are multiplied by the acres of forests that avoid conversion each year (Table 3).

Table 2a. Data used to calculate avoided emissions and protected sequestration coefficients for biomass and soils

	Loblolly shortleaf pine	*Oak-hickory*	*Oak-gum-cypress*
Mature Age Class (yrs)	30 yrs	60 yrs	70 yrs
Relative Dominance	52%	30%	19%
Biomass carbon stocks in new stands (tons C/ac)	10.70	8.5	7.3
Soil carbon stocks in new stands (tons C/ac)	29.50	18.3	63.9
Biomass carbon stocks at maturity (tons C/ac)	32.7	54.3	58.7
Soil carbon stocks at maturity (tons C/ac)	29.5	18.3	63.9
Sequestration rate (tons C/ac/yr)	0.73	0.76	0.73

Table 2b. Avoided emissions and protected sequestration coefficients

Avoided emissions*	tonsC/ac
Biomass	23.3
Soils	11.4
	tonsC/ac/yr
Protected sequestration *	0.74

*Weighted by forest group dominance

Forests that are protected from conversion in one year continue to sequester carbon in subsequent years, which is carbon sequestration that would not have occurred if the forest were converted to development. This is estimated and included as an additional GHG benefit using a weighted average annual carbon sequestration rate (Table 2b). For the three dominant forest groups in SC, carbon sequestration rates were calculated by subtracting carbon stocks at maturity from carbon stocks in new stands (age class 0 years) and divided by the number of years to maturity. The weighted average was calculated based on the relative dominance of the three forest groups. Soil carbon stocks are constant across stand age in the published yield tables, therefore, sequestration in soils is assumed to be zero in the analysis.

Annual sequestration is calculated by multiplying the cumulative forest acres that avoided development each year by the average carbon sequestration rate (Table 3). Cumulative acres are used because forests that are protected from conversion in one year continue to sequester carbon in subsequent years. All estimates are converted from tons carbon to million metric tons of CO_2 equivalent ($MMTCO_2e$).

Table 3. Estimated GHG Reductions from Avoided Emissions and Protected Sequestration Capacity

	Acres Protected	Avoided Emissions - Biomass (tons C)	Avoided Emissions - Soils (tons C)	Total Avoided Emissions (tons C)	Protected Sequestration Capacity (tons C)	Total (MMtCO2e)
2009	1,483	34,567	16,947	51,514	1,101	0.19
2010	2,967	69,133	33,894	103,027	3,303	0.39
2011	4,450	103,700	50,841	154,541	6,607	0.59
2012	5,933	138,266	67,789	206,055	11,011	0.80
2013	4,450	103,700	50,841	154,541	14,315	0.62
2014	8,900	207,399	101,683	309,082	20,922	1.21
2015	13,349	311,099	152,524	463,623	30,832	1.81
2016	17,799	414,799	203,366	618,165	44,046	2.43
2017	22,249	518,499	254,207	772,706	60,563	3.06
2018	26,699	622,198	305,048	927,247	80,384	3.69
2019	31,148	725,898	355,890	1,081,788	103,508	4.35
2020	41,531	967,864	474,520	1,442,384	134,340	5.78
Total	180,957	4,217,122	2,067,551	6,284,673	8,352,223	24.92

Costs:

The typical cost of conservation easements in North Carolina, $1300/ac, was used as a basis for the per acre cost of acquiring land for the purpose of preventing forest conversion. [NOTE: This estimate should be updated with data from SC. The average cost to acquire forestlands/wetlands in the SC Conservation bank was calculated as $428.22, which is significantly lower than the reported costs for NC and other states. The SC Conservation Bank data may not take into account contributions from other entities, assuming the costs were shared in some cases]. 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 2009-2020. Annual discounted costs were estimated using a 5% interest rate. In 2009, annual discounted costs were $1,928,266 rising each year to a total of $31,567,030 in 2020 (Table 4). The cumulative cost effectiveness of the total program was calculated by summing the annual discounted costs and dividing by cumulative carbon sequestration, yielding $6.39/tCO2e.

Table 4. Estimated Annual Costs

	Acres Protected	Carbon Savings (MMtCO2e)	Cost	Discounted costs
2009	1,483	0.19	$1,928,226	$1,928,226
2010	2,967	0.39	$3,856,452	$3,672,812
2011	4,450	0.59	$5,784,679	$5,246,874
2012	5,933	0.80	$7,712,905	$6,662,697
2013	4,450	0.62	$5,784,679	$4,759,069
2014	8,900	1.21	$11,569,357	$9,064,894
2015	13,349	1.81	$17,354,036	$12,949,849
2016	17,799	2.43	$23,138,715	$16,444,252
2017	22,249	3.06	$28,923,393	$19,576,491
2018	26,699	3.69	$34,708,072	$22,373,133
2019	31,148	4.35	$40,492,751	$24,859,036
2020	41,531	5.78	$53,990,334	$31,567,030
Total 2009-2020	180,957	24.92		$159,104,365

Key Assumptions: [TBD, as needed on TWG approval]

Key Uncertainties

Hurricanes, societal costs, tradeoffs, leakage

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]

AFW-8. Advanced Recycling and Composting

Policy Description

Increase the use of recycling and composting as waste diversion methods in order to limit greenhouse gas emissions associated with landfill methane generation and to increase production efficiencies of raw materials and new products. In order to achieve the goals set forth below, it will be necessary to: increase awareness of the value of recycling, develop consistent recycling programs across counties, promote "best practices" comparisons across counties and between other states, increase recycling programs, create new recycling programs, provide incentives for the recycling of construction & demolition (C&D) waste[75], develop markets for recycled materials and compost, and increase average participation/recovery rates for all existing recycling and composting programs.

Policy Design

Goals: Increase recycling of municipal solid waste (MSW), as defined by the EPA, in the state to a total of 35% by 2020. Increase composting to 10% by 2020. (See Appendix 8-A for the results of a 50% recycling rate by 2020).

Timing: Achieve an MSW recycling rate of 30% and a composting rate of 5.25% by 2012.

Parties Involved: Municipal and county government, private solid waste and recycling management companies, commercial, industrial and institutional generators, and SC DHEC.

Other: Out of an estimated 4.97 million tons of MSW generated in the state of South Carolina in fiscal year 2006, 3.24 million tons were landfilled and 0.22 million tons were incinerated. The FY2006 diversion rate in South Carolina was 30.4%, or 1.5 million tons (diversion includes recycling and composting). Based on the 30.4% diversion rate, the current disposal rate is 4.4 lb/person/year. The FY2006 recycling rate in South Carolina was 24.8% and the composting rate was 5.54%.[76]

The Division of Mining and Solid Waste Management of the South Carolina Department of Health and Environmental Control provides county-level recycling information. Table 8-00 displays this information. Note that the recycling rate includes organic waste that may be managed through composting.

Table 8-00: State and County Recycling Data, FY 2006

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[75] Note: SC does not include construction and demolition debris within the calculation of recycling rates for MSW recycling.

[76] SC DHEC. "South Carolina Solid Waste Management Annual Report; Fiscal Year 2006." Accessed on November 20, 2007 from: http://www.scdhec.net/eqc/lwm/recycle/forms/swmr_06.pdf

County	Population	Recycling Rate (Including Organics) (%)	Recycled (Including Organics) (p/p/d)	Disposed (p/p/d)	Generation (p/p/d)	Recycled (Including Organics) (tons)	Disposed (tons)
Abbeville	26,133	24.9%	1.07	3.22	4.29	5,103	15,358
Aiken	150,181	30.5%	1.52	3.46	4.98	41,602	94,909
Allendale	10,917	34.6%	1.55	2.92	4.46	3,079	5,813
Anderson	175,514	42.0%	2.62	3.61	6.24	83,974	115,778
Bamberg	15,880	14.3%	0.66	3.96	4.62	1,909	11,481
Barnwell	23,345	25.8%	1.44	4.14	5.59	6,142	17,653
Beafort	160,900	33.8%	2.61	5.11	7.72	76,572	150,129
Berkeley	151,673	43.5%	3.36	4.37	7.73	93,003	120,920
Calhoun	15,100	15.9%	0.55	2.90	3.45	1,513	8,001
Charleston	330,368	35.2%	2.72	5.01	7.73	164,214	302,081
Cherokee	53,844	11.0%	0.60	4.84	5.44	5,853	47,589
Chester	33,228	15.8%	0.63	3.33	3.95	3,795	20,169
Chesterfield	43,435	32.6%	0.80	1.66	2.46	6,359	13,132
Clarendon	33,363	40.0%	1.02	1.52	2.54	6,187	9,276
Colleton	39,605	19.8%	0.71	2.87	3.58	5,127	20,727
Darlington	67,346	35.3%	1.62	2.96	4.58	19,854	36,390
Dillon	30,974	17.1%	0.91	4.42	5.32	5,141	24,957
Dorchester	112,858	26.9%	1.39	3.77	5.16	28,544	77,739
Edgefield	25,528	27.4%	1.08	2.86	3.94	5,024	13,329
Fairfield	24,047	20.2%	1.19	4.68	5.87	5,208	20,549
Florence	131,097	14.7%	0.88	5.12	6.00	21,139	122,469
Georgetown	60,983	23.2%	1.28	4.23	5.50	14,213	47,052
Greenville	407,383	27.5%	2.53	6.67	9.19	187,951	495,637
Greenwood	67,979	23.8%	1.85	5.92	7.77	22,963	73,487
Hampton	21,329	28.0%	1.71	4.39	6.10	6,657	17,101
Horry	226,992	33.4%	2.87	5.72	8.60	118,979	237,103
Jasper	21,398	19.1%	1.25	5.30	6.55	4,877	20,716
Kershaw	56,486	19.9%	0.82	3.30	4.12	8,457	34,065
Lancaster	63,113	30.3%	1.11	2.56	3.66	12,769	29,430
Laurens	70,293	27.1%	1.19	3.21	4.40	15,258	41,134
Lee	20,638	21.5%	0.78	2.85	3.63	2,948	10,741
Lexington	235,272	23.6%	1.10	3.56	4.67	47,329	153,031
Marion	34,904	18.9%	0.72	3.10	3.83	4,611	19,772
Marlboro	28,021	31.5%	1.10	2.39	3.48	5,603	12,201
McCormick	10,108	27.0%	0.89	2.41	3.30	1,642	4,448
Newberry	37,250	41.4%	4.20	5.96	10.16	28,573	40,497
Oconee	69,577	42.6%	2.76	3.72	6.48	35,054	47,204
Orangeburg	92,167	14.6%	0.78	4.53	5.31	13,041	76,268
Pickens	113,575	45.8%	1.81	2.14	3.94	37,482	44,281
Richland	340,078	14.1%	0.84	5.11	5.94	52,065	316,845
Saluda	18,895	21.6%	0.89	3.24	4.14	3,077	11,183
Spartanburg	266,809	43.6%	3.63	4.69	8.32	176,831	228,503
Sumter	105,517	21.1%	1.01	3.76	4.77	19,418	72,494

County	Population	Recycling Rate (Including Organics) (%)	Recycled (Including Organics) (p/p/d)	Disposed (p/p/d)	Generation (p/p/d)	Recycled (Including Organics) (tons)	Disposed (tons)
Union	28,539	27.9%	0.95	2.45	3.40	4,939	12,747
Williamsburg	35,395	21.2%	0.75	2.80	3.55	4,848	18,055
York	190,097	37.6%	2.64	4.38	7.01	91,482	151,829
STATE TOAL	**4,278,134**	**30.4%**	1.93	4.44	6.37	**1,510,409**	**3,464,273**

Implementation Mechanisms

- Review current exclusions from the landfill to determine if there are possible additions – if so, recycling programs will need to be considered
- Establish C&D recycling targets and create a draft program
- Support increased business recycling efforts, e.g. SC Smart Business Recycling Program
- Establish ewaste recycling targets and a draft program – several states can be used as models (Maryland, California, Washington and Maine)
- Investigate a separate recycling program for the statewide hospitality industry (Note: NC will soon ban from landfills all alcohol beverage containers collected from restaurants)
- Evaluate and make recommendations relative to SC pilot programs to increase household/municipalities recycling rates – e.g. Charleston County
- Investigate national pilot programs to increase household/municipalities recycling rates – e.g. RecycleBank programs in Philadelphia and Wilmington, DL
- Investigate local and state level programs to increase household and commercial composting opportunities – e.g. Cobb County, GA has a well recognized commercial composting program, a NJ university installed a rotary digester/composting system to handle food waste
- Continue to evaluate, revise and fund education efforts aimed at consumers and businesses to increase awareness of the value of recycling and participation levels in recycling programs – Create a mandate to participate
- Continue efforts to improve reporting at the county level to make certain there is consistency across the counties
- Implement a “best practices” approach across all SC counties to improve overall recycling and composting levels
- Implement a “best practices” approach nationally to uncover innovative and effective actions to improve overall recycling and composting levelsIncrease the emphasis on alignment among state, county and local solid waste plans

Related Policies/Programs in Place

The S.C. Solid Waste Policy and Management Act of 1991 (Act) established the state’s approach to solid waste management. The Act sets statewide recycling and disposal goals. DHEC is required to publish a comprehensive annual report – based in part on the required information that counties provide – on solid waste management in the state for the previous fiscal year (FY). The annual report is an excellent source of current and historical information and recommendations relative to solid waste management in SC.

The Recycled Market Development Advisory Council, SC Department of Commerce, is a source of recent actions for Advanced Recycling. Another program to promote business recycling is the "Smart Business Program". DHEC is also issuing a new rule covering composting. This rule is due to be out in late July and covers wood waste only. Dept. of Commerce is currently considering incentives for recycling, especially business recycling. DOC is also considering waste-to-energy options and compost options. The South Carolina Recycling Market Development Advisory Council managed by the Department of Commerce maintains an ongoing program to explore market opportunities for recycled materials in SC. The RMDAC has recently produced a study of the "Economic Impact of the Recycling Industry in South Carolina." The RMDAC meets bi-monthly to "raise awareness of the current state of recycling in South Carolina through various marketing strategies." The Annual Report of the RMDAC is a resource for an overview of the current status of the recycling industry in SC. [Note to TWG, the CECAC would like to see information on current levels of recycling by county; should be available through DHEC] (This information is in the DHEC Annual Report at a high level of detail and should be available in greater detail as part of the Re-TRAC web based data collection system).

Type(s) of GHG Reductions

CH_4, CO_2: Methane reductions from avoided methane emissions from waste placed into landfills; GHG reductions from lower energy consumption associated with a reduction of wastes generated (e.g. energy used to create products or packaging); GHG reductions from lower energy consumption associated with utilizing recycled materials for production versus raw (virgin) materials.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2012, 2020 (MMtCO_2e): 1.18, 3.01

Net Cost per MtCO_2e: -$2.21

Data Sources: Data on current waste generation and recycling rates were taken from the Fiscal Year 2006 South Carolina Solid Waste Management Annual Report.[77] DHEC reports the composting of yard trimmings and food wastes as a part of the recycling stream in the FY2006 SWM report. The breakdown of the waste disposed in Maryland by type was derived from US-level data provided in the EPA 2005 Waste Characteristics Report.[78] GHG emission reductions were modeled using the U.S. Environmental Protection Agency's (EPA's) Waste Reduction Model (WARM).[79] Table 8-1 displays the historical data contained within the Annual Waste

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[77] *South Carolina Solid Waste Management Annual Report – FY2006.* SC DHEC: Division of Mining and Solid Waste Management. Accessed on December 13, 2007 from http://www.scdhec.gov/environment/lwm/recycle/pubs/swmr_06.pdf.

[78] *Municipal Solid Waste in the United States, 2005 Facts and Figures*, US EPA, Office of Solid Waste, EPA530-R-06-011, October 2006. Accessed on December 30, 2007 from: http://www.epa.gov/garbage/pubs/mswchar05.pdf.

[79] Version 8, May 2006. From http://www.epa.gov/climatechange//wycd/waste/calculators/WARM_home.html. EPA created WARM to help solid waste planners and organizations track and voluntarily report GHG emission reductions from several different waste management practices. WARM is available both as a Web-based calculator and as a Microsoft Excel spreadsheet. WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates

Management reports from fiscal years 2002-2006.[80] Note that waste characterization provided by the FY2002 and FY2003 reports did not provide information on the diversion of organic wastes in those years.

Table 8-1: Historical Disposal, Diversion, and Generation Data for South Carolina, 2002-2006.

Item	2002	2003	2004*	2005	2006
Landfill Disposal	2,921,378	3,059,022	3,111,627	3,219,645	3,239,763
Waste to Energy (Incinerator Disposal)	208,626	201,146	227,802	227,031	224,506
Diversion	1,262,331	1,318,119	965,916	1,222,098	1,510,409
Diversion %	28.7%	28.8%	22.4%	26.2%	30.4%
Recycling	1,262,331	1,318,119	775,408	929,454	1,234,596
Reycling %	28.7%	28.8%	18.0%	19.9%	24.8%
Composting	NA	NA	190,508	292,644	275,813
Composting %	NA	NA	4.42%	6.27%	5.54%
Total Generation	**4,392,335**	**4,578,287**	**4,305,345**	**4,668,774**	**4,974,678**
% Change		4.23%	-5.96%	8.44%	6.55%
Average Annual Change					3.31%
*Per conversation with Richard Chesley of SC DHEC, data collection practices changed at DHEC, causing a shift in the waste management profile.					

Quantification Methods:

GHG Benefits

The GHG benefits resulting from increased recycling and composting in South Carolina are quantified by:

1. Establishing business-as-usual (BAU) projections for landfill disposal, incineration, recycling, and composting;
2. Using the goals set forth by the TWG to project the policy scenario for waste management;

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emissions in tCe, tCO_2e, and energy units (million Btu) across a wide range of material types commonly found in MSW. For an explanation of the 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/wycd/waste/SWMGHGreport.html

[80] Annual reports from FY2004-2006 are available online at: http://www.scdhec.gov/environment/lwm/recycle/resource_center.htm. Reports from FY 2002-2003 were obtained via mail from SC DHEC and are publicly available upon request.

3. Using recycling data from the SC SWM Annual Report and national-level generation and disposal data from the EPA 2005 Waste Characteristics study, disaggregate the SC recycling, composting and disposal data; and

4. Inserting the resulting waste characterization for the baseline and policy scenarios into the WARM model to determine the incremental GHG benefit resulting from the goals set forth in this policy option.

As reported, the baseline recycling and composting rates for MSW in South Carolina are 24.8% and 5.54%, respectively. Based on the change in MSW generation over the last 5 years, it is assumed that the BAU average annual increase in MSW generation is 3.31%. Additionally, it is assumed that 4.51% of MSW generated is managed at waste-to-energy incineration facilities. Population projections are consistent with those used in the development of the South Carolina Inventory and Forecast (I&F). These assumptions are used to develop the BAU waste management scenario depicted in Table 8-2.

Table 8-2: Business-as-Usual Waste Management Projection for South Carolina

Item	2006	2010	2012	2015	2020
MSW Generation (3.31%/yr growth 2002-2005)	4,974,678	5,666,755	6,048,103	6,668,778	7,847,983
SC Population (from I&F)	4,274,818	4,458,930	4,540,859	4,687,920	4,916,870
MSW Generation per capita (tons/person)	1.16	1.27	1.33	1.42	1.60
MSW Recycled (24.8% of generation, not including organics)	1,234,596	1,406,353	1,500,994	1,655,031	1,947,681
MSW Disposed in landfills	3,239,763	3,690,479	3,938,832	4,343,047	5,111,005
Waste to Energy (incineration, 4.51% of generation)	224,506	255,739	272,949	300,960	354,178
Organic Composting (5.54% of generation)	275,813	314,184	335,327	369,740	435,119

The policy goals set forth by the TWG are applied to the baseline recycling and composting tonnages to project the future waste management under the policy scenario. The tons disposed through other management techniques (landfill and incineration) are filled in by assuming that the share of waste disposed managed by each remains constant. Table 8-3 shows the projected management of waste generated in SC under the policy scenario and Table 8-4 shows the incremental waste diversion, or the difference between the policy and BAU scenarios.

Table 8-3: Waste Management Projection for South Carolina – Including Policy Goals

Item	2006	2010	2012	2015	2020
MSW Generation	4,974,678	5,666,755	6,048,103	6,668,778	7,847,983

Item	2006	2010	2012	2015	2020
MSW Recycled	1,234,596	1,504,244	1,814,431	2,125,673	2,746,794
MSW Disposed in landfills (after incremental recycling & composting)	3,239,763	3,590,882	3,619,935	3,780,939	4,036,662
Waste to Energy (incineration, 7.96% of waste not recycled or composted)	224,506	248,838	250,851	262,008	279,729
Organic Composting	275,813	322,791	362,886	500,158	784,798

Table 8-4: Incremental Diversion Under Policy Goals

Item	2006	2010	2012	2015	2020
Recycling	-	97,891	313,436	470,642	799,112
Landfill Disposal	-	-99,597	-318,897	-562,108	-1,074,343
Waste to Energy (incineration)	-	-6,902	-22,099	-38,952	-74,449
Organic Composting	-	8,607	27,559	130,419	349,680

The national baseline composition of waste generated is used to develop the breakdown of waste generation for South Carolina by waste type.[81] The waste types used for this analysis correspond to the disaggregated recycling information provided in the SC SWM annual repots and the inputs available for the WARM model. Table 8-5 shows the waste generation characteristics of broad waste categories and Table 8-6 shows the mix of generation by specific waste type within some of these categories. Again, the information in these tables is national data that are assumed to adequately represent the South Carolina waste stream.

Table 8-5: Waste Generation Characteristics, by Category

Category	Baseline Genearation Composition (BAU)
Paper	34.2%
Organics	25.0%
Mixed Plastic	11.8%
Metals	7.6%
Glass	5.5%
Other	15.9%

Table 8-6: Waste Generation Characteristics, by Waste Type

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[81] *Municipal Solid Waste in the United States, 2005 Facts and Figures*, US EPA, Office of Solid Waste, EPA530-R-06-011, October 2006. Accessed on December 30, 2007 from: http://www.epa.gov/garbage/pubs/mswchar05.pdf.

Waste Type	**Baseline Generation Composition (BAU)**
% of Discarded Paper	
Corrugated Cardboard	42.8%
Magazines/Third Class Mail	9.9%
Newspaper	14.4%
Office Paper	7.8%
Phonebooks	0.8%
Mixed Paper, Broad	24.3%
% of Discarded Organics	
Food Waste	47.7%
Yard Trimmings	52.3%
% of Discarded Plastics	
HDPE	25.9%
LDPE	28.1%
PET	11.8%
Other (assumed mixed plastics)	34.2%
% of Discarded Metals	
Aluminum Cans	17.1%
Steel	12.7%
Mixed Metals	70.2%

The mix of waste generation shown in Tables 8-5 and 8-6 are applied to the total waste generation in SC. Next, the shares of waste recycled and composted (Table 8-7) within each of these categories are multiplied by the total amount of waste recycled (or composted for "Food Waste" and "Yard Trimmings") to yield the amount of waste recycled or composted by waste type.[82]

Table 8-7: Recycled and Composted Waste Characteristics, by Category and Waste Type

	Tons Collected			
Total Disposed	***4,974,678***	***% of Total***		
Landfill	3,239,763	65.13%		
Incinerator	224,506	4.51%		
Total Recycled	***1,510,409***	***30.36%***		
Total Recycled (excluding organics)	***1,234,596***	***24.82%***	***% of Recycled***	

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[82] *South Carolina Solid Waste Management Annual Report – FY2006.* SC DHEC: Division of Mining and Solid Waste Management. Accessed on December 13, 2007 from http://www.scdhec.gov/environment/lwm/recycle/pubs/swmr_06.pdf.

Paper	***822,026***	***16.52%***	***66.58%***	***% of Paper****
Corrugated Cardboard	453,956	9.13%	36.77%	55.22%
Magazines/Third Class Mail	11,549	0.23%	0.94%	1.40%
Newspaper	131,431	2.64%	10.65%	15.99%
Office Paper	58,917	1.18%	4.77%	7.17%
Phone Books	936	0.02%	0.08%	0.11%
Mixed/Other	165,238	3.32%	13.38%	20.10%
Organics	***275,813***	***5.54%***	***NA***	***% of Organics***
Food Waste	24	0.00%	0.00%	0.01%
Yard Trimmings	275,789	5.54%	22.34%	99.99%
Plastic	***20,380***	***0.41%***	***1.65%***	***% of Plastic***
HDPE	6,887	0.14%	0.56%	33.79%
LDPE	1,668	0.03%	0.14%	8.18%
PET	2,504	0.05%	0.20%	12.29%
Mixed/Other	9,321	0.19%	0.75%	45.74%
Metal	***201,241***	***4.05%***	***16.30%***	***% of Metal****
Aluminum	34,791	0.70%	2.82%	17.29%
Steel	2,817	0.06%	0.23%	1.40%
Mixed/Other	163,633	3.29%	13.25%	81.31%
Glass	***11,090***	***0.22%***	***0.90%***	
Other (Mixed Recyclables)	***179,859***	***3.62%***	***14.57%***	
*FY2005 percentages used due to unusual results for FY2006 in these categories. Tons collected calculated from these percentages.				

Once the tonnages of waste generated, recycled, and composted are established. Subtracting the waste generated for each waste type by the diversion for the corresponding waste type disaggregates the waste landfilled and incinerated. The shares of waste disposed that are landfilled and incinerated in FY2006 are preserved throughout the policy period for both the BAU and Policy scenarios. Therefore, the waste disposed for each waste type is multiplied by 0.935 to yield the tons of waste landfilled and 0.065 for the tons of waste incinerated.[83]

The results of this process are entered into the EPA WARM model. The WARM inputs for 2020 are displayed in Tables 8-8 and 8-9.

Table 8-8: 2020 Baseline WARM Inputs

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	101,992	54,886	44,053	3,053	NA
Steel Cans	75,749	4,443	66,684	4,621	NA
Copper Wire					NA

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[83] (3,239,763 tons landfilled) / (3,239,763 tons landfilled + 224,506 tons incinerated) = 0.935

Material	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Glass	431,639	17,495	387,305	26,839	NA
HDPE	239,850	10,865	214,146	14,840	NA
LDPE	260,223	2,631	240,898	16,694	NA
PET	109,275	3,950	98,499	6,826	NA
Corrugated Cardboard	1,148,756	716,154	404,567	28,035	NA
Magazines/Third-class Mail	265,717	18,219	231,459	16,039	NA
Newspaper	386,497	207,343	167,544	11,610	NA
Office Paper	209,353	92,947	108,862	7,544	NA
Phonebooks	21,472	1,477	18,699	1,296	NA
Textbooks					NA
Dimensional Lumber					NA
Medium-density Fiberboard					NA
Food Scraps	935,872	NA	875,186	60,648	38
Yard Trimmings	1,026,124	NA	552,740	38,303	435,081
Grass		NA			
Leaves		NA			
Branches		NA			
Mixed Paper (general)	652,214	260,677	366,164	25,374	NA
Mixed Paper (primarily residential)					NA
Mixed Paper (primarily from offices)					NA
Mixed Metals	418,706	258,146	150,155	10,405	NA
Mixed Plastics	316,713	14,705	282,436	19,572	NA
Mixed Recyclables	1,247,829	283,743	901,607	62,479	NA
Mixed Organics		NA			
Mixed MSW		NA			NA
Carpet					NA
Personal Computers					NA
Clay Bricks		NA		NA	NA
Concrete[1]				NA	NA
Fly Ash[2]				NA	NA
Tires[3]					NA

Table 8-9: 2020 Policy WARM Inputs

Material	Baseline Generation	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	101,992	77,405	22,994	1,593	NA
Steel Cans	75,749	6,266	64,980	4,503	NA
Copper Wire	-				NA
Glass	431,639	24,674	380,592	26,374	NA

Material	Baseline Generation	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
HDPE	239,850	15,323	209,977	14,551	NA
LDPE	260,223	3,711	239,889	16,624	NA
PET	109,275	5,571	96,984	6,721	NA
Corrugated Cardboard	1,148,756	1,009,984	129,779	8,993	NA
Magazines/Third-class Mail	265,717	25,694	224,468	15,555	NA
Newspaper	386,497	292,414	87,986	6,097	NA
Office Paper	209,353	131,082	73,199	5,072	NA
Phonebooks	21,472	2,083	18,133	1,257	NA
Textbooks	-				NA
Dimensional Lumber	-				NA
Medium-density Fiberboard	-				NA
Food Scraps	935,872	NA	875,158	60,646	68
Yard Trimmings	1,026,124	NA	225,750	15,644	784,730
Grass	-	NA			
Leaves	-	NA			
Branches	-	NA			
Mixed Paper, Broad	652,214	367,629	266,142	18,443	NA
Mixed Paper, Resid.	-				NA
Mixed Paper, Office	-				NA
Mixed Metals	418,706	364,060	51,104	3,541	NA
Mixed Plastics	316,713	20,738	276,794	19,181	NA
Mixed Recyclables	1,247,829	400,160	792,735	54,934	NA
Mixed Organics	-	NA			
Mixed MSW	-	NA			NA
Carpet	-				NA
Personal Computers	-				NA
Clay Bricks	-	NA		NA	NA
Concrete[1]	-			NA	NA
Fly Ash[2]	-			NA	NA
Tires[3]	-				NA

The results of the WARM analysis predict a GHG benefit of 1.18 MMtCO$_2$e in 2012 and 3.01 MMtCO$_2$e in 2020. Assuming the program implementation begins in 2010 and a linear increase in emissions reductions between target years, the cumulative GHG benefit is estimated to be 20.1 MMtCO$_2$e through 2020 (see Table 8-10).

Table 8-10: Overall Policy Results – GHG Benefits

Year	Avoided Emissions (MMtCO2e)	Incremental Waste Diversion (tons)	Incremental Composting (tons)	Incremental Recycling (tons)	Avoided Landfill Emplacement (tons)	Avoided WTE Emplacement (tons)

2009	-	-	-	-	-	-
2010	0.39	106,498	8,607	97,891	-99,597	-6,902
2011	0.79	220,047	17,784	202,263	-205,786	-14,260
2012	**1.18**	340,995	27,559	313,436	-318,897	-22,099
2013	1.41	422,576	59,713	362,863	-395,190	-27,386
2014	1.64	509,183	93,965	415,218	-476,185	-32,998
2015	1.87	601,061	130,419	470,642	-562,108	-38,952
2016	2.10	698,463	169,183	529,280	-653,198	-45,265
2017	2.33	801,654	210,371	591,283	-749,702	-51,952
2018	2.55	910,912	254,100	656,812	-851,879	-59,033
2019	2.78	1,026,524	300,493	726,031	-959,999	-66,525
2020	**3.01**	1,148,792	349,680	799,112	-1,074,343	-74,449
Totals	**20.1**	6,786,705	1,621,872	5,164,832	-6,346,884	-439,820

Cost Effectiveness

Recycling. The net cost of increased recycling rates in South Carolina was estimated by adding the increased costs of collection for two-stream recycling, revenue obtained for the value of recycled materials, and avoided landfill tipping fees. The additional cost for separate curbside collection of recyclables is $2.50/household/month, or $30/household/year.[84] Dividing this number by the incremental recycling per capita in 2020[85] times the average household size of 2.53[86] yields the maximum collection cost of $21/ton. The capital cost of additional recycling facilities in Maryland is $197 million.[87] Annualized over the 10 year policy period at 5% interest, the capital cost is $12.8 million per year. The avoided cost for landfill tipping is $36/ton.[88] CCS also factored in the commodity value of recycled materials with a value of $38/ton.[89] Table 8-11 provides the results of the cost analysis. The analysis assumes that costs begin to be incurred in 2010. The estimated cost savings result in an NPV of -$87 million. Cumulative reductions are over 19 MMtCO$_2$e, and the estimated cost-effectiveness is -$4.5/MtCO$_2$e.

Table 8-11: Cost analysis results for recycling

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[84] **Not a SC-specific estimate. Seek additional input from TWG.** T. Brownell, Eureka Recycling, personal communication with S. Roe, CCS, December 17, 2007. This value compares favorably with data provided to the AFW TWG (T. Troolin, St. Louis County) on recycling costs incurred by MN counties.

[85] Population projection for 2020 from the SC Inventory and Forecast.

[86] US Census Bureau. State & County QuickFacts – South Carolina. Accessed on February 5, 2008 from: http://quickfacts.census.gov/qfd/states/45000.html

[87] **Not a SC-specific estimate. Seek additional input from TWG.** Based upon ratio of Capital Cost per household used in Vermont Analysis. VT capital cost a result of Personal Communication with P. Calabrese.

[88] *South Carolina Solid Waste Management Annual Report – FY2006.* SC DHEC: Division of Mining and Solid Waste Management. Accessed on December 13, 2007 from http://www.scdhec.gov/environment/lwm/recycle/pubs/swmr_06.pdf.

[89] US Municipal Recycling Index – Spot market prices for February 1, 2008. Accessed on February 1, 2008 from: http://www.scrapindex.com/municipal.html. Adjusted to 2005$ using the calculator found on the following website: http://minneapolisfed.org/Research/data/us/calc/.

Year	Tons Recycled	Annual Collection Cost (MM$)	Annual Capital Cost (MM$)	Annual Recycled Material Revenue (MM$)	Landfill Tip Fees Avoided (MM$)	Net Policy Cost (Recycling) (MM$)	Discounted Costs (MM$)	GHG Reductions (MMtCO$_2$e)	Cost Effectiveness ($/MtCO$_2$e)
2009	-	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	0.00	
2010	97,891	$2.08	$12.78	$3.76	$3.52	$7.58	$7.22	0.38	
2011	202,263	$4.29	$12.78	$7.76	$7.28	$2.03	$1.84	0.76	
2012	313,436	$6.65	$12.78	$12.03	$11.28	-$3.87	-$3.35	1.13	
2013	362,863	$7.70	$12.78	$13.92	$13.06	-$6.50	-$5.35	1.35	
2014	415,218	$8.81	$12.78	$15.93	$14.95	-$9.28	-$7.27	1.57	
2015	470,642	$9.99	$12.78	$18.06	$16.94	-$12.23	-$9.13	1.79	
2016	529,280	$11.23	$12.78	$20.31	$19.05	-$15.35	-$10.91	2.01	
2017	591,283	$12.55	$12.78	$22.69	$21.29	-$18.64	-$12.62	2.23	
2018	656,812	$13.94	$12.78	$25.20	$23.65	-$22.12	-$14.26	2.45	
2019	726,031	$15.41	$12.78	$27.86	$26.14	-$25.80	-$15.84	2.67	
2020	799,112	$16.96	$12.78	$30.66	$28.77	-$29.69	-$17.36	2.89	
						-$133.87	**-$87.01**	**19.2**	**-$4.52**

Composting. Composting is included in the total recycling volume by the South Carolina Solid Waste Management Annual Report. However, as the WARM model considers the sole form of diversion for yard trimmings and food waste to be composting, the tons of these items that are "recycled" are assumed to be composted. The net costs for increased composting in South Carolina were estimated by adding the additional costs for collection (same calculation as recycling) with the net costs for composting operations. The net cost for composting operations is the sum of the annualized capital and operating costs of composting, increased collection fees, revenue generated through the sale of compost, the avoided tipping fees for landfilling. Information on the capital and operating costs of composting facilities was received from Cassella Waste Management during the analysis of a similar option in Vermont.[90] These data are summarized in Table 8-12.

Table 8-12. Cost information for composting facilities

Annual Volume (tons)	Capital Cost (2007 $,000)	Operating Cost ($/ton)
<1,500	75	25
1,500–10,000	200	50
10,000–30,000	2,000	40
30,000–60,000+	8,000	30

CCS assumed that the composting facilities to be built within the policy period would tend to be from the largest category (achieving the most efficient operating costs) shown in Table 8-12. The composting volumes in 2012 and 2020 shown in Table 8-13 suggest the need for 1 additional large composting operation by 2012 and 7 additional large operations by 2020. To annualize the

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[90] **Not a SC-specific estimate. Seek additional input from TWG.** P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, June 5, 2007.

capital costs for these facilities, CCS assumed a 15-year operating life and a 5% interest rate. Other cost assumptions include an assumed landfill tipping fee of \$36/ton,[91] an additional source-separated organics collection fee of \$2.50/household (or \$51/ton, as used above in the recycling element), a compost facility tipping fee of \$16/ton,[92] and a compost value of \$11.75/ton.[93]

Table 8-13 presents the results of the cost analysis for composting. GHG reductions were assumed not to begin until 2010, and the cumulative reductions estimated were 0.34 MMtCO$_2$e. An NPV of \$43 million was estimated along with a cost effectiveness of \$125/Mt.

Table 8-13: Cost analysis results for composting

Year	Annual Cost O&M (2006$MM)	Capital Cost (2007$MM)	Annualized Capital Cost (2006$MM)	Annual Collection Cost (2006$MM)	Avoided Landfill Tipping Fees (2006$MM)	Value of Composted Material (2006$MM)	Tons of Waste Composted	Total Annual Composting Cost (2006$)	Discounted Costs (2007MM$)	GHG Reductions (MMtCO2e)	Cost Effectiveness ($/Mt)
2009	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	-	$0.00	$0.00	-	
2010	$0.26	$8.00	$0.77	$0.18	$0.17	$0.10	8,607	$0.94	$0.89	0.00	
2011	$0.53	$0.00	$0.77	$0.38	$0.36	$0.21	17,784	$1.12	$1.01	0.00	
2012	$0.83	$0.00	$0.77	$0.58	$0.55	$0.32	27,559	$1.31	$1.13	0.01	
2013	$1.79	$8.00	$1.54	$1.27	$1.19	$0.70	59,713	$2.70	$2.22	0.01	
2014	$2.82	$8.00	$2.31	$1.99	$1.88	$1.10	93,965	$4.14	$3.25	0.02	
2015	$3.91	$0.00	$2.31	$2.77	$2.61	$1.53	130,419	$4.85	$3.62	0.03	
2016	$5.08	$8.00	$3.08	$3.59	$3.38	$1.99	169,183	$6.38	$4.53	0.04	
2017	$6.31	$8.00	$3.85	$4.47	$4.21	$2.47	210,371	$7.95	$5.38	0.05	
2018	$7.62	$8.00	$4.62	$5.39	$5.08	$2.99	254,100	$9.57	$6.17	0.05	
2019	$9.01	$8.00	$5.40	$6.38	$6.01	$3.53	300,493	$11.25	$6.90	0.06	
2020	$10.49	$8.00	$6.17	$7.42	$6.99	$4.11	349,680	$12.98	$7.59	0.07	
									$42.70	**0.34**	**$124.67**

The overall cost analysis – as seen in Table 8-14 – yields a NPV of -\$1,117 and a cost effectiveness of -\$6, based on the cumulative emission reductions of 183 MMtCO$_2$e.

Table 8-14: Overall Policy Results – Cost Effectiveness

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[91] *South Carolina Solid Waste Management Annual Report – FY2006.* SC DHEC: Division of Mining and Solid Waste Management. Accessed on December 13, 2007 from http://www.scdhec.gov/environment/lwm/recycle/pubs/swmr_06.pdf.

[92] Emerson, Dan. 2005. "Latest Trends in Yard Trimmings Composting." *Biocycle*. Vol. 46, No. 9, p. 22. Accessed on February 5, 2008 from: http://www.jgpress.com/archives/_free/000527.html. This tip fee is for Mecklenburg County, NC. As this county is in close proximity to NC, it is assumed that the compost tip fees will be similar in SC.

[93] Coker, Craig, and Nora Goldstein. 2004. "Characterizing the Composting Industry." *Biocycle*. Vol. 45, No. 12, p. 20. Accessed on February 5, 2008 from: http://www.jgpress.com/archives/_free/000324.html. 2004 price of \$10/yd. Assuming a dry solids content of 55% and a bulk density of 0.5 tons/yd, the value of composted material was calculated to be \$11 per ton of initial feedstock. Adjusting for 2005\$ yields a price of \$11.75/ton.

Year	Net Program Cost Recycling ($MM)	Net Program Cost Composting ($MM)	Total Net Program Cost ($MM)	Discounted Cost (2006$MM)	Cost Effectiveness ($/MtCO2e)
2009	$0.00	$0.00	$0.00	$0.00	
2010	$7.58	$0.94	$8.52	$8.11	
2011	$2.03	$1.12	$3.15	$2.86	
2012	-$3.87	$1.31	-$2.57	-$2.22	
2013	-$6.50	$2.70	-$3.80	-$3.12	
2014	-$9.28	$4.14	-$5.14	-$4.03	
2015	-$12.23	$4.85	-$7.38	-$5.50	
2016	-$15.35	$6.38	-$8.97	-$6.37	
2017	-$18.64	$7.95	-$10.69	-$7.24	
2018	-$22.12	$9.57	-$12.55	-$8.09	
2019	-$25.80	$11.25	-$14.55	-$8.94	
2020	-$29.69	$12.98	-$16.71	-$9.77	
				-$44.31	**-$2.21**

Key Assumptions: For the MSW management input data to WARM, the key assumption is that none of the goals would be achieved via existing programs in place. To the extent that those programs will achieve or partially achieve the goals of this policy, the GHG reductions estimated would be lower (no additional penetration from the current South Carolina recycling and composting campaigns has been incorporated into the BAU assumptions for this analysis). Therefore, the most important assumption relates to the assumed BAU projection for solid waste management. This BAU forecast is based on current practices and does not factor in the effects of further gains in recycling or composting rates during the policy period. The BAU assumptions are needed to tie into the assumptions used to develop the GHG forecast for the waste management sector, which does not factor in these changes in waste management practices during the policy period (2008–2020). To the extent that these gains in recycling and composting would occur without this policy, the benefits and costs are overstated.

The other key assumptions relate to the use of the WARM model in estimating lifecycle GHG benefits and the use of the stated assumptions regarding costs for increased source reduction, recycling, and organics recovery (composting in this example) programs.

Another important assumption is that under BAU, the waste directed to landfilling would include methane recovery (75% collection efficiency) and utilization. The need for this assumption is partly based on limitations of the WARM model (which doesn't allow for management of landfilled waste into both controlled and uncontrolled landfills), but also based on the overall direction of the policy recommendations of AFW-8.

Additionally, transportation emissions for WARM are taken as default. This analysis has not considered the impacts of reduced exports as a result of the goals in the Policy Design.

The cost estimates do not include cost savings that would be achieved through avoiding the need for additional WTE plants.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]Sample Draft Policy Option Template]

Appendix 8-A: Results of 50% MSW Recycling Rate

Based on assumptions consistent with the analysis for the TWG recycling goal of 35%, a 50% recycling rate leads to some waste types having negative tons landfilled and incinerated. This is a result of the use of different data sources for recycling and disposal characterization.[94] Assumptions will need to be modified to create a realistic waste management scenario (i.e. a waste disposal quantity greater than or equal to zero).

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[94] Recycling characterization based on DHEC Solid Waste Management Report for the FY 2006. Generation and disposal characterization based on national-level data from the 2005 EPA "Facts and Figures" Report.

AFW-9. Organics Management for Energy Recovery

Policy Description

Promote the use of anaerobic digesters and energy recapture for organic waste materials (e.g. food processing waste, yard waste, other organics; Note the linkage to AFW-2, whereby some organics from this waste stream could be co-managed with livestock wastes, and to the AFW-8 composting goals). Also, for waste that is landfilled, promote the use of landfill gas to energy (LFGTE) projects. These projects will help prevent the emission of methane while producing clean energy. Anaerobic digesters make a two-fold contribution to climate protection: the usual unchecked discharge of methane into the atmosphere is prevented; and the burning of fossil fuels is replaced with renewable energy (biogas). Use the clean, renewable energy created at landfills by anaerobic digesters to make electric power, space/process heat, and liquefied/compressed natural gas. Note that this policy is not promoting waste combustion to energy projects.

Policy Design

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 at uncontrolled landfill sites is controlled by 2020. This can be done through development of additional landfill gas to energy (LFGTE) and anaerobic digester projects.

Timing: By 2012, implement LFGTE/digester projects at currently uncontrolled landfills or other sites, such that 20% of methane released at these sites is recovered as an energy source; by 2020, achieve full implementation of the policy.

Parties Involved: Municipal and county governments, private solid waste management companies, local economic development agencies, SC DHEC, SC Department of Commerce, SC Energy Office, 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. South Carolina's Energy Office is a State Partner of the EPA Landfill Methane Outreach Program (LMOP). Through this partnership, it was determined that 30 landfills in South Carolina can potentially recover methane as an energy source. Based on current LMOP data, however, only 5 sites are generating electricity from landfill methane. According to the 15th edition of *The State of Garbage*, published by Biocycle and Columbia University, out of 3.2 million tons of MSW landfilled in SC in 2004, 228,000 tons of wastes were recovered for energy.[95]

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[95] P. Simmons, N. Goldstein, S. M. Kaufman, N.J. Themelis, and J. Thompson, Jr. "The State of Garbage in America." *BioCycle*. April 2006. Accessed on August 24, 2007 from http://www.seas.columbia.edu/earth/wtert/sofos/Simmons_SOG06.pdf

Implementation Mechanisms

TBD – [CCS drafts based on TWG inputs; this can be developed as they go along, and can start early or late as they prefer; the level of detail can vary on TWG approval]

Related Policies/Programs in Place

SC Alternative Energy bills establish tax incentives for industrial purchase of equipment to use landfill gas. Legislature passed S.1245, providing manufacturers with tax credits for 25% of cost of landfill gas energy equipment.

A state-owned utility is currently producing approximately 20 MW of electricity in SC from landfill methane gas. SC has six existing landfill methane to energy facilities. One facility provides power directly for manufacturing processes. More are in the pipeline.

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_2, CH_4, and N_2O from the combustion of fossil fuels.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2012, 2020 (MMtCO$_2$e): 0.41, 1.05

Net Cost per MtCO$_2$e: -$0.03

Data Sources: Data on current landfill operations using methane recovery for energy generation (direct or electric) is taken from the EPA LMOP website.[96] Baseline landfill gas emissions are consistent with the South Carolina Inventory and Forecast (SC I&F).[97] CCS used the results of LFG to energy cost modeling performed for a similar policy analysis with EPA's LFG cost model (LFGcost) to estimate the costs for this policy element.[98]

Quantification Methods:

GHG Benefits

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[96] http://www.epa.gov/landfill/proj/xls/lmopdatasc.xls.

[97] SC Inventory and Forecast. Available on SC CECAC website: www.scclimatechange.us.

[98] US EPA Landfill Methane Outreach Program, Landfill Gas Energy Cost Model (LFGcost), Version 1.4. "Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 4, LFGE Project Type: Standard Reciprocating Engine-Generator Set," March 2, 2007; "Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 2, No Section 45 Tax Credit LFGE Project Type: Small Engine-Generator Set," March 2, 2007; "Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 1, LFGE Project Type: Direct Use (0.5 mile pipeline)," March 2, 2007.

As the goal stated in the "Option Design" section requires control of methane emissions specifically from uncontrolled landfills, CCS is able to use the emissions estimates for uncontrolled landfills from the SC I&F as the baseline emission scenario. As the emissions from uncontrolled landfills are controlled, three GHG benefits are realized: the conversion of landfill methane to CO_2, the displacement of grid-based electricity, and the displacement of fossil fuel combustion for direct heat.[99] The first benefit is calculated by multiplying the baseline CH_4 emissions from uncontrolled landfills from the SC I&F by the landfill gas control goal set by the TWG. The second benefit (offset electricity) is found by converting the methane captured from $MtCO_2e$ units to cubic meters of gas, then calculating the electricity generated and the emissions offset through avoided grid-based generation.[100] The third GHG benefit is calculated by multiplying the fraction of captured landfill gas combusted for direct use by the quantity of landfill gas captured under this policy option, assuming that an equal amount of natural gas is not combusted for direct heat use. The estimated GHG benefit in 2012 and 2020 is 0.41 and 1.05 $MMtCO_2e$, respectively. The cumulative GHG benefit through 2020 is estimated to be 7.19 $MMtCO_2e$. Table 9-1 depicts the results of these calculations.

Table 9-1: Overall Policy Results – GHG Benefit

Year	Methane Control Goal	CH4 emissions from Uncontrolled landfills (MtCO2e)	GHG Benefit: CH4 reduction from methane control (MMtCO2e)	CH4 Controlled (m^3 CH4)	Electricity Generated (MWh)	GHG Benefit: Avoided Electricity Production (MMtCO2e)	GHG Benefit: Avoided Nat. Gas Combustion for Direct Use (MMtCO2e)	Total GHG Benefit (MMtCO2e)
2008	0.0%	1,798,640	-	-	-	-	-	-
2009	5.0%	1,801,607	0.09	3,431,632	7,783	0.00	0.01	0.10
2010	10.0%	1,804,579	0.18	6,874,587	15,591	0.01	0.02	0.21
2011	15.0%	1,807,556	0.27	10,328,891	23,425	0.01	0.03	0.31
2012	20.0%	1,810,538	0.36	13,794,574	31,285	0.01	0.04	**0.41**
2013	23.8%	1,813,525	0.43	16,408,080	37,213	0.02	0.05	0.49
2014	27.5%	1,816,516	0.50	19,030,171	43,159	0.02	0.05	0.57
2015	31.3%	1,819,513	0.57	21,660,869	49,126	0.02	0.06	0.65
2016	35.0%	1,822,515	0.64	24,300,195	55,111	0.02	0.07	0.73
2017	38.8%	1,825,521	0.71	26,948,170	61,117	0.03	0.08	0.81
2018	42.5%	1,828,533	0.78	29,604,815	67,142	0.03	0.08	0.89
2019	46.3%	1,831,549	0.85	32,270,152	73,187	0.03	0.09	0.97
2020	50.0%	1,834,571	0.92	34,944,202	79,251	0.03	0.10	**1.05**
Totals		**23,615,162**	**6.29**	**239,596,338**	**543,390**	**0.23**	**0.67**	**7.19**

Cost Effectiveness

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[99] Assumed to be natural gas.

[100] (Fraction of landfill gas used for electricity generation) * (CH_4 captured in $MtCO_2e$) * (1 $MtCH_4$ / 21 $MtCO_2e$) * (1 m^3CH_4 / 0.00125 $MtCH_4$) * (0.00254 MWh / m^3CH_4) * ($4.15*10^{-7}$ $MMtCO_2e$ / MWh)

Using the results from a previous LFGcost model run, the cost of this option are estimated based on whether the methane is converted to useable energy by a small engine, through direct use, or a large engine (800kW and greater).[101] CCS assumes that the current share of each three energy conversion techniques remains constant as uncontrolled sites are converted to control sites to meet the policy goal. As of the latest LMOP data output, however, South Carolina employed the use of one direct thermal LFGTE converter and four large electricity-generating units.[102]

Table 9-2: LFG Cost Modeling Results

EPA LFGcost Modeling Data	Scenario 1: Direct Use (0.5 mi. pipeline)	Scenario 2: Small Engine (<800 kW)	Scenario 3: Standard Engine (>800 kW)
Total Capital	$621,573	$753,365	$2,612,674
Average Annual O&M	$105,474	$102,141	$335,475
Annualized Costs	$198,088	$214,392	$724,763
Annual Revenue	$219,870	$70,020	$631,620
Annual Average Reductions	0.024	0.023	0.088
Project Reductions (MMtCO$_2$e)	0.36	0.34	1.32
CE ($/MtCO$_2$e)	-$0.82	$2.72	$0.15
NPV	-$296,892	$923,637	$200,660
Blended Cost Effectiveness (SC)			
Assumed Methane Fraction Controlled	11%	-	89%
Fractional CE	-$0.09	-	$0.14
Average CE	$0.05		

The average cost effectiveness ($0.05/MtCO$_2$e) is multiplied by the GHG benefit calculated in the GHG Benefit section for each year to determine the cost effectiveness of this policy option (Table 9-3). The net present value (NPV) of cost incurred through the implementation of this option is $0.23 million, and the discounted cost effectiveness is $0.03/MtCO$_2$e.

Table 9-3: Overall Policy Results – Cost Effectiveness

Year	**Avoided Emissions (MMtCO2e)**	**Annual Costs (MM$)**	**Discounted Costs (MM$)**	**Cost Effectiveness ($/MtCO2e)**
2008	-	$0.00	$0.00	

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[101] US EPA Landfill Methane Outreach Program, Landfill Gas Energy Cost Model (LFGcost), Version 1.4. “Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 4, LFGE Project Type: Standard Reciprocating Engine-Generator Set,” March 2, 2007; “Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 2, No Section 45 Tax Credit LFGE Project Type: Small Engine-Generator Set,” March 2, 2007; “Summary Report, Pechan for NC GHG Mitigation Plan—Scenario 1, LFGE Project Type: Direct Use (0.5 mile pipeline),” March 2, 2007.

[102] US EPA. Landfill Gas Energy Projects and Candidate Landfills. Online Database accessed on January 28 from: http://www.epa.gov/lmop/proj/index.htm.

Year	Avoided Emissions (MMtCO2e)	Annual Costs (MM$)	Discounted Costs (MM$)	Cost Effectiveness ($/MtCO2e)
2009	0.10	$0.00	$0.00	
2010	0.21	$0.01	$0.01	
2011	0.31	$0.01	$0.01	
2012	0.41	$0.02	$0.02	
2013	0.49	$0.02	$0.02	
2014	0.57	$0.03	$0.02	
2015	0.65	$0.03	$0.02	
2016	0.73	$0.03	$0.02	
2017	0.81	$0.04	$0.02	
2018	0.89	$0.04	$0.03	
2019	0.97	$0.05	$0.03	
2020	1.05	$0.05	$0.03	
Totals	**7.19**	**0.34**	**$0.23**	**$0.03**

Key Assumptions: The analysis does not factor in the closure of specific landfills or the adoption of LFG controls at specific landfills. Modeling GHG emissions and reductions at individual sites is beyond the scope of this analysis; however, the approach used is consistent with the methods used to develop the GHG forecast for the waste management sector.

Each of the cost inputs above contains key assumptions; additional study of these inputs could reduce the associated uncertainty in the cost estimates.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]Sample Draft Policy Option Template

AFW-10. Water and Wastewater Energy Efficiency Improvements

Policy Description

The collection and treatment of waste water and the treatment and delivery of drinking water cost around $4 billion per year and makes up 3% of the nation’s energy use. Goals of 10-25% energy efficiency would be savings of $400 million to $1 billion which translates into energy savings between 5 and 12.5 billion kWh. The efficiency in energy would also help in reducing GHG emission. Most facilities that carry out these operations were designed during periods of lower energy costs and/or in adequate considerations for GHG emissions to the environment. Simple improvements such as replacement of older equipment can realize savings. Organizations like the American Water Works (AWRA) Association Research Foundation and the Environmental Protection Agency (EPA) have launched initiatives to improve energy efficiency. The AWRA Research Foundation has launched the National Municipal Water and Wastewater Facility Initiative in December 2004 and the EPA has the Energy Star partnership.

Policy Design

Goals: Develop an energy conservation, management and efficiency plan to increase energy efficiency of plant operations by 25%; Use wastewater digester gas to produce energy where feasible.

Timing: 15% by 2012; 25% by 2020.

Parties Involved: Municipal and private/investor-owned water and wastewater treatment operators, EPA Energy Star program and the AWRA Research Foundation

Other: Not applicable.

Implementation Mechanisms

Policy design considerations include (1) Compliance with current drinking water standards (2) Water quality standards for waste water for discharge to streams/rivers and other water bodies.

The efficiency improvements will come from some or all of the following steps: (a) Variable frequency drives on any machine that has a variable load; (b) Efficient motor systems; (c) Lighting in these facilities are efficient high performance lighting; (d) Maintenance plans for heating and cooling and ventilation; (e) Proper monitoring of dissolved oxygen.

Related Policies/Programs in Place

South Carolina offers tax incentives for residential / business purchase of solar heating and cooling systems. The tax credit for such equipment is 25% of the installation cost, with a $3500 annual tax credit limit (Amount over the tax can be rolled over to subsequent years). *This does not seem to make sense as a Policy Related to this option.*

Type(s) of GHG Reductions

CO_2: A portion of electricity used by WWTPs in South Carolina is generated through the combustion of fossil fuels, a process that releases CO_2 into the atmosphere. Additionally, methane combusted on-site for the purposes of flaring or energy generation releases CO_2, as well as small amounts of CH_4 and N_2O. However, since CO_2 has a lower global warming potential (GWP) than CH_4, the practice of combusting methane at WWTPs results in a net reduction of GHGs when expressed in CO_2e.

CH_4: WWTPs that utilize anaerobic digestion as a method of wastewater treatment emit methane. However, as this analysis will show, there is a potential for facilities to capture this methane and combust it to produce heat and electricity.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reduction Potential in 2012, 2020 (MMtCO_2e): 0.16, 0.19

Net Cost per MtCO_2e: -$20.3

Data Sources: This analysis relied on data from EPA’s Clean Watershed Needs Survey (CWNS).[103] This survey reports the existing flow, projected flow, and population receiving treatment from the year 2004. These data were applied to aggregate South Carolina population data from the Draft South Carolina Inventory & Forecast (SC I&F). Data regarding the cost and efficiency of specific technologies were compiled from various sources; mostly case studies. There is a lack of data regarding specific energy requirements for WWTPs in SC.

Quantification Methods:

GHG Benefit

Electricity demand for WWTPs is measured using the CWNS 2004 data to determine the million gallons per day (MGD) discharge rate was for all residents served by the surveyed facilities. The CWNS dataset shows the existing municipal wastewater flow for 2004 was 394 MGD, while the system was designed to treat a maximum flow of 527 MGD. While the population generating wastewater for treatment at a centralized facility is an available data point, it is difficult to project this population into the future. Rather, CCS considers the per-capita influent flow rate to be equal to the existing municipal wastewater flow for 2004, divided by the 2004 SC population. The result of this quotient is multiplied by the population projection used in the SC I&F to yield the per-capita flow rate of $9.4*10^{-5}$MGD/cap.

Next, the energy use per million gallons is determined from the median of a survey of 12 WWTPs (2,286 kWh/MG).[104] The annual BAU WWTP electricity consumption is estimated by taking the product of the per capita discharge rate, the projected population, and the electricity

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[103] US EPA. CWNS 2004 DATA; Ask WATERS Simple Query Tool. http://www.epa.gov/cwns/2004data.htm.

[104] Energy Benchmarking Secondary Wastewater Treatment and Ultraviolet Disinfection Processes at Various Municipal Wastewater Treatment Facilities, prepared for Pacific Gas and Electric, prepared SBW Consulting , Inc., February 2002.

usage (in kWh/MG treated). The emission factor ($4.15*^{10-7}$ MMtCO2e/kWh) is available from eGRID.[105] The avoided emissions from electricity savings is determined by multiplying the annual efficiency improvement targets by the annual BAU WWTP electricity consumption and the annual electricity emission factor (see Table 10-1).

Table 10-1: GHG Benefit from Reduced Electricity Consumption

Year	Population	Annual BAU WWTF Electricity Consumption (kWh)	Efficiency Improvement	Reduced Electricity Consumption (kWh)	Avoided Emissions from Electricity (MMtCO2e)
2008	4,365,903	343,264,191	0.0%	-	-
2009	4,412,172	346,901,968	3.8%	13,008,824	0.01
2010	4,458,930	350,578,296	7.5%	26,293,372	0.01
2011	4,499,708	353,784,421	11.3%	39,800,747	0.02
2012	4,540,859	357,019,868	15.0%	53,552,980	0.02
2013	4,582,386	360,284,903	16.3%	58,546,297	0.02
2014	4,624,293	363,579,797	17.5%	63,626,465	0.03
2015	4,687,920	368,582,374	18.8%	69,109,195	0.03
2016	4,732,841	372,114,223	20.0%	74,422,845	0.03
2017	4,778,192	375,679,915	21.3%	79,831,982	0.03
2018	4,823,978	379,279,774	22.5%	85,337,949	0.04
2019	4,870,202	382,914,128	23.8%	90,942,105	0.04
2020	4,916,870	386,583,307	25.0%	96,645,827	0.04
				Total:	**0.31**

Also, any use of anaerobic digestion to reduce energy use and generate energy on-site will reduce emissions – both from the conversion of CH_4 to CO_2 and the offset of grid-based electricity. A publication from the US EPA Combined Heat and Power Partnership states that a wastewater treatment facility should generally have a flow 5 MGD for combined heat and power (CHP) to be economically viable.[106] Based on the data from the CWNS, 63% of the municipal wastewater flow in South Carolina is a candidate for CHP. The net electricity savings from the CHP system is 36%.[107] As CHP is a mid-range technical option, the installation of such systems is assumed to begin in 2012. Table 10-2 displays the GHG benefit that may be achieved through the full adoption of CHP at candidate facilities through 2020.

Table 10-2: GHG Benefit of Combined Heat and Power at Wastewater Treatment Facilities

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[105] Based on 915 lb CO2/MWh and 1.419 lb Nox/MWh from eGRID; http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

[106] US EPA. 2006. “Opportunities for and Benefits of Combined Heat and Power at Wastewater Treatment Facilities.” U.S. Environmental Protection Agency Combined Heat and Power Partnership. Accessed on February 11, 2008 from: http://www.epa.gov/CHP/documents/wwtf_opportunities.pdf.

[107] Northeast CHP Application Center. “Essex Junction WWTF – Project Profile.” Accessed on July17, 2007 from: http://www.northeastchp.org/uploads/Essex%20Junction%20Project%20Profile.pdf.

Year	WWTF Methane Emissions (MMtCO2e)	GHG Emissions avoided through converson of Methane to CO2 (MMtCO2e)	Electricity Demand Reduced due to CHP (kWh)	GHG Emissions Reductions from Electricity Savings (MMtCO2e)	Total GHG Benefit (MMtCO2e)
2008	0.21	-	-	-	-
2009	0.21	-	-	-	-
2010	0.22	-	-	-	-
2011	0.22	-	-	-	-
2012	0.22	0.14	44,841,366	0.02	0.16
2013	0.22	0.14	45,251,451	0.02	0.16
2014	0.22	0.14	45,665,287	0.02	0.16
2015	0.23	0.14	46,293,606	0.02	0.16
2016	0.23	0.14	46,737,203	0.02	0.16
2017	0.23	0.15	47,185,050	0.02	0.17
2018	0.23	0.15	47,637,189	0.02	0.17
2019	0.24	0.15	48,093,661	0.02	0.17
2020	0.24	0.15	48,554,506	0.02	0.17
Totals	**2.93**	**1.30**	**420,259,320**	**0.17**	**1.47**

The sum of total GHG benefits from Tables 10-1 and 10-2 yield the estimated GHG benefit of this policy option. The 2012 and 2020 GHG benefits are 0.16 and 0.19 MMtCO$_2$e, respectively, and the cumulative GHG reduction is 1.61 MMtCO$_2$e.

Cost Effectiveness

As mentioned in the Data Sources section, most of the cost estimates for the implementation of energy efficient technologies at WWTPs in South Carolina resulted from case study data from Vermont, and were often based on only one data point. For example, if it is known that a particular technology has reduced a facility's energy use by 1,000,000 kWh/years, and the capital cost $10,000, then the cost per kWh used in this analysis would be the annualized capital cost[108] divided by either the kWh reduced or the total BAU kWh used in the process to which the technology in question is applied. Each efficiency-improving technology is applied to the specific process in which it is implemented. Meaning that if a variable frequency device can improve the efficiency of an influent pump by 25% and the influent pump uses 4.5% of the WWTPs electricity, then the efficiency improvement is assumed to apply to the entire 4.5%, or 0.25 × 0.045 × BAU WWTP electricity use. Table 10-3 displays the fractions of electricity used by WWTP processes.

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[108] The cost for each technology in this analysis is annualized utilizing the Cost Recovery Factor method.

Table 10-3. Fractions of electricity used by WWTP processes

Fraction of Electricity used by WWTP	
Influent Pumping	5%
Solids Dewatering	7%
Clarifier & Sludge Pumping	16%
Aeration	56%
Heating	3%
Lighting	6%
Other	8%

After the net cost per kWh is determined, the option that is the most financially attractive (i.e., greatest cost savings) were fully implemented. Additional technology options were added on until the targets for 2012 and 2020 were met. Hence, this method calculated the best-case net cost scenario for this set of efficiency targets.

Since the capital cost of the equipment was annualized over the policy period, cost savings are quickly realized due to the high cost of electricity in South Carolina and the large potential for low-cost efficiency improvements at WWTPs. The levelized and discounted cost-effectiveness of this action is –\$20.3/MtCO$_2$e. Table 10-4 displays the results of the cost analysis.

Table 10-4: Overall Policy Results – Cost Effectiveness

Year	GHG Benefit (MMtCO2e)	Annualized Costs (MM$)	Discounted Costs (MM$)	Levelized & Discounted Cost Effectiveness
2008	-	$0.0	$0.0	
2009	0.01	-$0.6	-$0.6	
2010	0.01	-$0.7	-$0.6	
2011	0.02	-$0.7	-$0.6	
2012	0.16	-$3.6	-$3.0	
2013	0.16	-$4.0	-$3.1	
2014	0.17	-$4.3	-$3.2	
2015	0.17	-$4.7	-$3.4	
2016	0.17	-$5.1	-$3.5	
2017	0.18	-$5.5	-$3.6	
2018	0.18	-$6.0	-$3.7	
2019	0.19	-$6.4	-$3.7	
2020	0.19	-$6.8	-$3.8	
Totals	**1.61**	**-$48.5**	**-$32.7**	**-$20.3**

Key Assumptions:

The cost savings realized by this option is largely due to the assumption that capital cost may be annualized over the policy period. Also, it is assumed that the efficiency improvements for a given technology apply to the full fraction of WWTP electricity usage for each process. The following are additional assumptions made for the purposes of this analysis:

- The technology cost and efficiency data from case studies are used as averages that represent the population of WWTPs in South Carolina.
- This analysis assumes that WWTPs will meet and not exceed the efficiency targets.

Key Uncertainties

TBD – [as needed and approved by the TWGs]

Additional Benefits and Costs

TBD – [as needed and approved by the TWGs]

Feasibility Issues

TBD – [as needed and approved by the TWGs]

Status of Group Approval

Pending – [until CECAC moves to final agreement at meeting #5 or #6]

Level of Group Support

TBD – [blank until CECAC meeting #5]

Barriers to Consensus

TBD – [blank until final vote by the CECAC]