



Memo-Draft

To: Florida Agriculture, Forestry and Waste Technical Working Group
From: The Center for Climate Strategies
Subject: Assumptions for AFW Mitigation Policy Options Quantification
Date: July 22, 2008

This memo summarizes key assumptions used to estimate the GHG impacts and cost effectiveness for draft Agriculture Forestry and Waste (AFW) policy options. The quantification process is intended to support custom design and analysis of draft policy options, and provide both consistency and flexibility. The purpose of this memo is to present the assumptions used as part of the quantification process in order to ensure consistency between options and between subcommittees. Feedback on the assumptions is encouraged.

Quantifying reductions of GHG (particularly future reductions) is an inherently complex process and assumptions are important inputs into the quantification methodologies and models used to estimate policy costs and benefits. Models are representations of reality, and require the best available data on likely futures. An emphasis should be placed on using assumptions that are based on the best available data using local or regional data (when available) rather than national level data.

Unless directed otherwise by the Florida Action Team, CCS will estimate the lifecycle GHG reductions for each policy option, where data and methods are available to do so. In the FL GHG Inventory and Forecast (I&F), the only sector for which consumption-based emissions data are provided is the electricity consumption sector. In all other sectors of the inventory, the GHG emissions are strictly those that occur within the state as a result of energy consumption or other GHG emission process (e.g. methane from landfilled waste). For example, for fuel combustion in the RCI and Transportation sectors, only the emissions associated with fuel combustion are provided, not those associated with the extraction, transport, processing, and distribution of each fuel. Similarly, for waste management, only emissions associated with waste management processes in FL are included in the I&F (e.g. landfilling, waste combustion), not those associated with production and transportation of the initial packaging or product that became a component of the solid waste stream.

Development of consumption-based emission estimates (including embedded GHG from lifecycle assessments) for all sectors of the inventory are beyond the scope of this process. Indeed, in many cases, these types of inventory estimates would involve significant technical and data availability challenges. However, for some policy options, lifecycle emission reductions can be estimated, and it should be recognized that the portion of emission reductions that occur out of state as a result of in-state policies are not captured in the I&F. Some might see these

methodological differences in emissions and emission reductions accounting as a disconnect; however, CCS believes that the Action Team should consider taking credit for reductions that occur out of state as a result of actions taken within the state of FL. Some common examples of where this accounting occurs:

- Fossil fuel consumption: inventory estimates are based only on the GHG emissions associated with the combustion of each fuel; lifecycle emission reductions are estimated using GHGs from combustion plus the embedded GHGs from extraction, transportation, processing, and distribution;
- Solid waste management: landfill methane emissions or total GHG emissions are associated only with waste combustion and decomposition; lifecycle emission reductions include the landfill/waste combustion emissions plus those associated with production of the packaging or product (e.g. net difference of use of virgin materials versus recycled materials);
- Biofuels consumption: for fossil fuel displacement benefits, the inventory includes only GHGs from fossil fuel combustion; lifecycle emission reductions are estimated using the lifecycle gasoline/diesel emission factors compared to lifecycle biofuel emission factors (captures total GHGs from fuel production, processing, and distribution).

Biomass Supply

The table below indicates the biomass availability in Florida. The source/reference for the value is indicated in the notes section. The AFW Subcommittee will work to refine this initial assessment during the process.

| Biomass Resource | Annual Biomass Supply (Dry Tons) | Notes |
|--|---|--|
| Logging Residue | 12,200,000 | Source: Bioenergy at UF/IFAS, Advisory Council Meetgins, Powerpoint prepared by Mary Duryea, May-June 2008, see slide 3. |
| Urban Wood Waste | 5,000,000 | Source: Bioenergy at UF/IFAS, Advisory Council Meetgins, Powerpoint prepared by Mary Duryea, May-June 2008, see slide 3. |
| Forest Understory Species | TBD | |
| Primary Mill Residue (Unused) | 4,000 | 2005 NREL Report. Derived from the USDA Forest Service's Timber Product Output database for 2002, includes mill residues burned as waste or landfilled. |
| Agricultural Residue and Vegetable and Fruit Waste | 3,597,000 | 2005 NREL Report. Estimated using 2002 total grain production, crop to residue ratio, moisture content, and taking into consideration the amount of residue left on the field for soil protection, grazing, and other agricultural activities. 0.4 million dry tons of veg/fruit waste from Bioenergy at UF/IFAS, Advisory Council Meetgins, Powerpoint prepared by Mary Duryea, May-June 2008, see slide 3. |
| Energy Crops | TBD | |
| Willow and Hybrid Poplar or Other Fast-growing Hardwoods | | 2005 NREL Report estimates a potential 389,000 tons of willow or hybrid poplar could be grown on CRP lands. |
| Other Woody Energy Crops | 64,000,000 | Pine, eucalyptus, and cottonwood from Bioenergy at UF/IFAS, Advisory Council Meetgins, Powerpoint prepared by Mary Duryea, May-June 2008, see slide 3. Potential to grow 2,080,000 tons on marginal mining lands. Estimated based on 160,000 acres (from Southeastern Regional Biomass Energy Program 2003 Annual Report*) and 13 dry tons/acre. [†] |
| Poultry Litter | TBD | |
| Municipal Solid Waste (MSW) Fiber | 42,662,000 by 2025 | Forecast to 2025 based on average annual change between 2001-2006 from http://www.dep.state.fl.us/waste/categories/recycling/pages/06_data.htm |
| Wood Pulp | TBD | |
| Yard and Landscape Waste Debris | TBD | |
| Total Annual Biomass Supply | 127,463,000 | |

Land Value and Conservation Easement Costs

The AFW options assume Conservation Reserve Program (CRP) annual payments as a proxy for easement costs.

Total continuous CRP land annual payments for Florida were \$46 per acre as of March 2008. This payment includes annual incentive and maintenance allowance payments, but not one-time signing and practice incentive payments or payment reductions, such as for lands enrolled less than a full year and lands hayed or grazed (see http://www.fsa.usda.gov/Internet/FSA_File/mar2008.pdf).

Land Use

The reduction in fossil diesel fuel use from changing land use from intensive agriculture to alternative land use or practices is estimated at 3.5 gallons/acre.¹ The life-cycle fossil diesel GHG emission factor is 12.3 MtCO₂e/1,000 gallons.²

Fertilizer

The following fertilizer cost information is taken from U.S. Department of Agriculture, Economic Research Service's U.S. fertilizer use and price information (see <http://www.ers.usda.gov/Data/fertilizeruse/>).

| Month/Year | Average U.S. farm prices of selected fertilizers | | | | | Average |
|------------|--|------------------------|----------------------|------------------|---------------------|---------|
| | Anhydrous ammonia | Nitrogen solutions 30% | Urea 45-46% nitrogen | Ammonium nitrate | Sulfate of ammonium | |
| Apr 2007 | 523 | 277 | 453 | 382 | 288 | 385 |

The assumed emissions factor for nitrogen applied is 4.76 kg CO₂e / kg N applied (on-farm). This is obtained from the inventory and forecast. The avoided life cycle GHG emissions (i.e. emissions associated with the production, transport, and energy consumption during application) were taken from Wood and Cowie³. The estimate provided for the U.S. (taken from West and Marland, 2001⁴) was 858 grams (g) CO₂e per kilogram of nitrogen (kgN)⁵. This provides a total emissions factor of 5.61 kg CO₂e / kg N applied.

¹ Reduction associated with less intensive land use (e.g. fewer passes). The estimate is based on conservation tillage compared with conventional tillage, at <http://www.conservationinformation.org/Core4Brochures/CTBrochure.pdf>, accessed May 2008.

² Life-cycle emissions factor for fossil diesel from J. Hill et al., "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels," *Proceedings of the National Academy of Sciences*, 103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See <http://www.pnas.org/cgi/content/full/103/30/11099>

³ Sam Wood and Annette Cowie (2004) *A Review of Greenhouse Gas Emission Factors for Fertiliser Production* Research and Development Division, State Forests of New South Wales, Cooperative Research Centre for Greenhouse Accounting.

⁴ West, T. O. and Marland, G. 2001. *A Synthesis of Carbon Sequestration, Carbon Emissions and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States*. Agriculture, Ecosystems and Environment 1812, 1-16.

⁵ These emission factors provide an estimate of the typical life cycle GHG emissions (including resource extraction, the transport of raw materials and products, and the fertilizer production processes) per unit weight of fertilizer produced (i.e., gCO₂e/kg fertilizer).

Emission Factors

Standard emissions factors for fuel feedstocks are calculated from the Florida GHG Emissions Inventory and summarized below (note that these emission factors include CH₄ and N₂O emissions in addition to CO₂ emissions)

| Feedstock | (tCO ₂ e/mmbtu) |
|-------------------------------|----------------------------|
| Subbituminous coal | 0.096 |
| Natural gas | 0.054 |
| Residual oil | 0.078 |
| Diesel oil | 0.073 |
| Petroleum coke | 0.100 |
| LPG | 0.063 |
| Refuse derived fuel (fossil) | 0.043 |
| MSW (fossil) | 0.043 |
| Refuse derived fuel (biomass) | 0.002 |
| MSW (biomass) | 0.002 |
| Wood, waste wood and sawdust | 0.002 |
| Nuclear | 0.000 |
| Landfill gas ⁶ | 0.054 |
| Wind | 0.000 |
| Solar/PV | 0.000 |
| Other | 0.054 |
| Oil | 0.078 |
| Waste solvent | 0.073 |

The emissions factor for grid electricity was also taken from the FL I&F, derived by dividing total electricity consumption emissions in 2005 by electricity sales in 2005. This provided an Electricity Emissions Factor of 0.643 Metric Tons CO₂-e per MWh.

Fuel Prices

The following table shows fuel prices (in \$/MMBTU) for costs taken from Annual Energy Outlook 2008 (Early Release)⁷.

| | Distillate Fuel (in \$/MMBTU) | Natural Gas (in \$/MMBTU) | Coal (in \$/MMBTU) | Coal (in \$/ton) |
|------|-------------------------------|---------------------------|--------------------|------------------|
| 2009 | \$13.25 | \$6.82 | \$1.20 | \$30.10 |
| 2010 | \$12.65 | \$6.36 | \$1.24 | \$30.99 |
| 2011 | \$12.11 | \$6.07 | \$1.24 | \$31.11 |
| 2012 | \$11.33 | \$5.86 | \$1.23 | \$30.67 |

⁶ Assumed to be biogenic.

⁷ Fuel cost (in \$/MMBTU) come from Figure 1. Energy Prices 2006 dollars per million BTU From EIA AEO 2008. see <http://www.eia.doe.gov/oiaf/aeo/prices.html>.

| | | | | |
|-------------|---------|--------|--------|---------|
| 2013 | \$10.68 | \$5.60 | \$1.22 | \$30.56 |
| 2014 | \$10.41 | \$5.43 | \$1.23 | \$30.66 |
| 2015 | \$9.83 | \$5.32 | \$1.22 | \$30.47 |
| 2016 | \$9.42 | \$5.29 | \$1.21 | \$30.28 |
| 2017 | \$9.43 | \$5.34 | \$1.22 | \$30.39 |
| 2018 | \$9.57 | \$5.39 | \$1.25 | \$31.21 |
| 2019 | \$9.71 | \$5.42 | \$1.25 | \$31.30 |
| 2020 | \$9.81 | \$5.24 | \$1.26 | \$31.51 |

Assumed cost of electricity is based on Future Mid-Continent Area Power Pool prices from the EIA Annual Energy Outlook (see <http://www.eia.doe.gov/oiaf/aeo/supplement/index.html>), illustrated below:

| Florida Reliability Coordinating Council - Sector 08 | |
|--|---|
| Year | All Sector Average Electricity Price (2005\$ per kWh) |
| 2009 | 0.10 |
| 2010 | 0.11 |
| 2011 | 0.10 |
| 2012 | 0.10 |
| 2013 | 0.10 |
| 2014 | 0.10 |
| 2015 | 0.10 |
| 2016 | 0.09 |
| 2017 | 0.09 |
| 2018 | 0.09 |
| 2019 | 0.09 |
| 2020 | 0.10 |
| 2021 | 0.09 |
| 2022 | 0.09 |
| 2023 | 0.10 |
| 2024 | 0.10 |
| 2025 | 0.10 |

Capital costs and capacity factors

Estimates of capital costs and capacity factors for new generating capacity vary tremendously. The following table from the *Annual Energy Outlook 2007* shows the capital cost and O&M costs used by the National Energy Modeling System (NEMS) model.

Table 39. Cost and Performance Characteristics of New Central Station Electricity Generating Technologies

| Technology | Online Year ⁷ | Size (mW) | Leadtimes (Years) | Base Overnight Costs in 2006 (\$2005/kW) | Contingency Factors | | Total Overnight Cost in 2006 ³ (2005 \$/kW) | Variable O&M ⁴ (\$2005 mills/kWh) | Fixed O&M ⁵ (\$2005/kW) | Heatrate in 2006 (Btu/kWhr) | Heatrate nth-of-a-kind (Btu/kWhr) |
|---|--------------------------|-----------|-------------------|--|----------------------------|--|--|--|------------------------------------|-----------------------------|-----------------------------------|
| | | | | | Project Contingency Factor | Technological Optimism Factor ² | | | | | |
| Scrubbed Coal New ⁷ | 2010 | 600 | 4 | 1,206 | 1.07 | 1.00 | 1,290 | 4.32 | 25.91 | 8,844 | 8,600 |
| Integrated Coal-Gasification Combined Cycle (IGCC) ⁷ | 2010 | 550 | 4 | 1,394 | 1.07 | 1.00 | 1,491 | 2.75 | 36.38 | 8,309 | 7,200 |
| IGCC with Carbon Sequestration | 2010 | 380 | 4 | 1,936 | 1.07 | 1.03 | 2,134 | 4.18 | 42.82 | 9,713 | 7,920 |
| Conv Gas/Oil Comb Cycle | 2009 | 250 | 3 | 574 | 1.05 | 1.00 | 603 | 1.94 | 11.75 | 7,163 | 6,800 |
| Adv Gas/Oil Comb Cycle (CC) | 2009 | 400 | 3 | 550 | 1.08 | 1.00 | 594 | 1.88 | 11.01 | 6,717 | 6,333 |
| ADV CC with Carbon Sequestration | 2010 | 400 | 3 | 1,055 | 1.08 | 1.04 | 1,185 | 2.77 | 18.72 | 8,547 | 7,493 |
| Conv Combustion Turbine ⁵ | 2008 | 160 | 2 | 400 | 1.05 | 1.00 | 420 | 3.36 | 11.40 | 10,807 | 10,450 |
| Adv Combustion Turbine | 2008 | 230 | 2 | 379 | 1.05 | 1.00 | 398 | 2.98 | 9.91 | 9,166 | 8,550 |
| Fuel Cells | 2009 | 10 | 3 | 3,913 | 1.05 | 1.10 | 4,520 | 45.09 | 5.32 | 7,873 | 6,960 |
| Advanced Nuclear | 2014 | 1350 | 6 | 1,802 | 1.10 | 1.05 | 2,081 | 0.47 | 63.88 | 10,400 | 10,400 |
| Distributed Generation -Base | 2009 | 2 | 3 | 818 | 1.05 | 1.00 | 859 | 6.70 | 15.08 | 9,500 | 8,900 |
| Distributed Generation -Peak | 2008 | 1 | 2 | 983 | 1.05 | 1.00 | 1,032 | 6.70 | 15.08 | 10,634 | 9,880 |
| Biomass | 2010 | 80 | 4 | 1,714 | 1.07 | 1.02 | 1,869 | 2.96 | 50.18 | 8,911 | 8,911 |
| MSW - Landfill Gas | 2009 | 30 | 3 | 1,491 | 1.07 | 1.00 | 1,595 | 0.01 | 107.50 | 13,648 | 13,648 |
| Geothermal ^{6,7} | 2010 | 50 | 4 | 1,790 | 1.05 | 1.00 | 1,880 | 0.00 | 154.92 | 36,025 | 30,641 |
| Conventional Hydropower ⁸ | 2010 | 500 | 4 | 1,364 | 1.10 | 1.00 | 1,500 | 3.30 | 13.14 | 10,107 | 10,107 |
| Wind | 2009 | 50 | 3 | 1,127 | 1.07 | 1.00 | 1,206 | 0.00 | 28.51 | 10,280 | 10,280 |
| Solar Thermal ⁷ | 2009 | 100 | 3 | 2,675 | 1.07 | 1.10 | 3,149 | 0.00 | 53.43 | 10,280 | 10,280 |
| Photovoltaic ⁷ | 2008 | 5 | 2 | 4,114 | 1.05 | 1.10 | 4,751 | 0.00 | 10.99 | 10,280 | 10,280 |

Source: Assumptions to the AEO 2007, p. 77.⁸

Renewable Incentives

Inclusion of the federal production tax credit (PTC) in the levelized cost estimates for renewables in the Policy Options needs to be considered. The federal Renewable Electricity Production Tax Credit has been around in some form since 1992 but seems to always be about to expire (currently December, 2008). The existing incentive for wind, closed-loop biomass and geothermal is 2.0¢/kWh. Electricity from open-loop biomass, small irrigation hydroelectric, landfill gas, municipal solid waste resources receives a 1.0¢/kWh credit.

Biofuels

Fuel Life-Cycle Emission Factors

The fuel life-cycle emission factors are derived from the Argonne National Laboratory GREET 1.8b model for the year 2010 and utilize the model's default assumptions except where noted (downloadable from <http://www.transportation.anl.gov/software/GREET/>). The factors assume an average fuel economy of 100 miles/4.3 gallons (23.2 mpg) for gasoline-powered vehicles and 100 miles/3.6 gallons (27.8 mpg) for diesel-powered engines, based on the 2005 model year average. The life-cycle emission factor for gasoline is 11.3 metric tons CO₂e/1,000 gallons. This number assumes a mix of 50% conventional gasoline and 50% reformulated gasoline. The life-cycle emission factor for low-sulfur diesel is 11.3 metric tons CO₂e/1,000 gallons.

⁸ <http://www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf>

The life-cycle emission factor for 100% corn ethanol is 9.1 metric tons CO_{2e}/1,000 gallons. This value includes 195 g CO_{2e} /bushel emissions for land use change due to corn farming.

The life-cycle emission factor for cellulosic ethanol is 1.51 metric tons CO_{2e}/1,000 gallons. This number assumes a mix of 25% herbaceous biomass, 25% forest residue, 25% corn stover, and 25% woody biomass (from farmed trees).

The life-cycle emission factor for soybean-based biodiesel is 0.667 metric tons CO_{2e}/1,000 gallons.

Carbon emissions from land use change

Recent publications such as Searchinger, et al., 2008 (Searchinger et al., *Scienceexpress*, “Use of U.S. Croplands for Biofuels Increases Greenhouse Gases through Emissions from Land Use Change,” February 7, 2008), have attempted to estimate the carbon emissions that result from land use being converted to cropland to grow crops for fuel. This is based on the argument that the conversion of current cropland from food/feed/fiber production in one part of the world will drop the food/feed/fiber supply on the market and drive grassland or forest conversion to cropland in other parts of the world. There is still significant uncertainty regarding the value of carbon emissions due to land use change so at this juncture emissions from land use change are not incorporated into the quantification except those already included in the GREET model.