# Agriculture, Forestry, and Waste Management Technical Work Group

## Summary List of Policy Options

| | Policy Option | GHG Reductions ($MMtCO_2e$) | | | Net Present Value 2007–2028 (Million $) | Cost-Effective-ness ($\$/tCO_2e$) | Level of Support |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2028 | Total 2007-2028 | | | |
| | **AGRICULTURE, FORESTRY, AND WASTE MANAGEMENT** | | | | | | |
| **AFW-1** | **Programs to Support Local Farming/Buy Local** | **0.01** | **0.02** | **0.2** | ***TBD*** | ***TBD*** | **TBD** |
| **AFW-2** | **Agricultural Soil Carbon Management Programs** | **0.08** | **0.10** | **1.6** | **2.7** | **2** | **TBD** |
| **AFW-3** | **Manure Management Methods to Achieve GHG Benefits**<br>**Manure Digesters**<br>**Composting** | **0.01** | **0.02** | **0.3** | **30** | **117** | **TBD** |
| **AFW-4** | **Protect Open Space/Agricultural land** | **0.06** | **0.11** | **1.8** | **56** | **31** | **TBD** |
| **AFW-5** | **Forestry Programs to Enhance GHG Benefits** | **0.12** | **0.27** | **3.8** | ***TBD*** | ***TBD*** | **TBD** |
| **AFW-6** | **Increased Forest Biomass Energy Use** | *Quantified under ESD options* | | | ***TBD*** | ***TBD*** | **TBD** |
| **AFW-7** | **Forest Protection – Reduced Clearing and Conversion to Non-Forest Cover** | **0.4** | **1.8** | **19** | **34** | **2** | **TBD** |
| **AFW-8** | **Expanded Use of Durable Wood Products (especially from VT sources)** | ***TBD*** | ***TBD*** | ***TBD*** | ***TBD*** | ***TBD*** | **TBD** |
| **AFW-9** | **Advanced/Expanded Recycling and Composting** | **0.16** | **0.88** | **9.1** | **30** | **3** | **TBD** |
| **AFW-10** | **Programs to Reduce Waste Generation** | **0.34** | **0.73** | **10** | ***TBD*** | ***TBD*** | **TBD** |
| **AFW-11** | **Waste Water Treatment – Energy Efficiency Improvements** | **0.004** | **0.011** | **0.15** | **-19** | **-133** | **TBD** |
| **AFW-12** | **In-State Liquid Biofuels Production – Ethanol Production**<br>**In-State Liquid Biofuels Production – Biodiesel Production** | **0.03**<br>**0.004** | **0.42**<br>**0.24** | **3.7**<br>**2.2** | **5.0**<br>**40** | **1**<br>**18** | **TBD** |
| | **SECTOR TOTAL AFTER ADJUSTING FOR OVERLAPS** | | | | | | |

| | Policy Option | GHG Reductions (MMtCO$_2$e) | | | Net Present Value 2007–2028 (Million $) | Cost-Effective-ness ($/tCO$_2$e) | Level of Support |
|---|---|---|---|---|---|---|---|
| | | 2012 | 2028 | Total 2007-2028 | | | |
| | **REDUCTIONS FROM RECENT ACTIONS (table to be added below)** | | | | | | |
| | **SECTOR TOTAL PLUS RECENT ACTIONS** | | | | | | |

# AFW–1. Programs to Support Local Farming / Buy Local

## Policy Option Description

Programs that promote the production, storage, processing, distribution and consumption of locally-grown food products reduce transportation and manufacturing emissions by offsetting the consumption of products with higher embodied energy.

Food products consumed in the U.S. can travel thousands of miles before reaching a grocery or clothing store in the form of a final product (a typical food product can travel over 1,500 miles and change hands dozens of times). Vermont food buyers should focus the majority of their food product purchases from New England and New York markets.

In addition to Vermont production, storage and processing, the percentage of locally grown food consumed in Vermont should also be a priority as it will reduce fossil fuel use and its associated GHG emissions. Establishment and support of creative and effective multi-layered marketing programs including "a virtual marketplace for local farmers markets" (e.g., Local Foods Plymouth) has shown to boost consumption of local foods.

## Policy Option Design

**Goals:** To increase the production, storage, and processing of locally grown animal products, grains, vegetables and fruits and their consumption in Vermont *such that 30% of these products purchased by Vermonters are produced regionally.*

**Timing:** To increase sales *and consumption* of local farm products by 50% and increase storage and processing capacity of locally grown farm products by 20% by 2012 **above current levels**. *Achieve the 30% goal by 2028.*

**Parties Involved:** Center for Sustainable Agriculture at UVM, Agency of Agriculture, Vermont farmers and industry associations.

**Other:** Promote the use waste heat generated from farm or industry practices to increase the levels of year-round vegetable and fruit production.

## Implementation Mechanisms

Working together to further define, develop, implement and promote all local foods production, storage, processing and consumption in accordance with sustainable agricultural practices will require several strategies:

- Establish and promote a "virtual farmers market" to help boost sales;
- Explore the barriers and obstacles on the production side;
- Expand meat production and self-sustaining cold and warm weather products;

- Support continued research and data collection to establish a baseline on local farm sales for farmers markets and farm stands.

## Related Policies/Programs in Place

Vermont Sustainable Agriculture Council (www.uvm.edu/sustainableagriculture);

VSJF, VFN, NOFA-VT, Intervale, CSA, UVM, Shelburne Farms, North Country Framers, RAFFL, Vital Communities—Sustainable Ag Network (SAN);

UVM efforts to define local products and work with Sadexo Food Services to include greater percentages of local food in campus dining rooms;

Local Foods Plymouth (http://lfp.dacres.org/);

NH Farmers Market Association (www.nhfma.org).

## Types(s) of GHG Reductions

To be determined. (TBD)

## Estimated GHG Savings and Costs per MtCO$_2$e

- **GHG reduction potential in 2012, 2028 (MMtCO$_2$e):** 0.006, 0.02.
- **Net Cost per MtCO$_2$e:** *Costs to be developed after obtaining input from contacts at VT Sustainable Agriculture Council.*

- **Data Sources:** U.S. per capita food consumption was taken from the USDA Economic Research Service (ERS) Food Availability (Per Capita) Data System. Per capita consumption of each food type is shown in the table below. Per capita food expenditures were also obtained from ERS.[1] Vermont local food expenditures for 2000 were obtained from the 2005 Report from the Vermont Sustainable Agriculture Council.[2] The average travel distance of imported food was taken from an Iowa study of food miles.[3]

| Food Category | US per capita consumption (lbs) |
|---|---|
| red meat | 116 |
| chicken | 86 |
| turkey | 17 |
| fish | 12 |

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[1] USDA, Economic Research Service, Food CPI, Prices, and Expenditures: Per Capita Food Expenditures, http://www.ers.usda.gov/Briefing/CPIFoodAndExpenditures/Data/table15.htm

[2] Vermont's Agriculture: Generating Wealth from the Land, Vermont Sustainable Agriculture Council, 2005, http://www.uvm.edu/%7Esusagctr/CouncilReport05.PDF.

[3] Pirog, R., "Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions". Leopold Center for Sustainable Agriculture, 2003, http://www.leopold.iastate.edu/pubs/staff/files/food_travel072103.pdf

| Food Category | US per capita consumption (lbs) |
|---|---|
| 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 |
| 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** |

- **Quantification Methods:** First, U.S. per capita food expenditures were multiplied by the Vermont population to give an estimate of total Vermont food expenditures ($1.4 billion). The amount of local food expenditures in Vermont ($148 million) was divided by the total food expenditures to give a BAU percentage of locally purchased food of 10.6%. A separate estimate was made of locally purchased food by using weight-based estimates of total consumption and in-state consumption *(provide additional detail and citation)*. This estimate yielded 12.7% of in-state food coming from local sources. The average of these two estimates (12%) was used in this analysis as the BAU in-state consumption percentage. Total consumption of food was estimated for each year by multiplying projected population by the per capita consumption data referenced above. The table below shows the estimated food consumption and the amount of food imported from out-of-state sources with the policy goal and without the policy goal (BAU).

| Year | Population | % Locally Purchased Food | Food From Out-of-State (tons) | BAU Food From Out-of-State (tons) |
|---|---|---|---|---|
| 2007 | 639,592 | 12.0% | 577,664 | 577,664 |
| 2008 | 643,899 | 13.2% | 573,623 | 581,553 |
| 2009 | 648,205 | 14.4% | 569,476 | 585,443 |
| 2010 | 652,512 | 15.6% | 565,223 | 589,332 |

| | | | | |
|---|---|---|---|---|
| 2011 | 656,643 | 16.8% | 560,715 | 593,064 |
| 2012 | 660,775 | 18.0% | 556,105 | 596,795 |
| 2013 | 664,906 | 18.8% | 554,463 | 600,527 |
| 2014 | 669,038 | 19.5% | 552,759 | 604,258 |
| 2015 | 673,169 | 20.3% | 550,990 | 607,989 |
| 2016 | 676,672 | 21.0% | 548,649 | 611,153 |
| 2017 | 680,176 | 21.8% | 546,254 | 614,318 |
| 2018 | 683,679 | 22.5% | 543,805 | 617,482 |
| 2019 | 687,183 | 23.3% | 541,302 | 620,646 |
| 2020 | 690,686 | 24.0% | 538,745 | 623,810 |
| 2021 | 694,281 | 24.8% | 536,205 | 627,057 |
| 2022 | 697,875 | 25.5% | 533,609 | 630,303 |
| 2023 | 701,470 | 26.3% | 530,958 | 633,550 |
| 2024 | 705,064 | 27.0% | 528,251 | 636,796 |
| 2025 | 708,659 | 27.8% | 525,490 | 640,043 |
| 2026 | 712,347 | 28.5% | 522,741 | 643,374 |
| 2027 | 716,035 | 29.3% | 519,936 | 646,705 |
| 2028 | 719,723 | 30.0% | 517,074 | 650,036 |

The reduction of food miles was estimated by taking the difference between the BAU food from out-of-state and the food from out-of-state under this policy and multiplying by average miles traveled by out-of-state food. The average miles traveled by out-of-state food was assumed to be 1,500 miles plus and additional 25% to account for trucks returning to their points of origin empty (1,825 miles) *need to incorporate citation*. The food transport emission factor (0.162 lb $CO_2$/ton-mile) was estimated by assuming 23 ton payload trucks, 6 truck miles/gal diesel, and 22.4 lb $CO_2$/gal diesel.

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–2. Agricultural Soil Carbon Management Programs

## Policy Option Description

Use of conservation practices to increase the incorporation of organic green manures, implement grass based rotations and cover-cropping, which will reduce soil erosion, maintain/increase soil organic matter level, and increase overall soil tilth. In addition, maximize the use of farm organic wastes to improve crop fertility and to lower the importation of oil based synthetic fertilizers. This option is designed to increase the acreage using soil management practices that lead to higher soil carbon content and reduce nitrogen run-off which has the potential to reduce nitrous oxide emissions.

## Policy Option Design

- **Goals:** Implement Nutrient Management Plans (NMPs) aimed at increasing soil carbon levels and minimizing nitrogen run-off and subsequent $N_2O$ emissions on 75% of farm acreage by 2012 and 90% by 2028. Inject 10% of liquid dairy manure and processed waste water by 2012. Increase acreage managed under cover crop to 25% of annual cropland by 2012 and 50% by 2028.
- **Timing:** see goals above.
- **Parties Involved:** Vermont Agricultural Agencies, Vermont non-profit farming organizations, Agricultural Coops, eco-agriculture consulting companies, Vermont farmers, USDA, NRCS, Vermont natural resource agencies, environmental organizations, University of Vermont and other Vermont Colleges.
- **Other:** Nutrient Management Plans would cover a wide variety of practices that will increase soil carbon levels and reduce nitrogen run-off. These include: maximizing the use of on farm manure and processed waste water to reduce imported fertilizers; using crop rotation and increasing the use of cover cropping on annual crop land to minimize the loss of organic matter from soil erosion; and increasing the use of manure injector technologies on grass and no-till crop land. Additional practices for increasing soil organic matter include: planned grazing; biological subsoiling (using root crops and deep tap-rooted plants); composting and compost tea; pasture cropping, or double cropping; charcoal soil amendments (e.g. amazon dark earths and the Epridra Process); biodynamic preparations; mineralization schemes, including rock dusts and sea minerals; microbial stimulants (e.g. effective microorganisms, indigenous microorganisms); cover cropping; green manures; mulches; seaweed products; recycled green wastes; biosolids; humic substances; Dung beetle and earthworm re-introduction.

## Implementation Mechanisms

- Fund and Implement the NRCS Grassland Reserve Program in order to increase carbon sequestration.
- Provide cost share assistance for farmers to purchase manure injection equipment to retrofit existing manure spreaders or purchase new equipment.
- Implement 590 nutrient management plans on large and medium livestock farms through agency permitting programs.
- Implement 590 nutrient management plans on small livestock farms when they receive state or federal cost share to construct waste management systems.
- Provide cost share assistance for farms to develop nutrient management plans and provide annual assistance so that existing plans continue to be implemented.
- Provide cost share assistance so that farms implement cover crops and other soil erosion and land cover practices.

## Related Policies/Programs in Place

- USDA's Natural Resource Conservation Service (NRCS) Grassland Reserve Program
- NRCS Environmental Quality Incentives Program (EQIP), a cost share program
- Vermont Best Management Practices cost share program
- Vermont Nutrient Management Plan Cost share program
- Vermont Farm Agronomics Practices cost share program
- Conservation District Technical Assistance Program
- University of Vermont Extension Program

## Types(s) of GHG Reductions

- $N_2O$: reductions occur when nitrogen run-off and leaching are reduced, which leads to the formation and emission of $N_2O$.
- $CO_2$: reductions occur as soil carbon levels in crop soils are increased above business as usual levels. Increasing the levels of carbon in soils indirectly sequesters carbon from the atmosphere.

## Estimated GHG Savings and Costs per MtCO$_2$e

- **GHG reduction potential in 2012, 2028 (MMtCO$_2$e):** 0.08. 0.10.

  *GHG savings only estimated for reduction in nitrogen run-off/leaching from fertilizer and manure application. Reductions for potential increases in soil carbon levels are still being analyzed.*

- **Net Cost per MtCO$_2$e:** \$2
  *Cost estimate includes the cost savings from lower fertilizer expenditures.*

- **Data Sources:** *$N_2O$.* Annual $N_2O$ emissions from synthetic fertilizer and manure applications were taken from the VT I&F. The average reduction in fertilizer usage resulting from implementation of Nutrient Management Plans (15%) was taken from an EPA guidance document.[4] Cost information for synthetic fertilizers was taken from the U.S. Department of Agriculture Economic Research Service.[5] The average cost of synthetic fertilizers in the U.S. in 2004 was $260/ton.

**2002 Emissions from Fertilizer and Manure Applications**

| Source | $MMtCO_2e$ |
|---|---|
| Synthetic Fertilizer | 0.279 |
| Direct | 0.047 |
| Indirect | 0.004 |
| Leaching and Runoff | 0.227 |
| Manure Application | 0.542 |
| Direct | 0.130 |
| Leaching and Runoff | 0.412 |
| **Total** | **1.36** |

*Soil Carbon. Still under development.*

- **Quantification Methods:**

Estimates of GHG reductions and costs are provided below for the different management practices assumed to be implemented under this policy option.

*$N_2O$ Reduction in Lower Fertilizer Usage*

*GHG Benefits.* The reduction in $N_2O$ emissions was estimated by applying the NMP nitrogen reduction (15%) by the annual $N_2O$ emissions and then multiplying by the policy percentage of acreage under NMPs (75% in 2012, 90% in 2028) minus the BAU percentage of acreage under NMPs (estimated to be 13%)[6]. It is assumed that the 15% reduction applies to both commercial fertilizer (through lower amounts applied annually) and manure application (through soil incorporation or other methods that reduce nitrogen leaching).

*Costs.* Incremental costs for staff, lab costs, and travel were estimated to be $250,000 per year. The cost of preparation of a guidance document was estimated to be $75,000 in the first year of

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[4] "Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters", http://www.epa.gov/owow/nps/MMGI/Chapter2/ch2-2c.html#Practices, Table 2-14.

[5] http://www.ers.usda.gov/Data/FertilizerUse/Tables/Table7.xls.

[6] The state has contracted to have NMPs written for 92,000 acres out of 700,000 acres that may receive manure (100,000 cropland and 600,000 hay/pasture land).

the program. Costs for soil and manure tests were estimated to be $140,000 per year (12,000 soil tests plus 2,000 manure tests at $10 per test).[7] The cost savings for reduced synthetic fertilizer usage were estimated by multiplying the annual synthetic fertilizer consumption by the percentage reduced in each year and the average cost of fertilizer ($260/ton). Overall costs were estimated as the net of costs and cost savings.

*Cover Crops*

Like manure injection, GHG benefits for cover crops were not estimated due to lack of data and the many variables involved. Cover crops can influence GHG emissions in numerous ways, such as weed suppression which reduces the need for herbicides and reduction in soil erosion. Nitrogen-fixation by a legume cover crop may reduce the need for fertilizers. However, other types of cover crops may require additional application of fertilizers. Some cover crops add biomass to the soil, increasing carbon sequestration, while other types remove carbon from the soil decreasing soil carbon stocks. The benefits from cover crops are highly dependent on the type of cover crop and local conditions.

*Other Management Practices?*

- **Key Assumptions:** The nitrogen reduction is representative of agricultural practices in Vermont; a reduction in nitrogen use from commercial fertilizers will lead to a similar level of reduction in $N_2O$ emissions. No change in net soil carbon levels occur as a result of this option.

## Key Uncertainties

The effects of manure injection and cover crops on $N_2O$ emissions are highly uncertain due to highly variable conditions and lack of emissions data. While manure injection has been shown to result in lower ammonia ($NH_3$) emissions than manure broadcasting, the lower $NH_3$ volatilization may actually lead to higher $N_2O$ emissions. On the other hand, injection may result in higher fertilizer replacement value of the manure applied, leading to a reduction of mineral fertilizers and less nitrogen leaching on conventional farms (lower leaching of nitrogen could lead to lower $N_2O$). For this assessment, CCS has assumed that since most of the $N_2O$ emissions are associated with leaching and runoff, these emissions can be reduced through NMP's that successfully address this issue (by retaining nitrogen in the soils).

## Additional Benefits and Costs

Higher levels of soil organic carbon can lead to higher levels of crop productivity. Measures adopted that result in decreases in fossil fuel combustion will lead to lower GHG and other air pollutant emissions.

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[7] Estimated number of soil and manure tests provided by Philip Benedict, Vermont Agency of Agriculture, Food & Markets, personal communication with H. Lindquist, CCS, May 2007.

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–3. Manure Management Methods to Achieve GHG Benefits

## Policy Option Description

The methane emissions inherent from the anaerobic decomposition process of manure and other wastes may be captured and used as an energy source. Methane and nitrous oxide emissions can occur at several different places in the manure management process. Management techniques aimed can reduce GHG emissions and, with energy recover, offset fossil-based energy. This option covers producer incentives to adopt programs to increase the number of methane capture and energy recovery projects or other manure management techniques that reduce methane and nitrous oxide emissions.

## Policy Option Design

**Goals:** Digest half of dairy cattle manure by 2028; Compost 50% of the poultry and livestock manure produced on farms by 2028; Implement nutrient management strategies which meet the NRCS Technical Practice Code 590 on 90% of the land which receives manure or processed wastewater by 2028.

**Timing:** Increase the anaerobic digestion from five (5) percent (in operation and under construction) to 15 percent of the dairy cattle manure in Vermont over the next five years (2012). By 2028, digest 50 percent of the dairy cattle manure in Vermont; Increase the percent of manure composted on poultry and livestock farms to 25% by 2012 and to 50% by 2028; Implement nutrient management plans on 75% of the lands receiving manure and processed wastewater by 2012 and on 90% of this land base by 2028.

**Parties Involved:** Vermont Agency of Agriculture, Vermont Agency of Natural Resources, Vermont Department of Public Service, USDA Natural Resources Conservation Service, USDA Rural Development, Vermont Power Supply Companies, Vermont Farm Bureau, Rural Vermont, University of Vermont, Vermont Technical College-Business and Sustainable Technology, Vermont Center for Emerging Technology.

**Other:** Anaerobic digestion of half of Vermont's dairy manure could produce 15 megawatts of electric generation and 350 billion Btu's of heat energy per year.

## Implementation Mechanisms

- Implement 590 nutrient management plans on large and medium livestock farms through agency permitting programs.
- Implement 590 nutrient management plans on small livestock farms when they receive state or federal cost share to construct waste management systems.
- Provide cost share assistance for farms to develop nutrient management plans and provide annual assistance so that existing plans continue to be implemented.

- Provide cost share assistance so that farms implement cover crops and other soil erosion and land cover practices.
- Provide cost share assistance for the construction of waste management systems including methane digestion and composting facilities where appropriate.
- Provide technical assistance on the adoption of new technologies and support the development of service industries to maintain the new technologies.

## Related Policies/Programs in Place

- NRCS Environmental Quality Incentives Program
- Vermont Best Management Practices cost share program
- Vermont Nutrient Management Plan cost share program
- Vermont Farm Agronomics Practices cost share program
- Conservation District Technical Assistance Program
- University of Vermont Extension Program
- Vermont Clean Energy Fund
- CVPS Biomass Grants Program
- USDA Rural Development 2006 Renewable Energy Systems and Efficiency Grants Program
- EPA AgStar Program.
- Federal Renewable Electricity Production Tax Credit.
- USDA Farm Bill Renewable Energy and Energy Efficiency Loan and Grant Program - The Renewable Energy and Energy Efficiency loan and grant program was established under Section 9006 of the 2002 Farm Bill. It provides loan guarantees and grants to agricultural producers and rural small businesses for the purchase and installation of renewable energy systems or for energy efficiency improvements. Loan guarantees cover up to 50 percent of a project's cost, not to exceed $10 million. Grants are available for up to 25 percent of a project's cost, not to exceed $250,000 for energy efficiency improvements and $500,000 for renewable energy systems. These loans and grants are expected to reduce greenhouse gas emissions by 0.97 million metric tons, replace 821 million barrels of foreign oil and generate almost 2 million kilowatt hours of electricity annually. USDA has funded more than 800 loans and grants since the renewable energy program began in FY 2003.

## Types(s) of GHG Reductions

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

- **$CO_2$:** carbon dioxide is reduced when the methane is converted to energy and that energy is used to offset fossil-based energy (e.g., electricity, natural gas, etc.). Small amounts of $N_2O$ and $CH_4$ are also reduced from the fossil-based energy that is offset. See ES-6 for estimates of $CO_2$ offsets.

## Estimated GHG Savings and Costs per $MtCO_2e$

- **GHG reduction potential in 2012, 2028 ($MMtCO_2e$):** Manure digesters – 0.006, 0.02;

  *These reductions just account for the $CH_4$ reduced. Some additional reductions occur via offsetting grid-based power. These will be added by CCS. Reduction estimates for the composting element of this option to be added.*

- **Net Cost per $MtCO_2e$:** Manure digesters: $117;
  *Manure digester cost estimates include the reduction in capital costs associated with grants for renewable energy projects from the Federal Farm Bill but do not include the effects of other existing federal and state tax incentives. This estimate does not currently incorporate GHG reductions from offsetting grid-based power. Cost estimates for the composting element of this option to be added.*

- **Data Sources:**

  *Manure Digesters*
  Manure management emissions estimates were taken from the VT GHG I&F. An electricity conversion factor of 10,000 Btu/kW-hr was taken from the Vermont Methane Pilot Project Resource Assessment.[8] Cost estimates were taken from a list of NYSERDA anaerobic digester projects[9] and a list of digester operations from the EPA AgSTAR program[10].

  *Composting*

  *To be added.*

- **Quantification Methods:**

  *Manure Digester GHG Benefit*
  Methane emissions data from the VT I&F were used as the starting point to estimate the GHG benefits of capturing and controlling the volumes of methane targeted by the policy. For 2012 and 2028, the GHG benefit for capturing methane was estimated by multiplying the methane emissions from dairy operations by the applicable goal (15% in 2012, 50% in 2028) minus the BAU percentage of dairy populations affected (5%), multiplying by an assumed collection efficiency of 75%[11], and converting to $CO_2e$.

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[8] Vermont Methane Pilot Project Resource Assessment, http://www.vermontagriculture.com/methresource.pdf.
[9] Cornell Manure Management Program, NYSERDA Project List: Anaerobic Digestion, http://www.manuremanagement.cornell.edu/Lessons/List_anaerobicDigestion.aspx.
[10] EPA AgSTAR, Guide to Operation Systems, U.S. Operating Digesters by State, http://www.epa.gov/agstar/operation/bystate.html.
[11] 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).

*Manure Digester Costs*

Costs were estimated based on data from the NYSERDA and EPA AgSTAR project lists. The average capital cost per head was calculated for dairies with between 150 and 1,200 cows, resulting in a value of $674/head. (The highest capital cost/head value was removed because it was over 30% higher than the next highest value.) This capital cost was assumed to represent the "high" end of the range for capital costs. The "low" capital cost estimate was assumed to be $190/head for regional digesters (those serving multiple nearby operations), taken from a New Mexico Dairy Producers Association report.[12]

Annual costs were estimated based on data from the NYSERDA project list. The average of annual operating and maintenance costs minus benefits (excluding electricity and heat savings) resulted in an annual cost of $36/head.

CCS assumed that the 25% Farm Bill grant would be available to each project initiated as a result of this policy.[13] After adjustment of the capital costs, annualized costs per head were estimated assuming a 5% interest rate and a 15-year project life. The value of the electricity produced was assumed to be $0.073/kW-hr in 2012 and $0.064/kW-hr in 2028.[14] Additional incentives to the farmer from the Renewable Energy Production Incentives were not included but could have a small effect on the estimated costs (about $1/MtCO$_2$e reduced). The annualized per head cost estimates were multiplied by the head of livestock to be controlled in each year to estimate total costs.

*Composting GHG Benefit*

*To be added.*

*Manure Composting Costs*

*To be added.*

- **Key Assumptions:** That the cost data for the studies cited is representative of actual costs; 75% collection efficiency for farm-level methane emissions for the digester. Farm Bill grant will be available to all projects in subsequent cycles of the Farm Bill through 2020. Composting emission factors are representative of all types of manure (dairy, feedlot, and poultry).

## Key Uncertainties

TBD

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[12] *DPNM Biomass Project 2005*, prepared by Agri-Energy and the Dairy Producers of New Mexico, no publish date provided.

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

[14] Electricity costs come from the study “Avoided Energy Supply Costs in New England” prepared by ICF Consulting for the Avoided Energy Supply Component (AESC) Study Group. December 23, 2005

## Additional Benefits and Costs

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

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

  A study of an anaerobic digester project for a dairy farm[15] demonstrated that these projects can substantially reduce total volatile solids (39.5 percent) and chemical oxygen demand (38.5 percent). These reductions translate directly into a lower potential for depletion of dissolved oxygen in natural waters. Although anaerobically digested manure is not suitable for direct discharge to surface or ground waters, these reductions still are significant due to the potential for these wastes to enter surface waters by nonpoint source transport mechanisms. The study also showed that mesophilic anaerobic digestion at an average hydraulic retention time of 29 days reduced the mean densities of the fecal coliform group of enteric bacteria by 99 percent and fecal streptococcus group by 90 percent;
- Economic benefits for the digester industry.

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

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[15] "An Evaluation of a Mesophilic, Modified Plug Flow Anaerobic Digester for Dairy Cattle Manure", prepared by Eastern Research Group, prepared for the U.S. EPA AgSTAR Program, July 20, 2005.

## Barriers to Consensus

TBD

# AFW–4. Protect Open Space / Agricultural Land

## Policy Option Description

Reduce the rate at which existing crop and pasture are converted to developed uses. The carbon sequestered in soils and aboveground biomass can be higher in agricultural lands than in developed land uses. Policies are needed to protect working farms and forests (see AFW-7) from unwise and unplanned development.

## Policy Option Design

**Goals:** To reduce the rate at which agricultural lands are converted to development by 50%.

**Timing:** Reduce the rate of conversion by 25% by 2012; achieve 50% reduction in the rate of conversion by 2020 and maintain this rate of conversion through the policy period.

**Parties Involved:** Pending.

**Other:** Vermont has established planning goals to protect the historic pattern of development which favors compact settlement surrounded by open and productive countryside. The state provides incentives to land owners to keep their property in the production of food, fuel and fiber for local consumption, but much more can be done. Vermont's landscape is susceptible to land development that will negatively impact the viability of farm and forestland unless land conservation programs are expanded and fully funded, and rural sprawl is controlled in a responsible manner.

## Implementation Mechanisms

(1) Fully fund the Vermont Housing and Conservation Trust Fund according to the formula set in statute.

(2) Expand enrollment in Vermont's Use Value Appraisal (UVA) Program (Current Use). To expand landowner incentives for enrollment in UVA, allow properties to be enrolled for farm and forest management, carbon sequestration and the protection of open space.

(3) Strengthen regional and local land use planning to better protect the viability of farm and forestland from conversion and development.

(4) Reduce and eliminate policies that promote sprawl in rural lands without appropriate environmental review. Options include eliminating Act 250 exemptions for utility lines and long roads that can promote indiscriminate rural development. Act 250 should be strengthened to conserve the integrity of farm and forestland resources.

(5) Strengthen incentives for landowners to pursue conservation easements by adjusting property tax rates for landowners who hold easements to reflect use value or a comparable rate.

## Related Policies/Programs in Place

Housing and Conservation Board, Use Value Appraisal Program, Forest Legacy Program, Land Trust activity, Regional Planning, Growth Centers Legislation, Act 200, Act 250, NRCS and other federal programs.

## Types(s) of GHG Reductions

- **$CO_2$:** Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass. Also, emissions are indirectly reduced to the extent that development patterns are influenced and vehicle miles traveled (VMT) are reduced (see TLU Option 1).
- **$CH_4$ and $N_2O$:** Are also indirectly reduced as VMT are reduced.

## Estimated GHG Savings and Costs per $MtCO_2e$

- **GHG reduction potential in 2012, 2028 ($MMtCO_2e$):** 0.06, 0.11
- **Net Cost per $MtCO_2e$:**: $31

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

- **Data Sources:** The annual rate of agricultural land in Vermont converted to developed uses is 10,000 acres per year based on 1982-1997 data from the National Resources Inventory.[16] The typical level of soil carbon in agricultural soils in Vermont was estimated by averaging soil carbon data for entisol and inceptisol type cultivated soils to depths of 30 cm[17], resulting in a value of 0.016 MMtC/1,000 acres. The cost of establishing conservation easements on agricultural lands was estimated by averaging the project costs and NRCS funds for agricultural easements reported in the Vermont Housing and Conservation Board 2006 Annual Report.[18]

- **Quantification Methods:**

  *GHG Benefits*
  Studies are lacking on the changes in below and above-ground carbon stocks when agricultural land is converted to developed uses. For some land use changes, carbon stocks could be higher in the developed use relative to the agricultural use (e.g., parks). In other instances, carbon stocks are likely to be lower (graded and paved surfaces). CCS assumed that the agricultural land would be developed into typical tract-style suburban development.

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[16] Ray Godfrey, Resource Inventory Coordinator, VT USDA-NRCS, personal communication with H. Lindquist, CCS, March 13, 2007.

[17] Mann, L.K. 1986. Changes in soil carbon storage after cultivation. Soil Science 142(5):279-288, http://cdiac.ornl.gov/programs/CSEQ/terrestrial/mann1986/mann1986.html.

[18] Vermont Housing and Conservation Board 2006 Annual Report, http://www.vhcb.org/pdfs/ar2006sm.pdf.

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 30 cm of soil for these graded and covered surfaces would be lost and not replaced. CCS assumed no change in the levels of aboveground carbon stocks.

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

**Land Protection Schedule and Associated Benefits**

| Year | % of Conversion Reduced | Ag Acres Protected | $MMtCO_2e$ Saved |
|---|---|---|---|
| 2007 | 0 | 0 | 0.00 |
| 2008 | 5 | 500 | 0.01 |
| 2009 | 10 | 1,000 | 0.02 |
| 2010 | 15 | 1,500 | 0.03 |
| 2011 | 20 | 2,000 | 0.05 |
| 2012 | 25 | 2,500 | 0.06 |
| 2013 | 30 | 3,000 | 0.07 |
| 2014 | 35 | 3,500 | 0.08 |
| 2015 | 35 | 3,500 | 0.08 |
| 2016 | 40 | 4,000 | 0.09 |
| 2017 | 40 | 4,000 | 0.09 |
| 2018 | 45 | 4,500 | 0.10 |
| 2019 | 45 | 4,500 | 0.10 |
| 2020 | 50 | 5,000 | 0.11 |

*Costs*

To estimate program costs in each year, CCS used multiplied the estimated agricultural acres protected from development by the conservation cost ($2,100/acre) minus the assumed contribution from NRCS ($873/acre). The resulting cost effectiveness is $54/Mt. This estimate only accounts for the direct reductions associated with soil carbon losses estimated above and does not include potentially much larger indirect benefits associated with reductions in vehicle miles.

- **Key Assumptions:** No change in above-ground carbon stocks; 75% loss of soil carbon on 50% of developed land

## Key Uncertainties

As described above, these include the estimated above and below ground carbon stocks for agricultural and developed land uses.

### Additional Benefits and Costs

TBD

### Feasibility Issues

TBD

### Status of Group Approval

TBD

### Level of Group Support

TBD

### Barriers to Consensus

TBD

## AFW–5. Forestry Programs to Enhance GHG Benefits

### Policy Option Description

Carbon dioxide is captured and stored in trees, soil and other forest biomass. Forest management activities that promote forest production have the potential to increase net carbon dioxide sequestration rates and enhance GHG benefits. Retaining forest management where it is being done and expanding the area covered by management plans would stimulate the rate of production, both in terms of forest growth and the amount of biomass harvested. Increasing production of high quality, high density wood with subsequent use of these products in durable wood products (building materials, furniture, etc.) is important for ensuring net carbon benefits associated with forest management. Use of biomass waste from forestry programs for energy purposes is covered under AFW-6.

### Policy Option Design

**Goals:** Increase production (i.e., forest carbon sequestration and harvest volume of high quality, high density wood) of Vermont's forests by 40%

**Timing:** Increase production by 20% by 2028 and 40% by 2048.

**Parties Involved:** Pending.

**Other:** Improved forest management (IFM) can increase carbon sequestration in two primary ways. First IFM can increase forest growth rates by 1-3%/yr (Wilmont, pers com), which would increase carbon sequestration within VT forests. In addition, IFM can shift wood production from low-value, less dense species to high-value hardwood species valued for durable products (such as maple, cherry, oak). This will increase carbon sequestration by increasing the amount of carbon transferred from the forest into durable wood products where it is stored for long periods of time. The goal stated above relates specifically to increasing production in terms of harvest volume through IFM. Both the potential in-forest greenhouse gas benefits (i.e., carbon sequestration from forest in-growth) and greenhouse gas benefits in the supply of durable harvested wood products are accounted for under this option. The later process will also increase the available supply of locally produced durable wood products, which links to the goal stated under AFW-8, and the supply of locally produced biomass for energy combustion, which links to the goal stated under AFW-6.

Increases in production can increase carbon sequestration within Vermont's forest ecosystems as a result of improved forest health and enhanced forest growth. In addition, carbon sequestration can increase in durable wood products harvested from the forests—the increased harvest volume is intended to provide more high quality wood (high density, large diameter wood) for the wood products industry. The impacts of increased production on harvested wood products, in terms of GHG benefits and cost/cost savings, will be covered in AFW-8.

## Implementation Mechanisms

VT Current Use Program (to be elaborated)

Develop markets for durable wood products made form high-quality wood (e.g., Wood Products Development Program) (to be elaborated)

New state forest management program (to be elaborated)

Voluntary programs (to be elaborated)

## Related Policies/Programs in Place

Carbon sequestration in forest biomass

Carbon sequestration in durable wood products

## Estimated GHG Savings and Costs per MtCO$_2$e

- **GHG reduction potential in 2012, 2028 (MMtCO$_2$e):** 0.12, 0.27 (HWP 100-yr method)
- **Cumulative GHG reduction potential (MMtCO$_2$e, 2007-2028):** 3.8 (HWP 100-yr method)
- **Net Cost per MtCO$_2$e:** TBD
- **Data Sources:** US Forest Service Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the US, General Technical Report NE-343 (also published as part of the Department of Energy Voluntary GHG Reporting Program), US Forest Service Forest Inventory Analysis Program.
- **Quantification Methods:**

The acres targeted for improved forest management (IFM) are inferred from the stated goal level, which is a 20% increase in production (harvest volume) on average across all of VT forests by 2028. This would, in reality, result from greater than 20% gains on some portion of VT forests. For the purposes of this analysis, it was assumed that a 50% increase in production would be achieved on 3.6 million acres of VT forests by 2028, i.e., on 80% of the estimated 4.5 million acres of forests in VT (FIA 1997). Under this scenario, approximately 171,000 acres/yr would be treated with IFM during 2008-2028. It was also assumed that these forests would be harvested at rate of 1.3%/yr.

This analysis assumes the IFM is implemented on the three major forest types in Vermont, Maple/Beech/Birch, Spruce/Fir, and White/Red/Jack, in proportion to their relative dominance. Table 1 shows the total number of acres that will be treated by IFM by 2028 under this scenario, by forest type.

**Table 1. Cumulative Number of Acres Treated with Improved Forest Management from 2008-2028, by Forest Type**

| Year | Maple/Beech/Birch | Spruce/Fir | White/Red/Jack | Total |
|---|---|---|---|---|
| 2008 | 129,932 | 19,711 | 21,114 | 170,757 |
| 2009 | 259,864 | 39,423 | 42,228 | 341,515 |
| 2010 | 389,796 | 59,134 | 63,342 | 512,272 |
| 2011 | 519,728 | 78,845 | 84,456 | 683,030 |
| 2012 | 649,660 | 98,557 | 105,570 | 853,787 |
| 2013 | 779,592 | 118,268 | 126,684 | 1,024,545 |
| 2014 | 909,524 | 137,980 | 147,798 | 1,195,302 |
| 2015 | 1,039,457 | 157,691 | 168,912 | 1,366,059 |
| 2016 | 1,169,389 | 177,402 | 190,026 | 1,536,817 |
| 2017 | 1,299,321 | 197,114 | 211,140 | 1,707,574 |
| 2018 | 1,429,253 | 216,825 | 232,254 | 1,878,332 |
| 2019 | 1,559,185 | 236,536 | 253,368 | 2,049,089 |
| 2020 | 1,689,117 | 256,248 | 274,482 | 2,219,846 |
| 2021 | 1,819,049 | 275,959 | 295,596 | 2,390,604 |
| 2022 | 1,948,981 | 295,671 | 316,710 | 2,561,361 |
| 2023 | 2,078,913 | 315,382 | 337,824 | 2,732,119 |
| 2024 | 2,208,845 | 335,093 | 358,938 | 2,902,876 |
| 2025 | 2,338,777 | 354,805 | 380,052 | 3,073,634 |
| 2026 | 2,468,709 | 374,516 | 401,166 | 3,244,391 |
| 2027 | 2,598,641 | 394,227 | 422,280 | 3,415,148 |
| 2028 | 2,728,573 | 413,939 | 443,394 | 3,585,906 |

## Forest Carbon Sequestration

Forest carbon sequestration rates under baseline conditions (no improved forest management) were based on published carbon stocks (tons carbon per acre in forest biomass) for Maple/Beech/Birch, Spruce/Fir, and White/Red/Jack stands in the Northeast region of the US (USFS GTR-343). Annual rates of carbon sequestration (tons carbon sequestered per year) were calculated by subtracting total carbon stocks in forest biomass of 35 yr old stands from total carbon stocks in forest biomass of new stands and dividing by 35. An average for 35-yr old stands was used to take into account the relatively fast rate of carbon accumulation anticipated from natural accretion in Vermont's relatively young forests.

It was assumed that IFM would increase forest growth and hence carbon sequestration by 3%, based on expert opinion that IFM can increase forest growth in VT by 1-3%/yr (Wilmont, personal communication). USFS estimates of soil carbon stocks are constant over time. Therefore, this analysis assumes no net carbon sequestration in forest soils occurs under the baseline or policy scenarios. Carbon stocks and annual carbon sequestration rates under baseline and policy implementation are shown in Table 2.

### Table 2. Forest Carbon Stocks and Annual Sequestration, by Forest Type, for Baseline and Improved Forest Management

| | Baseline | | Improved Forest Management | |
|---|---|---|---|---|
| | *Biomass* | *Soils* | *Biomass* | *Soils* |
| **Carbon Stocks, by stand age** | tons C/acre | | | |
| Maple/beech/yellow birch | | | | |
| 0 yrs | 25.0 | 28.1 | 25.8 | 28.9 |
| 35 yrs | 43.6 | 28.1 | 44.9 | 28.9 |
| 65 yrs | 63.8 | 28.1 | 65.7 | 28.9 |
| 125 yrs | 88.6 | 28.1 | 91.3 | 28.9 |
| Spruce Fir | | | | |
| 0 yrs | 22.7 | 39.7 | 23.4 | 40.9 |
| 35 yrs | 33.6 | 39.7 | 34.6 | 40.9 |
| 65 yrs | 52.0 | 39.7 | 53.6 | 40.9 |
| 125 yrs | 76.7 | 39.7 | 79.0 | 40.9 |
| White/Red/Jack | | | | |
| 0 yrs | 14.7 | 31.6 | 15.1 | 32.5 |
| 35 yrs | 32.8 | 31.6 | 33.8 | 32.5 |
| 65 yrs | 45.5 | 31.6 | 46.9 | 32.5 |
| 125 yrs | 62.2 | 31.6 | 64.1 | 32.5 |
| **Annual Carbon Sequestration (0-35 yrs)** | tons C/acre/yr | | | |
| Maple/beech/yellow birch | 0.5 | 0.0 | 0.5 | 0.0 |
| Spruce Fir | 0.3 | 0.0 | 0.3 | 0.0 |
| White/Red/Jack | 0.5 | 0.0 | 0.5 | 0.0 |

To assess net carbon sequestration within forests, both the annual amount of carbon sequestered from growth and the annual amount of carbon lost from removals (harvest) are taken into account to calculate the net annual carbon flux (i.e., removals are subtracted from annual increases in carbon stocks). It is assumed that 1.3%/yr of the targeted forest area is harvested annually and that 66% of the biomass carbon stocks are removed. Research suggests that approximately 66% of forest biomass is removed during a clearcut harvest (33% of which goes into harvested wood products) (*need reference from Sandy*). The amount of carbon stored in harvested wood is calculated in the second part of this analysis.

Annual carbon sequestration under policy implementation was calculated by multiplying the cumulative number of acres treated each year by the annual carbon sequestration rate for Improved Forest Management in Table 2. This accounts for annual carbon sequestration benefits beginning in the first year that an area of forest is treated and continuing through the duration of the timeframe of analysis (in this case until 2028). Annual removals were calculated by multiplying the number of acres treated each year by 1.3%, which yields approximately 2,200 ac/yr, and multiplying this by 66% of biomass carbon stocks in 35-yr old stands. Sequestration minus removals was calculated to yield a net annual carbon flux. Annual sequestration, removals, and net carbon flux under baseline conditions were calculated using the same area data and applying the baseline annual sequestration and 35-yr carbon stocks values. The difference in net carbon flux between the policy and baseline cases is the total additional carbon sequestered within forests under this option. Results are shown in Table 3.

**Table 3. Estimate Annual Carbon Sequestration, Removals, and Net Carbon Flux under Baseline and Policy Scenarios**

| | Baseline | | | Policy Scenario | | | GHG Benefits | |
|---|---|---|---|---|---|---|---|---|
| | Annual Seq. | Annual Removals | Net Carbon flux | Annual Seq. | Annual Removals | Net Carbon flux | Additional Seq. | Additional Seq. |
| | (tons C/yr) | | | | | | | MMtCO2e/yr |
| 2008 | 86,107 | -60,231 | 25,877 | 88,690 | -62,037 | 26,653 | 776 | 0.003 |
| 2009 | 172,214 | -60,231 | 111,984 | 177,381 | -62,037 | 115,343 | 3,360 | 0.012 |
| 2010 | 258,322 | -60,231 | 198,091 | 266,071 | -62,037 | 204,034 | 5,943 | 0.022 |
| 2011 | 344,429 | -60,231 | 284,198 | 354,762 | -62,037 | 292,724 | 8,526 | 0.031 |
| 2012 | 430,536 | -60,231 | 370,306 | 443,452 | -62,037 | 381,415 | 11,109 | 0.041 |
| 2013 | 516,643 | -60,231 | 456,413 | 532,143 | -62,037 | 470,105 | 13,692 | 0.050 |
| 2014 | 602,751 | -60,231 | 542,520 | 620,833 | -62,037 | 558,796 | 16,276 | 0.060 |
| 2015 | 688,858 | -60,231 | 628,627 | 709,524 | -62,037 | 647,486 | 18,859 | 0.069 |
| 2016 | 774,965 | -60,231 | 714,735 | 798,214 | -62,037 | 736,177 | 21,442 | 0.079 |
| 2017 | 861,072 | -60,231 | 800,842 | 886,905 | -62,037 | 824,867 | 24,025 | 0.088 |
| 2018 | 947,180 | -60,231 | 886,949 | 975,595 | -62,037 | 913,558 | 26,608 | 0.098 |
| 2019 | 1,033,287 | -60,231 | 973,056 | 1,064,286 | -62,037 | 1,002,248 | 29,192 | 0.107 |
| 2020 | 1,119,394 | -60,231 | 1,059,164 | 1,152,976 | -62,037 | 1,090,938 | 31,775 | 0.117 |
| 2021 | 1,205,501 | -60,231 | 1,145,271 | 1,241,666 | -62,037 | 1,179,629 | 34,358 | 0.126 |
| 2022 | 1,291,609 | -60,231 | 1,231,378 | 1,330,357 | -62,037 | 1,268,319 | 36,941 | 0.135 |
| 2023 | 1,377,716 | -60,231 | 1,317,485 | 1,419,047 | -62,037 | 1,357,010 | 39,525 | 0.145 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2024 | 1,463,823 | -60,231 | 1,403,593 | 1,507,738 | -62,037 | 1,445,700 | 42,108 | 0.154 |
| 2025 | 1,549,930 | -60,231 | 1,489,700 | 1,596,428 | -62,037 | 1,534,391 | 44,691 | 0.164 |
| 2026 | 1,636,038 | -60,231 | 1,575,807 | 1,685,119 | -62,037 | 1,623,081 | 47,274 | 0.173 |
| 2027 | 1,722,145 | -60,231 | 1,661,914 | 1,773,809 | -62,037 | 1,711,772 | 49,857 | 0.183 |
| 2028 | 1,808,252 | -60,231 | 1,748,022 | 1,862,500 | -62,037 | 1,800,462 | 52,441 | 0.192 |

### Carbon Sequestration in Durable Wood Products

*Note: Metric units are used in this portion of the analysis because default coefficients in the USFS methodology for quantifying carbon sequestration in harvested wood products are in metric units.*

Improved forest management is also expected to increase the amount of high-density, high-quality wood available for harvest. The removal of biomass through harvesting transfers carbon stored in forest biomass to carbon stored in harvested wood products (HWP). Increased levels of production under this option will lead to more carbon transferred into HWP. The analysis below estimates the amount of additional carbon stored in HWP as a result of a 50% increase in production on 80% of VT forests by 2028 (for an average 20% increase on all VT forests).

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

Data from the US Forest Service Forest Inventory Analysis program in 1997 were used to estimate current levels of productivity for Maple/Beech/Birch, Spruce/Fir, and White/Red/Jack in VT. Average production was calculated separately for each forest type by dividing the total growing stock volume in timberlands by the total area of timberland in 1997. Average productivity in Maple/Beech/Birch, Spruce/Fir, and White/Red/Jack stands in VT was calculated to be 131, 128, and 185 cubic meters per hectare, respectively. Under implementation of this policy option, production is expected to increase by 50%, therefore, production on forests with improved forest management was calculated as a 50% increase over current levels (i.e., 196, 192, and 278 $m^3$/ha on Maple/Beech/Birch, Spruce/Fir, and White/Red/Jack, respectively).

**Table 4. Background Information on Forest Production by Forest Type (FIA 1997)**

| Species | Area of timberlands (ha) | Growing stock volume ($m^3$/yr) | Baseline Average Production ($m^3$/ha/yr) | Average Production with Improved Forest Management ($m^3$/ha/yr) |
|---|---|---|---|---|
| Maple/Beech/Birch | 1,223,136 | 159,723,335 | 130.59 | 195.88 |
| Spurce/Fir | 185,556 | 23,792,627 | 128.22 | 192.34 |
| White/Red/Jack | 198,760 | 36,790,658 | 185.10 | 277.65 |

There are several steps in the analysis where default coefficients for the Northeastern US region are applied to the starting point of average production. First, for each forest type, average production (m3/ha/ys) is apportioned into classes of wood harvested (i.e., softwood sawlog, softwood pulpwood, hardwood sawlog, hardwood pulpwood) and the per-area carbon volumes of each class are calculated. Next, the quantity that is processed into primary wood products is calculated (factoring out carbon in logging residue, fuelwood, and waste), using the following ratios: ratio of industrial roundwood to growing stock volume removed as roundwood; ratio of carbon in bark to carbon in wood; fraction of growing stock volume removed as roundwood; and the ratio of fuelwood to growing stock volume removed as roundwood. The results are approximate per-area carbon stocks (tons carbon per hectare) in industrial roundwood, excluding bark and fuelwood. Carbon stocks in industrial roundwood were estimated for the baseline case using current levels of production as the starting point, and for the policy scenario using levels of production under improved forest management as the starting point (Table 5).

**Table 5. Calculated Carbon Stocks in Industrial Roundwood**

| Product Pool | Baseline (tC/ha) | Improved Forest Management (tC/ha) |
|---|---|---|
| Softwood saw log carbon in industrial roundwood | 29.15 | 43.72 |
| Softwood pulpwood carbon in industrial roundwood | 53.63 | 80.45 |
| Hardwood saw log carbon in industrial roundwood | 16.96 | 25.45 |
| Hardwood pulpwood carbon in industrial roundwood | 42.61 | 63.92 |

The average disposition pattern of HWP over time in the Northeast is provided by the USFS methodology. The disposition pattern is the flow of HPW between four pools over time: carbon in HWP in use, carbon in HWP in landfills, carbon emitted with energy capture, and carbon emitted without energy capture. Disposition patterns are provided separately for softwood and hardwood categories, each with sawlog and pulpwood subcategories.

Tables 6a and 6b show the disposition patterns used in this analysis for a single harvest.For example, in Table 6a, in the year following harvest, 57% of the carbon in softwood sawlogs goes into use, 24% is emitted with energy capture, 19% is emitted without energy capture, and none is placed in landfills. Over time the amount of carbon in use declines as it is transferred into the categories of carbon in landfills and carbon emitted to the atmosphere, such that by 100 years after harvest, approximately 10% of carbon remains in HWP in use, 22% is in landfills, and 68% has been emitted (note: carbon emissions from HWP are considered biogenic and are not counted as direct emissions).

**Table 6a. Disposition pattern of carbon in HWP as a fraction of industrial roundwood for Softwood in the Northeast**

| | Sawlog | | | | Pulpwood | | | |
|---|---|---|---|---|---|---|---|---|
| Year after production | Fraction in use | Fraction in landfill | Fraction emitted w/ energy capture | Fraction emitted w/o energy capture | Fraction in use | Fraction in landfill | Fraction emitted w/ energy capture | Fraction emitted w/o energy capture |
| 0 | 0.569 | 0 | 0.24 | 0.19 | 0.513 | 0 | 0.306 | 0.181 |
| 1 | 0.542 | 0.014 | 0.246 | 0.197 | 0.436 | 0.025 | 0.334 | 0.204 |
| 2 | 0.517 | 0.027 | 0.252 | 0.203 | 0.372 | 0.046 | 0.359 | 0.223 |
| 3 | 0.495 | 0.039 | 0.257 | 0.209 | 0.317 | 0.063 | 0.381 | 0.239 |
| 4 | 0.474 | 0.05 | 0.262 | 0.214 | 0.271 | 0.077 | 0.399 | 0.253 |
| 5 | 0.455 | 0.06 | 0.266 | 0.219 | 0.232 | 0.088 | 0.415 | 0.265 |
| 6 | 0.438 | 0.069 | 0.27 | 0.223 | 0.197 | 0.098 | 0.429 | 0.276 |
| 7 | 0.422 | 0.078 | 0.274 | 0.227 | 0.167 | 0.106 | 0.441 | 0.286 |
| 8 | 0.406 | 0.085 | 0.277 | 0.231 | 0.139 | 0.113 | 0.452 | 0.296 |
| 9 | 0.392 | 0.093 | 0.281 | 0.235 | 0.114 | 0.118 | 0.463 | 0.305 |
| 10 | 0.379 | 0.099 | 0.284 | 0.238 | 0.093 | 0.123 | 0.472 | 0.313 |
| 15 | 0.326 | 0.126 | 0.296 | 0.252 | 0.037 | 0.128 | 0.497 | 0.338 |
| 20 | 0.288 | 0.144 | 0.304 | 0.264 | 0.021 | 0.122 | 0.505 | 0.352 |
| 25 | 0.259 | 0.158 | 0.311 | 0.273 | 0.016 | 0.114 | 0.509 | 0.362 |
| 30 | 0.234 | 0.168 | 0.316 | 0.281 | 0.014 | 0.107 | 0.51 | 0.369 |
| 100 | 0.095 | 0.223 | 0.338 | 0.344 | 0.006 | 0.0884 | 0.51 | 0.4 |

**Table 6b. Disposition pattern of carbon in HWP as a fraction of industrial roundwood for Hardwood in the Northeast**

| | Sawlog | | | | Pulpwood | | | |
|---|---|---|---|---|---|---|---|---|
| Year after production | Fraction in use | Fraction in landfill | Fraction emitted w/ energy capture | Fraction emitted w/o energy capture | Fraction in use | Fraction in landfill | Fraction emitted w/ energy capture | Fraction emitted w/o energy capture |
| 0 | 0.614 | 0 | 0.237 | 0.149 | 0.65 | 0 | 0.185 | 0.166 |
| 1 | 0.572 | 0.025 | 0.246 | 0.157 | 0.59 | 0.021 | 0.202 | 0.186 |
| 2 | 0.534 | 0.048 | 0.255 | 0.163 | 0.539 | 0.039 | 0.218 | 0.203 |
| 3 | 0.5 | 0.067 | 0.263 | 0.17 | 0.496 | 0.054 | 0.232 | 0.218 |
| 4 | 0.469 | 0.085 | 0.271 | 0.175 | 0.459 | 0.067 | 0.244 | 0.231 |
| 5 | 0.44 | 0.102 | 0.278 | 0.18 | 0.426 | 0.078 | 0.254 | 0.242 |
| 6 | 0.415 | 0.116 | 0.284 | 0.185 | 0.398 | 0.087 | 0.263 | 0.253 |
| 7 | 0.391 | 0.129 | 0.29 | 0.19 | 0.372 | 0.095 | 0.271 | 0.262 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8 | 0.369 | 0.141 | 0.295 | 0.194 | 0.349 | 0.102 | 0.279 | 0.271 |
| 9 | 0.349 | 0.152 | 0.3 | 0.198 | 0.327 | 0.108 | 0.286 | 0.279 |
| 10 | 0.331 | 0.162 | 0.305 | 0.202 | 0.308 | 0.114 | 0.292 | 0.286 |
| 15 | 0.26 | 0.198 | 0.324 | 0.218 | 0.252 | 0.127 | 0.31 | 0.311 |
| 20 | 0.212 | 0.221 | 0.338 | 0.229 | 0.226 | 0.13 | 0.319 | 0.325 |
| 25 | 0.178 | 0.235 | 0.348 | 0.239 | 0.211 | 0.131 | 0.323 | 0.335 |
| 30 | 0.152 | 0.245 | 0.356 | 0.247 | 0.198 | 0.132 | 0.327 | 0.343 |
| 100 | 0.035 | 0.281 | 0.387 | 0.296 | 0.103 | 0.158 | 0.336 | 0.403 |

The disposition over time of carbon stocks was modeled using the carbon stocks in Table 5 (separately for the baseline and policy cases) and the disposition patterns in Tables 6a and 6b (same pattern used in baseline and policy case). This provides per-acre estimates of carbon stocks (tC/ha) remaining in each pool over time starting from a single harvest for both the baseline and policy scenarios. The total amount of carbon stocks, and their disposition over time, from a single harvest was calculated by multiplying the per-acre carbon stocks mentioned above by an average annual harvested area of 898 ha/yr (i.e., 1.3% of the annual area of treated forest). The net impact of carbon storage in HWP as a result of regular annual harvests over the period of analysis was modeled for the baseline and policy cases. The incremental increase in carbon stocks was calculated as the difference between the two scenarios.

The results of the analysis are summarized in Table 7, which show the amount of carbon stored in landfills and products in-use each year above what would have happened in the baseline, spanning the time period 2008-2028. While the amount of additional carbon in landfills and in products from a given harvest decreases each year (as it is emitted through decay or energy capture), additional wood is harvested each year, adding new carbon stocks to total HWP stream. Thus for every year in the time series, the carbon stocks in the wood products pool are increasing. This analysis is carried out until 2028 and does not capture the continued disposition of carbon through the wood products pools in time.

The values in the table are incremental increases in HWP carbon stocks, with annual totals shown at the bottom. Carbon sequestration is calculated as the annual change in carbon stocks (subtracting stocks in year 2 from stocks in year 1). The net sequestration rate (last row) is sensitive to the year of analysis because the transfer of carbon between HWP pools is dynamic over time. Total incremental annual sequestration in HWP remaining in use and landfills is estimated at 0.32 MMtCO2e in 2012 (from harvests during 2008-2011) and 0.13 MMtCO2e in 2028 (from harvests during 2008-2027).

### Table 7. Disposition of Carbon in HWP Over Time, Shown by Tracking Individual Annual Harvests from 2008-2028 ($MMtCO_2e$).

| | Incremental increase above baseline in carbon in use or in landfill by the end of this year | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year of Harvest | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 |
| 2008 | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 | 0.136 | 0.132 | 0.129 | 0.125 |
| 2009 | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 | 0.136 | 0.132 | 0.129 |
| 2010 | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 | 0.136 | 0.132 |
| 2011 | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 | 0.136 |
| 2012 | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 |
| 2013 | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 |
| 2014 | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 |
| 2015 | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 |
| 2016 | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 |
| 2017 | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 |
| 2018 | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 |
| 2019 | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 |
| 2020 | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 |
| 2021 | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 |
| 2022 | | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 |
| 2023 | | | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 |
| 2024 | | | | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 | 0.319 |
| 2025 | | | | | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 | 0.359 |
| 2026 | | | | | | | | | | | | | | | | | | | 0.548 | 0.470 | 0.408 |
| 2027 | | | | | | | | | | | | | | | | | | | | 0.548 | 0.470 |
| 2028 | | | | | | | | | | | | | | | | | | | | | 0.548 |
| C stocks | 0.548 | 1.018 | 1.426 | 1.784 | 2.103 | 2.389 | 2.648 | 2.884 | 3.100 | 3.300 | 3.485 | 3.662 | 3.831 | 3.992 | 4.144 | 4.289 | 4.429 | 4.565 | 4.698 | 4.826 | 4.951 |
| C flux | | 0.470 | 0.408 | 0.359 | 0.319 | 0.286 | 0.259 | 0.236 | 0.216 | 0.199 | 0.185 | 0.177 | 0.169 | 0.161 | 0.152 | 0.144 | 0.140 | 0.136 | 0.132 | 0.129 | 0.125 |

An alternative approach for estimating carbon stored in wood products is to estimate the amount of carbon remaining in products and landfills after 100 years and to apply that value to the year of harvest as an annual sequestration rate (GTR NE-343, 1605b technical guidelines). This approach essentially accounts for emissions occurring during 100 years after a harvest in the year of the harvest and assumes that the carbon remaining after 100 years is stored permanently. This approach was developed to simplify annual reporting of carbon stored in wood products and to account for the long term dynamics of carbon flows in harvested wood products pools. For comparison to the analysis shown in Table 7, which tracks actual annual stocks and carbon sequestration during 2008-2028, the additional amount of carbon stored permanently above baseline levels 100-yrs after a single annual harvest is estimated to be 0.081 MMtCO2e. Using the 100-yr method, the total amount of incremental carbon permanently stored from harvests during 2008-2028 is 1.7 MMtCO2e. This can be compared to the cumulative amount of carbon sequestration during 2008-2028 as shown in Table 7 of 4.4 MMtCO2e.

Total carbon savings, including net carbon flux in the forest and carbon stored in harvested wood products are shown in Figures 1a and 1b. Figure 1a shows the literal annual account of carbon fluxes in HWP starting with harvests in 2008 and extending until 2028. The flux is high initially because most carbon still remains in use. Over time, the carbon flux converges on a smaller value as the amount of carbon entering the HWP pool each year is balanced by carbon emitted as a result of combustion or decay. This pattern is a function of the time frame of analysis. It is also important to note that this analysis assumes instantaneous increase in harvest volume when forests are treated with improved forest management. In reality, the gains would not be realized for several years into the future, outside of the timeframe of this analysis.

In comparison, Figure 1b uses the amount of carbon stocks remaining 100-yrs after harvest as an annual flux value in the year of harvest. This approach is a way to standardize the analysis and take into account the long-term dynamics of HWP carbon flows. In both figures, the forest carbon estimate is the net carbon flux on the cumulative amount of forest area treated with improved forest management since 2008.

**Figure 1a**

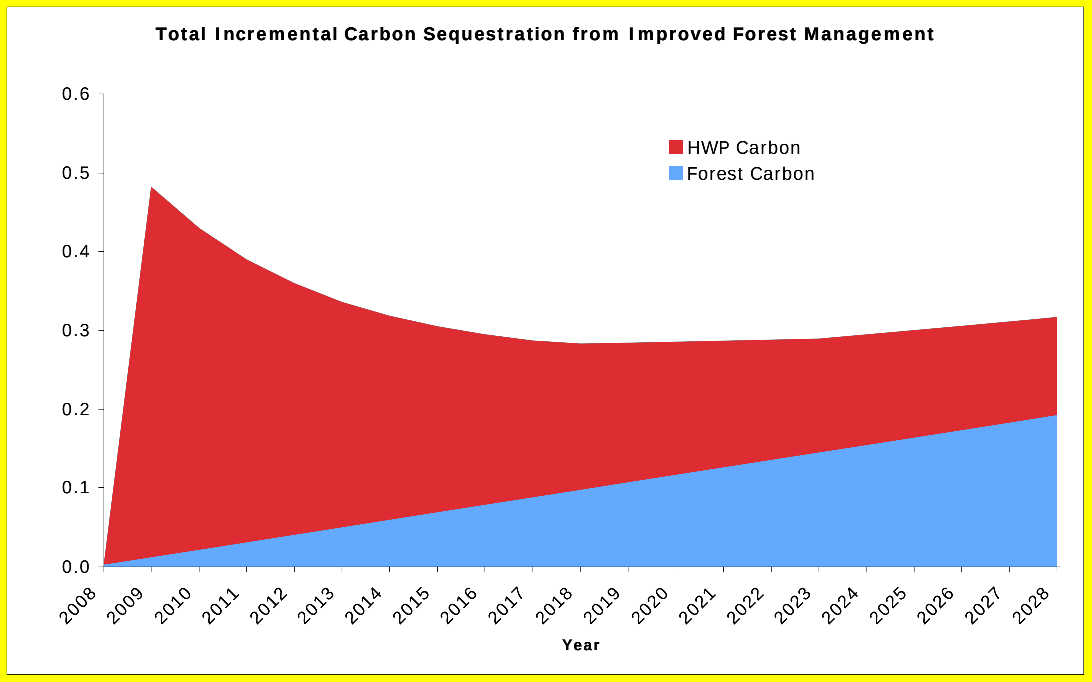
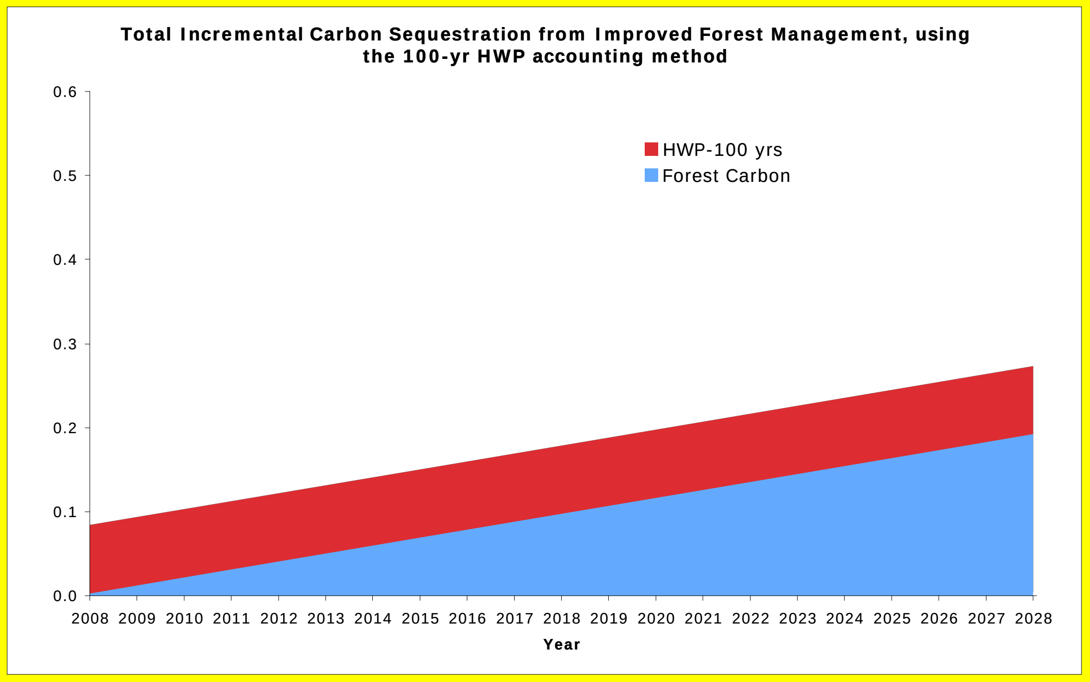


**Figure 1b**



*Note: The TWG should determine which HWP method they prefer to use in the summary totals for this option.*

- **Key Assumptions:** Improved forest management (IFM) increases carbon sequestration by 3%; approximately 80% of VT forests will be treated with IFM by 2028; harvest rates are 1.3%/yr; regional patterns in the disposition of HWP represent conditions in VT.

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

Preliminary investigations at the UVM Jericho Research Forest suggest that carefully planned harvests may be able to increase net sequestration potential in young to mature stands, but this potential is highly sensitive to assumptions regarding long-term forest carbon dynamics, the ability to produce higher grade timber on a given site, and the behavior of forest product markets.

Achievement of net carbon sequestration benefits will depend on: (1) specific choice of silvicultural system targeted under the program; and (2) opportunities to increase market consumption of durable wood products. (see AFW-8).

Feasibility hinges on definition of production: is it the on growth within the forest, whether or not that growth is harvested, or is it the amount of wood that is carried out of the forest for another use?

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–6. Increased Forest Biomass Energy Use

## Policy Option Description

The goals of this option are to increase the use of low value wood material, including logging and mill residues, by appropriate processing centers for energy purposes (electricity, heating or liquid fuels). Offsetting fossil fuel use with biomass for energy, in applications such as distributed generation, combined heat and power and community energy systems will yield additional GHG emissions reductions benefits.[19]

## Policy Option Design

**Goals:** Increase production and use of forest biomass energy feedstocks in Vermont by 30% through sustainable harvesting practices.

**Timing:** Achieve 5% increase by 2010 and 30% increase by 2028

**Parties Involved:** Pending.

**Other:** Current levels of forest biomass feedstock production and use in Vermont are estimated at about 12.5% of annual forest growth (50% of annual growth is harvested each year, 25% of which goes to biomass energy). A biomass energy resource assessment is in preparation and publication anticipated in June 2007. Preliminary information from the assessment is being sought and may influence the above goal levels.

Sustainable harvesting practices should ensure sufficient biomass is left after harvest to provide the necessary nutrients to sustain forest growth (see Feasibility section for more details). The TWG will provide an estimate of the amount of annual growth that should be left in the forest after harvest.

The methodology used in AFW-5 for estimating carbon sequestration in harvested wood products (HWP) also provides estimates of the incremental amount of $CO_2$ emissions associated with combusting and capturing energy from harvested biomass. The analysis suggests that improved forest management implemented at goal levels under AFW-5 would make available roughly 30,000 additional tons per year of biomass feedstocks for energy. This is inferred from the additional 0.22 MMtCO2e of biogenic emissions from biomass energy under full implementation of AFW-5 (based on the carbon stocks accumulated in the HWP pool “carbon emitted with energy capture”). This is equivalent to 60,000 tons of carbon per year, or 30,000 tons of biomass per year, assuming a 50% carbon content in biomass.

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[19] Howard and Marland, application of GORCAM Model (1998)—will get the specific citation for research and modeling analysis for three Vermont community applications (i.e., combining biomass and district energy—economic and environmental benefits).

*Note: The goal above focuses on the supply of forest biomass feedstocks. The TWG strongly encourages complimentary goals related to infrastructure development in the ES and RCI sectors. Specifically, the TWG recommends encouraging bioenergy production through retention and expansion of distributed generation sources, combined heat and power, promotion of district energy production, and establishment of forest biomass power plants. Development of small-scale biomass power generation, close to forest resources should be a priority.*

## Implementation Mechanisms

- Vermont is currently experiencing a market transition away from providing raw material for paper production. The biomass that would normally be used for paper production should be shifted over to use for energy production. Currently 12-15% of harvested biomass is going to paper production.
- Productivity increases in AFW-5 may also increase feedstock supply
- Other implementation mechanisms might address the retention and use of wood pallets in Vermont.

## Related Policies/Programs in Place

TBD

## Types(s) of GHG Reductions

Displaces emissions from fossil fuel combustion

## Estimated GHG Savings and Costs per MtCO$_2$e

*Discussions with CCS facilitators for ESD indicate GHG reductions from biomass energy generation are being calculated under options related to increasing energy generation from renewable energy sources (i.e., ESD-6: Incentives and/or Mandate for Renewable Electricity; ESD-8 Incentives for Clean Distributed Technologies for Electricity or Heat). Thus, reductions associated with the displacement of fossil fuels with biomass energy sources are accounted for in quantification of those options.*

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

Significantly intensified harvests for biomass fuels carry a potential risk to forest habitat values, primarily due to the removal of defective and dying trees (“cull”) that have important ecological functions. Whole tree harvesting carries additional risk to long-term productivity and forest health if conducted on nutrient impaired sites.

These risks could be reduced through consistently applied standards and guidelines (e.g. retention standards for ecologically important elements of stand structure; procedures for evaluating the site-specific appropriateness and intensity of whole tree harvesting) for biomass fuel procurement.

Availability of feedstocks depends on forest capacity to produce biomass (AFW-5), as well as competition for wood from other policy options (AFW-12, AFW-8 for example).

### Status of Group Approval

TBD

### Level of Group Support

TBD

### Barriers to Consensus

TBD

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

## Policy Option Description

Reduce losses of forested lands and their carbon sequestration potential to development or other non-productive land uses. Forestland captures and stores carbon dioxide in trees, soil and other forest biomass. Developed areas contain lower amounts of biomass and its associated carbon. These developed areas also sequester less carbon dioxide than forested areas.

## Policy Option Design

**Goals:** Reduce the rate of forest loss by 50%

**Timing:** Reduce the rate of forest loss by 7% by 2010 and 50% by 2028.

**Parties Involved:** Pending.

**Other:** Chittenden County alone experienced a 4.4% loss in forestland over the past 15 years. NRI data show a statewide 0.13%/yr annual rate of forest loss from 1982-1997 for VT. Landsat TM (classified satellite imagery) data show a statewide 0.52%/yr annual rate of forest loss from 1992-2002 (J. Jenkins and E. Quigley, UVM).

### Implementation Mechanisms

- Increased enrollment in the Use Value Appraisal Program (see Related Policies/Programs in Place).
- Incentives to reduce landowners dividing forests into small parcels.
- Incentives to maintain forest cover in developed uses.
- Encourage forest stewardship and best practices.

## Related Policies/Programs in Place

- Housing and Conservation Board
- Use Value Appraisal Program
- Forest Legacy Program, Land Trust activity
- Regional Planning Commissions
- Growth Centers Legislation
- Act 200, Act 250
- Forest Stewardship Program
- Urban & Community Forestry Program
- Agency of Natural Resources

  - Wood Utilization programs
  - Biomass Energy Resource Center.

## Types(s) of GHG Reductions

Avoided emissions from forest clearing

Maintenance of annual carbon sequestration from forest growth

## Estimated GHG Savings and Costs per $MtCO_2e$

- **GHG reduction potential in 2012, 2028 ($MMtCO_2e$):** 0.4, 1.8
- **Cumulative GHG reduction potential ($MMtCO_2e$, 2008-2028):** 19
- **Net Cost per $MtCO_2e$: $2**
- **Data Sources:** Forestry: 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 forest conversion from NRCS National Resource Inventory and from Landsat TM satellite imagery analysis. Data on forest types from FIA, 1997.
- **Quantification Methods:** Carbon savings from this option were estimated from two sources: A. the amount of carbon that would be lost as a result of forest conversion to non-forest uses (i.e., “avoided emissions”); and B. the amount of annual carbon sequestration in the protected forest area. The area of forestland protected annually is based on a gradual implementation of the goals outlined above, so that a 7% reduction in forest conversion rates is achieved by 2010, and a 50% reduction by 2028. A current conversion rate of 22,635 ac/yr was assumed based on satellite land cover data from 1992-2002, which show a 0.52%/yr rate of forest loss. The percentages in the goals represent a decrease from the current conversion rate of 1,584 acres/yr in 2010 and 11,317 acres/yr in 2028. This option assumes that Maple/Beech/Birch forest types are those protected, based on the relatively high dominance of this forest type in VT.

The forest carbon stocks (tons carbon per acre) and annual carbon flux (annual change in tons carbon per acre) data are based on default carbon sequestration values for Maple/Beech/Birch forest types in the Northeastern US (USFS GTR-343, Table A2). Average forest carbon stock for Maple/Beech/Birch (including biomass and soils) is based on coefficients for 35-yr old stands. Annual rates of carbon sequestration (tons carbon sequestered per year) were calculated by subtracting total carbon stocks in forest biomass of 35 yr old stands from total carbon stocks in forest biomass of new stands and dividing by 35. An average for 35-yr old stands was used to take into account the relatively fast rate of carbon accumulation anticipated from natural accretion in Vermont’s forests. Soil carbon density was assumed constant and is not included in the annual carbon flux calculations because default values for soil carbon density are constant over time in USFS GTR-343.

**Table 1. Carbon stocks and annual sequestration rates for Maple/Beech/Birch forests in the Northeastern US**

| | Maple/Beech/Birch |
|---|---|
| Carbon Stocks (tons C/acre) | |
| Biomass | 43.6 |
| Soils | 28.1 |
| Annual Carbon flux (tons C/ac/yr) | 0.53 |

Loss of forests to non-forest uses results in a large one-time surge of carbon emissions. In this case, it was assumed that 66% 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 clearcutting of forests results in 1/3rd of biomass emitted directly, 1/3rd transferred to harvested wood products, and 1/3rd is left on site (*need reference from Sandy*). The use of sixty-six percent in this analysis may overestimate emissions because is does not take into account the potential long-term storage of carbon in durable wood products. 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 (*need reference from Jen*). To estimate avoided emissions, the total number of acres protected in a year was multiplied by the percent-adjusted carbon stock value for biomass and soils. Results were converted to units of million metric tons $CO_2$ equivalent ($MMtCO_2e$) and are provided in Table 2.

Forests preserved in one year continue to sequester carbon in subsequent years. Thus, annual sequestration includes benefits from acres preserved cumulatively under the program. Annual carbon sequestration was calculated each year by multiplying the cumulative acres protected by the average annual carbon flux (Table 2).

**Table 2. Emissions Avoided and Maintenance of Annual Sequestration Potential in Forest Land Protected from Conversion in Vermont**

| | Acres Protected | Avoided emissions (MMTCO2e) | Annual Sequestration (MMtCO2e) | Total C Savings (MMTCO2e) |
|---|---|---|---|---|
| 2008 | 528 | 0.07 | 0.00 | 0.08 |
| 2009 | 1,056 | 0.15 | 0.00 | 0.15 |
| 2010 | 1,584 | 0.22 | 0.01 | 0.23 |
| 2011 | 2,125 | 0.30 | 0.01 | 0.31 |
| 2012 | 2,666 | 0.38 | 0.02 | 0.39 |
| 2013 | 3,207 | 0.45 | 0.02 | 0.48 |
| 2014 | 3,747 | 0.53 | 0.03 | 0.56 |
| 2015 | 4,288 | 0.61 | 0.04 | 0.64 |
| 2016 | 4,829 | 0.68 | 0.05 | 0.73 |
| 2017 | 5,370 | 0.76 | 0.06 | 0.82 |
| 2018 | 5,910 | 0.84 | 0.07 | 0.91 |
| 2019 | 6,451 | 0.91 | 0.08 | 0.99 |
| 2020 | 6,992 | 0.99 | 0.09 | 1.08 |
| 2021 | 7,532 | 1.07 | 0.11 | 1.18 |
| 2022 | 8,073 | 1.14 | 0.13 | 1.27 |
| 2023 | 8,614 | 1.22 | 0.14 | 1.36 |
| 2024 | 9,155 | 1.30 | 0.16 | 1.46 |

| | | | | |
|---|---|---|---|---|
| 2025 | 9,695 | 1.37 | 0.18 | 1.55 |
| 2026 | 10,236 | 1.45 | 0.20 | 1.65 |
| 2027 | 10,777 | 1.53 | 0.22 | 1.75 |
| 2028 | 11,317 | 1.60 | 0.24 | 1.84 |

The cost of protecting forest land was estimated at $504.60/acre using average cost data from the State of Vermont, which is one of three main organizations that purchase forest conservation easements in Vermont. It was assumed that all of the forest land would be protected with conservation easements and that costs would be incurred one-time in the initial year that land is protected. The analysis does not take into account potential cost savings from forest products revenue on working forest lands that are protected under this policy. Annual costs were estimated by multiplying the number of acres protected by the cost per acre. Annual discounted costs were then estimated using a 5% interest rate. The cumulative cost effectiveness of the total program was calculated by summing the annual discounted costs and dividing by cumulative carbon sequestration, yielding $2/tCO2e. The sum of annual discounted costs also provides an estimate of the Net Present Value of this option of $34 million dollars.

- **Key Assumptions:** Sixty-six and thirty-five percent total forest biomass and soil carbon stocks, respectively, are lost when forests are converted to non-forest uses; no appreciable carbon sequestration occurs post-conversion. Distribution of forest types protected is assumed based on forest dominance.

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–8. Expanded Use of Durable Wood Products (Especially from VT Sources)

## Policy Option Description

This option covers programs designed to increase the use of durable wood products in VT with an emphasis on wood products produced in VT. Development of markets for high value wood materials promotes the retention of forestland as actively managed, productive forests, thereby enhancing carbon dioxide sequestration. Wood products have lower embodied energy than many types of building materials (e.g. cement, steel). To the extent that wood products displace products with higher embodied energy, GHG emissions can be reduced.

## Policy Option Design

**Goals:** Increase the amount of wood from local and out of state production used in materials for residential, institutional and commercial buildings, and in other long lived wood products *by 10% by 2028*. In addition, increase the supply of locally produced durable wood products as a result of increasing forest productivity under AFW 5.

**Timing:** *By 2012, increase wood products use by 2%; achieve 10% increase by 2028.*

**Parties Involved:** Vermont Wood Products Marketing Council; Associated Industries of Vermont, Vermont Logger's Association, Vermont Forest Products Association, Vermont Wood Manufacturer's Association, and Vermont Woodland's Association.

**Other:** The increased supply of locally grown and produced durable wood products envisioned under this option comes in part from the goals levels states under AFW-5. Under full implementation of AFW-5, approximately 75,000 tons of additional biomass per year will be available for use in durable wood products, based on the estimated additional carbon sequestration in HWP in the year immediately following harvest (0.55 $MMtCO_2e$).

## Implementation Mechanisms

Leveraging/expanding the Cornerstone Project and Vermont Sustainable Job Funds (see Related Policies/Programs in Place).

Leveraging/ Expanding Use Value Appraisal Program

## Related Policies/Programs in Place

The Cornerstone Project and Sustainable Jobs Fund: increase the use and production of wood products (e.g., furniture).

Use Value Appraisal Program

## Types(s) of GHG Reductions

Displacement of lifecycle emissions associated with production and use of industrial building materials (e.g., steel and concrete)

## Estimated GHG Savings and Costs per MtCO$_2$e

*Quantification in progress*

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

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

Feasibility of this option depends on forests shifting from low-value, less dense species to high-value hardwood species valued for durable products (such as maple, cherry, oak). This relates to AFW-5.

Note the economic multiplier of this option: in addition to enhanced value of harvest for products, employing more people in forest-related jobs in sawmills, wood production facilities, etc. will contribute to local economies and sustain forests and thus the forest industry.

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–9. Advanced/Expanded Recycling and Composting

## Policy Option Description

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

## Policy Option Design

- **Goals:** Increase per capita diversion to 50% (2005 actual diversion rate is 30%).[20]
- **Timing:** 25% of the goal reached by 2012 (35% diversion rate); 50% diversion by 2028.
- **Parties Involved:** Federal, state and municipal government, private solid waste and recycling service providers, commercial, industrial and institutional waste generators, Vermont Agency of Natural Resources Solid Waste Division.
- **Other:** Per capita diversion as calculated by ANR Solid Waste Division.

### Implementation Mechanisms

Working together in further defining, developing, implementing, and promoting sustainable recycling practices will require an in depth understanding of the cost effectiveness and environmental benefits of recycling.

- Develop advanced recycling infrastructure so that the entire state is able to participate in single stream recycling. Currently only the Chittenden County area is served by single stream recycling.
- Develop an incentive/rewards based recycling infrastructure, coupled with single stream hardware infrastructure, to encourage all Vermont residents and businesses to divert recyclable materials from the waste stream (VT's diversion rate is essentially unchanged in the last several years (2002: 30%, 2003: 31%, 2004: 29%, 2005: 30%[21]) This incentive/reward system could be expanded to include end of life electronics and promote the recovery, reuse and recycling of all obsolete electronic equipment.

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[20] Vermont, Agency of Natural Resources, 2005 Solid Waste Generation Report, Table 2, retrieved from www.anr.state.vt.us/dec/wastediv/solid/DandD.htm.

[21] Vermont, Agency of Natural Resources, 2005 Solid Waste Generation Report, Table 2, retrieved from www.anr.state.vt.us/dec/wastediv/solid/DandD.htm.

- Develop additional processing capacity across the state for processing organic wastes and expand the collection of commercially generated organic waste materials.
- Develop a used clothing recycling program (curb-side and rural drop off model) for used clothing. Approximately 6% of the municipal solid waste stream is used clothing.[22]
- Develop an incentive/rewards based recycling infrastructure specifically for construction and demolition material to encourage all Vermont residents and businesses to divert recyclable construction materials from the waste stream (2005 C&D disposed of 99,654 tons).[23]

## Related Policies/Programs in Place

- Vermont Environmental Assistance Division – Business Environmental Partnership Program
- Vermont Food Rescue/Waste Division Grants for Organic Diversion
- Vermont Technology and Information Transfer and Exchange Program
- Vermont Construction & Demolition Waste Reduction Assistance Program
- Vermont ANR has just established the Center for Climate Change and Waste Reduction (CCWR). The document at the following link provides an overview of the goals of the CCWR – www.anr.state.vt.us/site/cfm/tvwf/CCWR.pdf.

## Types(s) of GHG Reductions

- $CO_2$: Upstream Energy Use Reductions – The energy and GHG intensity of manufacturing a product is generally less using recycled feedstocks than from using virgin feedstocks.
- Methane: Diverting biodegradable wastes from landfills will result in a decrease in methane gas releases from landfills.

## Estimated GHG Savings and Costs per $MtCO_2e$

**Estimated GHG Savings in 2012 and 2028:** 0.16, 0.86.

**Cost Effectiveness:** $3.27

- **Data Sources:** Municipal solid waste (MSW) diversion data for 2005 was obtained from the VT Agency of Natural Resources (ANR).[24] These data are shown below:

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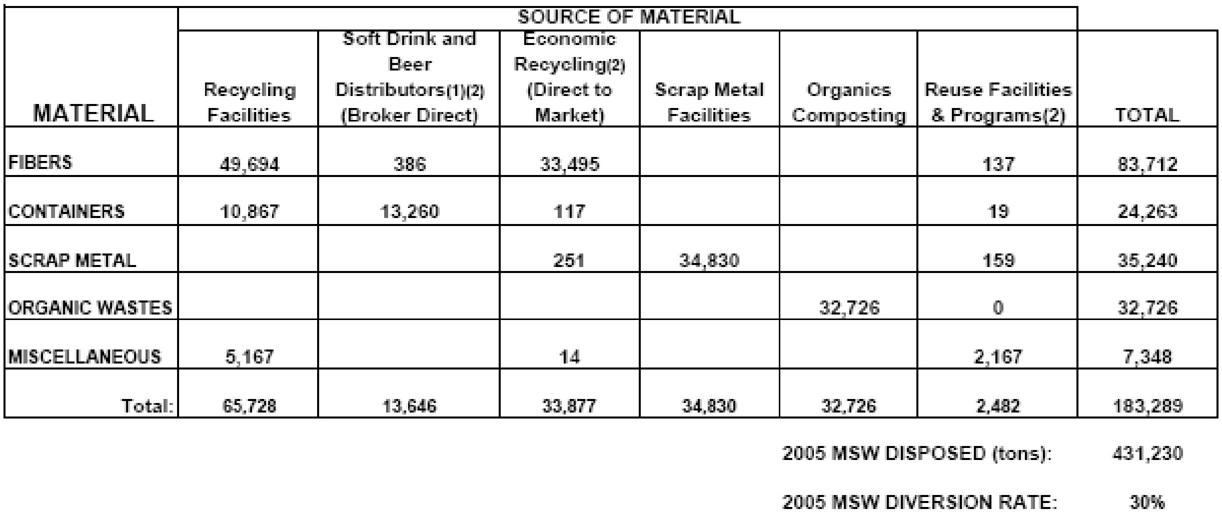
[22] U.S. EPA "Waste Wise" retrieved from www.epa.gov/epaoswer/non-hw/reduce/wstewise/pubs/overview.pdf.

[23] Vermont, Agency of Natural Resources, 2005 Solid Waste Generation Report, Summary, retrieved from www.anr.state.vt.us/dec/wastediv/solid/DandD.htm.

[24] C. Grodinsky, VT ANR, personal communication with S. Roe, CCS, April 24, 2007. Data were taken from the report: *Vermont Solid Waste Generation, Diversion & Disposal, 2005 Report,* Agency of Natural Resources, Department of Environmental Conservation, December 1, 2006.



| MATERIAL | SOURCE OF MATERIAL | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|
| | Recycling Facilities | Soft Drink and Beer Distributors(1)(2) (Broker Direct) | Economic Recycling(2) (Direct to Market) | Scrap Metal Facilities | Organics Composting | Reuse Facilities & Programs(2) | |
| FIBERS | 49,694 | 386 | 33,495 | | | 137 | 83,712 |
| CONTAINERS | 10,867 | 13,260 | 117 | | | 19 | 24,263 |
| SCRAP METAL | | | 251 | 34,830 | | 159 | 35,240 |
| ORGANIC WASTES | | | | | 32,726 | 0 | 32,726 |
| MISCELLANEOUS | 5,167 | | 14 | | | 2,167 | 7,348 |
| Total: | 65,728 | 13,646 | 33,877 | 34,830 | 32,726 | 2,482 | 183,289 |

2005 MSW DISPOSED (tons): 431,230

2005 MSW DIVERSION RATE: 30%

- **Quantification Methods: GHG Reductions:**

*Non-Organics Recycling*

EPA's Waste Reduction Model (WARM) was used to estimate GHG reductions achieved via recycling.[25] The wastes in the table above were aggregated into the applicable WARM material categories: mixed paper waste (fibers in the table above), mixed metals (scrap metals in the table above), and mixed recyclables (containers and miscellaneous in the table above). A baseline estimate of waste diversion and associated GHG reductions for 2005 (representing a 30% MSW diversion rate) was established by inputting the diverted quantities for each waste material.

The incremental benefit for 2012 and 2028 was then determined by inputting the additional quantities of waste that would be diverted in each year (35% overall in 2012 and 50% in 2028). These additional quantities of diverted waste also included organic materials (addressed below). CCS assumed that the fractions of materials diverted remained the same as in 2005: mixed paper (0.56); mixed metals (0.23); and mixed recyclables (0.21). CCS also grew the waste generation in each future year using the 0.6%/yr population growth as used in the GHG inventory and forecast. The table below shows the resulting waste recycling amounts and rates in each year.

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[25] The WARM model and associated documentation can be downloaded from: www.yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html. Assumptions used in the WARM modeling included: landfill gas recovery for energy; 75% landfill gas collection efficiency; and default distances to landfill, recycling facility, and composting facility (20 miles each).

**Table 1. Waste Diversion Rates**

| | 2005 | 2010 | 2012 | 2028 |
|---|---|---|---|---|
| MSW Disposed | 431,230 | 444,323 | 449,671 | 494,837 |
| MSW Diversion (minus organics) | 150,563 | 178,405 | 199,393 | 406,012 |
| Organics Composted | 32,726 | 38,778 | 43,339 | 88,250 |
| Diversion Rate | 30% | 33% | 35% | 50% |
| Incremental Recycle Tons | 0 | 3,270 | 42,391 | 233,241 |
| Incremental Organics Composted Tons | 0 | 5,058 | 9,214 | 50,697 |

For the incremental tons recycled, WARM provided the following results:

| Scenario | $MtCO_2e$ |
|---|---|
| Baseline WARM GHG Reduction | 556,520 |
| 2012 Incremental GHG Reduction | 155,893 |
| 2028 Incremental GHG Reduction | 857,738 |

*Composting of Organic Material*

By composting organic material, the $CH_4$ emissions that would have been generated via anaerobic decomposition in a landfill are avoided. Landfill methane avoided for the baseline (2005) organics material diversion was estimated using an estimate of the degradable organic carbon (DOC) content from the United Nations Framework Convention on Climate Change (UNFCC).[26] Since, landfill gas generated at operating landfills in VT is largely collected and controlled, the EPA default methane collection efficiency of 75% is applied. Also, the default assumption of 10% oxidation of $CH_4$ as it diffuses through the landfill soil cover is applied. The baseline landfill methane avoided is (see footnote for additional details):

$$\text{Baseline } CH_4 = (32{,}726 \text{ ton organics}) \times (0.21) \times (0.50) \times (0.907 \text{ Mt/ton}) \times (16/12) \times 21 \times (1-0.75) \times (1-0.10)$$

$$= 19{,}635 \text{ MtCO}_2\text{e}$$

Using this method for calculating the GHG reductions and the incremental tons of organics to be recycled in 2012 (9,214) and in 2028 (50,697) as shown in Table 1 above, the benefit of organic material recycling in 2012 is 5,528 $MtCO_2e$ and 30,417 $MtCO_2e$ in 2028.

Because GHG emissions also occur as a result of composting, these emissions need to be factored in to obtain a net GHG benefit for organics recycling. CCS used an average $CH_4$ emission factor of 1.12 lb/ton material from tests conducted by the South Coast Air Quality

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[26] UNFCC, CDM – Executive Board, "Approved baseline and monitoring methodology AM0039", September 29, 2006. The average DOC content for lawn & garden, food, and wood/straw waste is 21%. Default $CH_4$ content of landfill gas is 50%. 16/12 is the ratio of molecular weights of carbon and methane. 21 is the global warming potential of methane.

Management District in California.[27] $CH_4$ emissions from the incremental composting in 2012 are estimated to be 99 $MtCO_2e$ and in 2028 to be 540 $MtCO_2e$. Nitrous oxide emissions were estimated from tests done on composting of cattle manure[28] (no data on MSW organic materials were identified). The average $N_2O$ emission factor was 0.94 lb/ton of manure. Applying this emission factor to the incremental organic materials composted in 2012 and 2028 yielded: 731 $MtCO_2e$ and 4,020 $MtCO_2e$, respectively. Hence, the net GHG benefits for the incremental organics composting are:

| Estimate | 2012 $MtCO_2e$ | 2028 $MtCO_2e$ |
|---|---:|---:|
| Landfill methane avoided | 5,528 | 30,417 |
| Composting methane | 99 | 540 |
| Composting nitrous oxide | 731 | 4,020 |
| **Net GHG Benefit** | **4,699** | **25,856** |

Therefore, the overall emission reductions for the policy option are 0.16 MMtCO2e in 2012 and 0.88 $MMtCO_2e$ in 2028.

**Costs:**

*Non-organics recycling.* CCS assumed that the policy would be applied to households in Rutland County (26,007 households), Bennington (15,061 households), and Windham County (18,760 households). Single-stream recycling service would cost $3-4 per pick-up with each pick-up occurring every two weeks.[29] Further, households would fill a 96-gallon container with mixed recyclables. This resulted in an annual average cost per household of $91. The total annual cost for all households is $5.4 million.

There are also societal cost savings associated with this option in that landfill tipping fees are avoided for the waste that is diverted. Tipping fees in VT are currently $103 per ton[30]. Using an EPA estimate of waste density (0.05 ton/$yd^3$), the volume of the recycle container, the number of annual pick-ups, and the number of households, the total waste to be diverted was estimated to be 37,333 tons/yr. Using the tipping fee of $103 per ton, the avoided landfill cost is $3.8 million/yr. The net cost for the non-organics recycling is $1.6 million/yr. Using the GHG reduction estimates derived above, the cost effectiveness in 2028 is $2.4 million/880,902 Mt = $2.72/$MtCO_2e$.

*Organics Composting.* The cost of organics composting is based on the total quantity of organic material composted under the business as usual (BAU) scenario, less the total quantity of organics composted after the adoption of the targets imposed by this action. The per-ton cost was

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[27] Average of three facilities conducting composting of a variety of organic materials – digested biosolids, manure, wood waste, rice hulls, and green waste. Documented in Roe et al, 2004, *Estimating Ammonia Emissions from Anthropogenic Nonagricultural Sources*, Final Report, prepared for the U.S. EPA, Emission Inventory Improvement Program, April 2004.

[28] X. Hao, C. Chang, F.J. Larney, and G.R. Travis, "Greenhouse Gas Emissions during Cattle Feedlot Manure Composting", *Journal of Environmental Quality*, 30:376-386 (2001).

[29] P. Calabrese, Cassella Waste Management, personal communication with S. Roe, CCS, April 26, 2007. Provided information on pick-up service costs, tipping fees, and additional information to derive assumptions for this analysis.

[30] Taylor, Holly, Intervale Compost Project, Personal Communication with Brad Strode, CCS, May 29, 2007.

largely derived from a cost study of a theoretical MSW composting facility serving New York City. It is assumed that capital and O&M costs will be the same in Vermont, with the exception of land and electricity. All capital costs are annualized over 28 years, with the exception of equipment, which is annualized over 10 years. The table below details the annual per-ton costs of large-scale composting.

| **Parameter**[31] | **Value ($/ton)** |
|---|---|
| ***Annual Cost (Capital)***[32] | 38.06 |
| Equipment | 23.18 |
| Engineering and Permitting | 1.18 |
| Land[33] | 0.01 |
| Contingency and Spare Parts | 1.96 |
| Buildings | 11.33 |
| Financing and Miscellaneous | 0.40 |
| ***Annual Cost (O&M)***[34] | 93.62 |
| Salaries | 41.93 |
| Other than Personal Services (OTPS)[35] | 9.11 |
| Repair and Recovery | 11.04 |
| Electricity[36] | 9.71 |
| Disposal[37] | 21.83 |
| ***Total Annual Cost*** | 131.69 |

As reported above, the current tipping fee in Vermont is $103 per ton. Therefore, since the total annual cost-per-ton is greater than the tipping fee, composting projects are expected to have a net cost. The net present value of costs – assuming a constant $103 tipping fee and 2% escalation in O&M cost - related to composting is $9.1 million.

***K*ey Assumptions:** Assumptions used in the EPA WARM modeling include the use of the “current mix” of recycled and virgin material inputs to production (i.e. new products are not produced with 100% virgin materials); landfill gas is recovered for energy purposes; 75% collection efficiency for LFG; default distance to the landfill and recycling facilities (20 miles). Another key assumption is the ability of the $N_2O$ composting emission factor to represent emissions from MSW organic materials composting.

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[31] Capital and O&M costs derived from “New York City MSW Composting Report” Chapter 7; http://www.nyc.gov/html/nycwasteless/html/recycling/waste_reports.shtml#a.

[32] All estimates derived from a theoretical MSW composting facility in NYC processing 90600 tons per year.

[33] Land estimate based on 15-acre site. The cost of land is assumed to be the same as in AFW-4 analysis; $2,100 per acre.

[34] O&M costs are assumed to escalate at a rate of 2% per year.

[35] Includes heating, diesel fuel, compost testing, and off-site deliveries.

[36] Assume 88.3 kWh/ton (derived from NYC study) at VT retail price of $0.11 per kWh (EIA data, same as used in AFW-11 analysis.)

[37] This value may be subject to change if composted product has market value.

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

Post consumer organic waste diversion.

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–10. Programs to Reduce Waste Generation

## Policy Option Description

Institute programs to reduce waste generation at the source to reduce downstream emissions at the waste management site and for transporting these materials to the site. Reducing waste generation can also reduce the emissions associated during manufacturing of the original products.

## Policy Option Design

**Goals:** Reduce the rate of municipal solid waste generation to 50% below 2005 actual rate of 5.40 pounds per person per day.[38]

**Timing:** 25% by 2012; 50% by 2028.

**Parties Involved:** Residential, commercial, industrial and institutional waste generators, Vermont Agency of Natural Resources Solid Waste Division

**Other:** Not applicable.

## Implementation Mechanisms

The policy should aim to develop accessible, cost effective and sustainable policies, strategies and educational/media campaigns that will promulgate cultural and behavioral changes across the state with the ultimate goal of reducing the amount of waste generated. The policy should reflect the principles of the waste hierarchy and reduce the generation of all waste.

- Develop prototype residential and commercial waste prevention programs that will validate costs savings realized by the waste prevention.
- Develop a communication portal that will keep all constituents apprised of waste reduction/minimization initiatives and actively promote waste minimization efforts, including the results of prototype programs and specific case studies.
- Develop sector-specific waste minimization strategies (schools, hotels, hospitals, restaurants, retail, banks, etc.). Develop these strategies in collaboration with other organizations and the local community.
- Develop an assistance program to provide engineering support to businesses to: 1) reduce product packaging and shipping materials 2) select product packaging and shipping materials that are highly recyclable.

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[38] Vermont, Agency Natural Resources, *2005 Solid Waste Generation, Diversion, and Disposal*, Table 2, retrieved from www.anr.state.vt.us/dec/wastediv/solid/DandD.htm.

- Encourage manufacturers to provide end-of-life management solutions that reduce the environmental impact of waste (e.g. "cradle-to-cradle" responsibility of waste).
- Develop and implement a green purchasing program for all state operations, and use that program as a model and encourage adoption of that model by all municipalities and businesses.

## Related Policies/Programs in Place

- Vermont Department of Environmental Conservation "Beyond Disposal & Recycling Waste Prevention Stakeholders Forum" (along with Agency of Natural Resources is developing the Vermont Waste Prevention Plan).
- Vermont Agency of Natural Resources Environmental Assistance Office Partnership.
- Vermont ANR has just established the Center for Climate Change and Waste Reduction (CCWR). The document at the following link provides an overview of the goals of the CCWR – www.anr.state.vt.us/site/cfm/tvwf/CCWR.pdf.

## Types(s) of GHG Reductions

- $CO_2$: Upstream Energy Use Reductions – The energy and GHG intensity of manufacturing a product is generally less using recycled feedstocks than from using virgin feedstocks.
- Methane: Diverting organic wastes from landfills will result in a decrease in methane gas releases from landfills.

## Estimated GHG Savings and Costs per $MtCO_2e$

**Estimated GHG Savings in 2012 and 2028:** 0.34, 0.73

**Cost Effectiveness:** $TBD

- **Data Sources:** These include the 2005 Vermont Solid Waste Generation, Diversion & Disposal Report,[39] data on the amounts of waste recycled in 2005,[40] and a 2002 report on municipal solid waste (MSW) composition in VT,[41] and the EPA Waste Reduction Model (WARM).[42]

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[39] *Vermont Solid Waste Generation, Diversion & Disposal, 2005 Report*, Agency of Natural Resources, Department of Environmental Conservation, December 1, 2006.

[40] C. Grodinsky, VT ANR, personal communication with S. Roe, CCS, May 16, 2007, spreadsheet provided via email.

[41] *Final Report, Vermont Waste Composition Study*, prepared for the Vermont Department of Environmental Conservation, Solid Waste Program, prepared by DSM Environmental Services, Inc., June 2002.

[42] The WARM model and associated documentation can be downloaded from: www.yosemite.epa.gov/oar/globalwarming.nsf/content/ActionsWasteWARM.html. Assumptions used in the WARM modeling included: landfill gas recovery for energy; 75% landfill gas collection efficiency; and default distances to landfill, recycling facility, and composting facility (20 miles each).

- **Quantification Methods:** WARM provides estimates of the lifecycle GHG emissions avoided via source reduction, recycling, and composting. The 2005 VT waste generation rate was 614,519 tons (5.4 lb/person-day). Waste composition data from the 2002 study cited above were used to provide inputs to the WARM model, as shown in the table below.[43] This table shows an assumed baseline for 2012. The tons generated in 2012 are those estimated for 2005 and adjusted for population growth. The tons recycled, combusted and composted were held static from 2005.

| Material | Tons Generated | Tons Recycled | Tons Landfilled | Tons Combusted | Tons Composted |
|---|---|---|---|---|---|
| Aluminum Cans | 5,790 | 1,981 | 3,809 | | NA |
| Steel Cans | 26,379 | 1,404 | 24,975 | | NA |
| Copper Wire | | | | | NA |
| Glass | 17,372 | 13,719 | 3,653 | | NA |
| HDPE | 30,517 | 916 | 29,601 | | NA |
| LDPE | 23,337 | - | 23,337 | | NA |
| PET | 5,984 | 1,968 | 4,016 | | NA |
| Corrugated Cardboard | 57,906 | 36,366 | 21,540 | | NA |
| Magazines/Third-class Mail | 18,659 | 881 | 17,778 | | NA |
| Newspaper | 31,526 | 21,281 | 10,245 | | NA |
| Office Paper | 42,465 | 585 | 41,880 | | NA |
| Phonebooks | | | | | NA |
| Textbooks | 4,504 | 18 | 4,486 | | NA |
| Dimensional Lumber | | | | | NA |
| Medium-density Fiberboard | | | | | NA |
| Food Scraps | | NA | | | |
| Yard Trimmings | | NA | | | |
| Grass | | NA | | | |
| Leaves | | NA | | | |
| Branches | | NA | | | |
| Mixed Paper (general) | - | - | - | | NA |
| Mixed Paper (primarily residential) | | | | | NA |
| Mixed Paper (primarily from offices) | | | | | NA |
| Mixed Metals | - | | - | | NA |
| Mixed Plastics | - | - | - | | NA |
| Mixed Recyclables | | | | | NA |
| Mixed Organics | 193,021 | NA | 160,295 | | 32,726 |
| Mixed MSW | 174,361 | NA | 124,690 | 49,671 | NA |
| Carpet | | | | | NA |
| Personal Computers | 11,581 | - | 11,581 | | NA |
| Clay Bricks | | NA | | NA | NA |
| Aggregate | | | | NA | NA |
| Fly Ash | | | | NA | NA |

Plastics composition was estimated as follows using information in the 2005 solid waste report: high density polyethylene (HDPE) – 51%; polyethylene terephthalate (PET) 39%; other plastics, assumed to be primarily low density polyethylene (LDPE) – 10%. Steel cans includes ferrous cans and all other ferrous waste. Newspaper includes newspaper/inserts as well as half of the “dirty paper” identified in the solid waste composition study; office paper includes “mixed paper” and the other half of the “dirty paper” identified in the solid waste composition study.

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[43] For all waste categories, the data in Table 7a of the 2002 waste composition study cited above were used. The August urban and rural values were averaged; then the November urban and rural values were averaged; finally the average values obtained for August and November were averaged to represent an “annual average” waste percentage by weight.

The next table shows an alternative solid waste management scenario for 2012 assuming that waste in all categories has been source reduced by 25%. The recycled and waste combusted amounts were held constant from 2005 levels. Composting levels were increased to reflect a 25% reduction in organics being landfilled (while this is not technically source reduction it does reduce the landfill emissions that would occur from this organic waste; also, WARM does not have the capability to model source reduction of organics). For mixed MSW, WARM also does not have the capability to estimate the benefits of source reduction. Therefore, CCS reduced the amount of waste being landfilled for that category in 2012 to reflect the waste not landfilled due to source reduction. While this captures the reduction in landfill emissions, it does not capture the rest of the lifecycle emissions. Hence, the benefits are slightly underestimated as a result.

| Material | Baseline Generation | Tons Source Reduced | Tons Recycled | Tons Landfilled | Tons Combusted | Tons Composted |
|---|---|---|---|---|---|---|
| Aluminum Cans | 5,790 | 1,448 | 1,981 | 2,361 | | NA |
| Steel Cans | 26,379 | 6,595 | 1,404 | 18,380 | | NA |
| Copper Wire | - | | | | | NA |
| Glass | 17,372 | 3,653 | 13,719 | - | | NA |
| HDPE | 30,517 | 7,629 | 916 | 21,972 | | NA |
| LDPE | 23,337 | 5,834 | - | 17,503 | | NA |
| PET | 5,984 | 1,496 | 1,968 | 2,520 | | NA |
| Corrugated Cardboard | 57,906 | 14,477 | 36,366 | 7,063 | | NA |
| Magazines/Third-class Mail | 18,659 | 4,665 | 881 | 13,113 | | NA |
| Newspaper | 31,526 | 7,882 | 21,281 | 2,363 | | NA |
| Office Paper | 42,465 | 10,616 | 585 | 31,264 | | NA |
| Phonebooks | - | | | | | NA |
| Textbooks | 4,504 | 1,126 | 18 | 3,360 | | NA |
| Dimensional Lumber | - | | | | | NA |
| Medium-density Fiberboard | - | | | | | NA |
| Food Scraps | - | NA | NA | | | |
| Yard Trimmings | - | NA | NA | | | |
| Grass | - | NA | NA | | | |
| Leaves | - | NA | NA | | | |
| Branches | - | NA | NA | | | |
| Mixed Paper, Broad | - | NA | - | | | NA |
| Mixed Paper, Resid. | - | NA | | | | NA |
| Mixed Paper, Office | - | NA | | | | NA |
| Mixed Metals | - | NA | | | | NA |
| Mixed Plastics | - | NA | - | | | NA |
| Mixed Recyclables | - | NA | | | | NA |
| Mixed Organics | 193,021 | NA | NA | 112,040 | | 80,981 |
| Mixed MSW | 174,361 | NA | NA | 81,100 | 49,671 | NA |
| Carpet | - | | | | | NA |
| Personal Computers | 11,581 | 2,880 | | 8,701 | | NA |
| Clay Bricks | - | | NA | | NA | NA |
| Aggregate | - | NA | | | NA | NA |
| Fly Ash | - | NA | | | NA | NA |

WARM estimated a 0.34 MMtCO$_2$e reduction in 2012 due to the 25% source reduction shown above. A similar assessment was done for 2028 with the goal of achieving a 50% reduction in waste generation. For 2028, a GHG reduction of 0.73 MMtCO$_2$e.

- **Key Assumptions:** TBD

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–11. Water and Wastewater Treatment – Energy Efficiency Improvements

## Policy Option Description

Energy efficiency programs at water and wastewater treatment plants can reduce GHG emissions by reducing consumption of electricity to run pumps, fans, and other electrical equipment. Included in this option is a review of the potential for installing anaerobic digesters for biosolids and subsequent use of the methane as an energy source for generating electricity (e.g. using internal combustion engines or microturbines).

## Policy Option 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 2028.

**Parties Involved:** Municipal and private/investor-owned water and wastewater treatment operators, Vermont Agency of Natural Resources Wastewater Treatment Division

**Other:** Not applicable.

## Implementation Mechanisms

An evaluation of the potential for energy efficiency and energy production improvements in municipal and private/investor-owned water and wastewater treatment sector is needed. Energy costs can account for 30% of the total operation and maintenance costs of WWTPs. WWTPs account for 3% in electric load in the United States.[44]

Goals of the assessment are to:

- Quantify the energy consumed in Vermont's municipal and private/investor-owned water and wastewater treatment sector annually, to establish a baseline for the sector.
- Assess the potential for energy savings for the sector.
- Assess the potential for energy production using digester gas (in anaerobic plants).

Near-term opportunities for energy savings:

1. Lighting retrofits from T12 systems to T8;
2. Heating retrofits from electric heat;

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[44] EPA, Wastewater Management Fact Sheet – Energy Conservation, July 2006.

3. Installation of high-efficiency influent and effluent pumps, high-efficiency motors and variable frequency drives;
4. Evaluate the costs and benefits to second-stage activated sludge mixing and aeration;
5. Identify opportunities for peak demand reduction and optimizing load profiles.

Mid-term opportunities for energy savings:

- Co-generating electricity and thermal energy on-site; capturing and using anaerobic digester gas.

## Related Policies/Programs in Place

None identified.

## Types(s) of GHG Reductions

- $CO_2$: A portion of electricity used by WWTPs in Vermont is generated through the combustion of fossil fuels, a process which 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 $CO_2$e.
- Methane: 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 Savings and Costs per $MtCO_2e$

**Estimated GHG Savings in 2012 and 2028:** 0.004, 0.011

**Cost Effectiveness:** $-133

- **Data Sources:** This analysis relied on data from EPA's Clean Watershed Needs Survey (CWNS).[45] This survey reports the existing flow, projected flow, and population receiving treatment from the year 2000. These data were applied to aggregate Vermont population data from the Draft Vermont Inventory and Forecast.[46] 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 Vermont, so many of the estimates provided in this analysis are based upon as few as one data point, reducing the accuracy of the quantification.
- **Quantification Methods:**

  *GHG Reductions:* The first step in quantifying the GHG reduction potential and cost effectiveness of this assessment was to estimate the electricity demand for WWTPs and the

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[45] US EPA. CWNS 2000 DATA; Ask WATERS Simple Query Tool. http://www.epa.gov/cwns/2000data.htm.

[46] Primary source for 2000-2020 projections: http://www.census.gov/population/projections/SummaryTabA1.xls. Linear extrapolation used to estimate population after 2020.

emission factor of electricity in Vermont. Electricity demand for WWTPs was measured using the CWNS 2000 data to determine what the million gallons per day (MGD) discharge rate was for all residents served by the surveyed facilities. Next, the energy use per million gallons was determined from the median of a survey of 12 WWTPs.[47] The annual BAU WWTP electricity consumption was estimated by taking the product of the per-capita discharge rate, the projected population, and the electricity usage (in kWh/MG treated). The emission factor (MMtCO$_2$e/kWh) was calculated by dividing the projected emissions[48] by the projected Vermont electricity sales from the VT I&F. The avoided emissions from electricity savings were determined by multiplying the annual efficiency improvement targets by the annual BAU WWTP electricity consumption and the annual electricity emission factor. The cumulative (2008-2028) CO$_2$ emission reduction from achieving the energy efficiency targets defined by this option is 0.15 MMtCO$_2$e.

GHG reduction from the conversion of methane to CO$_2$ was calculated by first examining the CWNS data to determine which WWTPs had combined heat and power (CHP) potential, identifying the fraction of Vermont wastewater capacity that can utilize anaerobic digestion to produce methane for CHP, and multiplying that fraction by the annual WWTP methane emissions provided by the VT I&F. The resulting GHG emission reduction from the conversion of methane to CO$_2$ was minimal; on the order of $10^{-7}$ MMtCO$_2$e.

*Cost:* As mentioned in the Data Sources section, most of the cost estimates for the implementation of energy efficient technologies at WWTPs in Vermont resulted from case study data 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/yr, and the capital cost $10,000, then the cost per kWh used in this analysis would be the annualized capital cost[49] 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. The table below displays the fractions of electricity used by WWTP processes.

| **Fraction of Electricity used by WWTP** | |
|---|---|
| Influent Pumping | 0.045 |
| Solids Dewatering | 0.07 |
| Clarifier & Sludge Pumping | 0.156 |
| Aeration | 0.556 |
| Heating | 0.033 |
| Lighting | 0.0606 |

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[47] *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.

[48] Projected from EIA Historical Data (1990-2004).

[49] The cost for each technology in this analysis is annualized over a 10-year period.

| | |
|---|---|
| Other | 0.0794 |

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 2028 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 ten years, cost savings are quickly realized due to the high cost of electricity in Vermont and the large potential for low-cost efficiency improvements at WWTPs. The levelized and discounted cost-effectiveness of this action is \$-133/MtCO$_2$e.

- **Key Assumptions:** The large cost savings realized by this option is largely due to the assumption that capital cost may be annualized over ten years. Also, it is assumed that the efficiency improvements for a given technology apply to the full fraction of WWTP electricity usage for each process. Additional assumptions include:
    - The technology cost and efficiency data from case studies are used as averages that represent the population of WWTPs in Vermont.
    - This analysis assumes that WWTPs will meet and not exceed the efficiency targets.

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

TBD

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD

# AFW–12. In-State Liquid Biofuels Production

## Policy Option Description

This option covers incentives needed to increase biodiesel and ethanol production in Vermont. Use of biodiesel offsets the consumption of diesel fuel produced from petroleum (petrodiesel). Since biodiesel has a lower GHG content than petrodiesel, overall GHG emissions are reduced. By producing biodiesel in the state for consumption within the state, the highest benefits can be achieved, since the fuel is transported over shorter distances to the end user. Also, feedstocks for biodiesel production (e.g. vegetable oils) produced from GHG-superior sources than the current dominant feedstock (soybean oil) can produce additional significant reductions. An example of a superior feedstock would be cultivated algae, which is capable of sequestering considerable quantities of $CO_2$ in its lifecycle and converting it to oil and protein meal.

This option also seeks to offset fossil fuel use (gasoline) with in-state production of ethanol. Offsetting gasoline use with ethanol can reduce GHGs to the extent that the ethanol is produced with lower GHG content. Incentives are needed for the research and production of ethanol, especially from GHG-superior cellulosic crops, forest sources, animal waste, and municipal solid waste.

*Note: This option is linked with TLU Option 5 on Alternative Fuels and Infrastructure. This option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biodiesel and ethanol using feedstocks with greater GHG benefits than the likely business as usual national production methods. In addition, VT consumption of biodiesel and ethanol produced in-state will produce better GHG benefits than these same fuels obtained from a national market due to lower embedded CO2 associated with transportation of biodiesel and ethanol or its feedstocks from distant sources.*

## Policy Option Design

**Goals:** The goal levels and timing for increasing production of biofuels in Vermont are shown in the table below.

| Phase | Year | Gallons of biodiesel produced in Vermont | Represents percentage of total distillate used in state (in 2006) | Gallons of cellulosic ethanol produced in Vermont | Represents percentage of total gasoline used in state (in 2006) |
|---|---|---|---|---|---|
| 1 | 2010 | 1,000,000 | 0.4% | 0 | 0% |
| 2 | 2015 | 14,500,000 | 6% | 10,000,000 | 3% |
| 3 | 2028 | 50,000,000 | 21% | 50,000,000 | 15% |

**Timing:** See table above.

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

**Other:** The goals above are incremental to business as usual (BAU) production, which include the planned Biocardel plant described in the Feasibility Issues section below.

## Implementation Mechanisms

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

## Related Policies/Programs in Place

*Insert relevant information on new House Bill.*

## Types(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),[50] 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

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

gasoline, whereas an 18-29% reduction is measured from starch-based ethanol production compared to gasoline.

### Estimated GHG Savings and Costs per $MtCO_2e$

- **GHG reduction potential in 2012, 2028 ($MMtCO_2e$):** Biodiesel: 0.004, 0.24; Ethanol: 0, 0.4
- **Net Cost per $MtCO_2e$:** Biodiesel: \$18; Ethanol: \$1
- **Data Sources:**

  The $CO_2e$ emission factor for fossil diesel used in the inventory and forecast is 10.04 Mt/1,000 gallons. The lifecycle fossil diesel emission factor is 12.3 Mt/1,000 gallons (Hill et al., 2006; cited in the footnotes).
- **Quantification Methods:**

  *Biodiesel GHG Reductions*

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

  For this option, the incremental benefit of in-state production is derived from the lower embedded GHG content of biodiesel feedstocks (vegetable oil and algal oil) avoided from having to transport the feedstocks from their likely source region. For this assessment, the likely source regions for soybean or canola oil are the U.S. mid-west or northern plains regions. Using South Dakota as a potential source region, rail transport would require shipments to central Vermont of about 1,700 miles.[51] Rail fuel consumption is about 400 ton-miles/gallon.[52] The density of vegetable oil is about 3,700 tons/MMgal. From these inputs, a GHG emission rate of 158 $MtCO_2$/MMgal oil was calculated.

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

  In addition to soybean oil, other oil feedstocks included in this analysis include canola, sunflower, waste vegetable oil (WVO), and algal oils. For oil sources other than soybean oil,

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[51] U.S. National Atlas, at http://nationalatlas.gov/natlas/Natlasstart.asp.

[52] U.S. National Atlas, at http://nationalatlas.gov/articles/transportation/a_freightrr.html.

the benefit for substituting in-state biodiesel for fossil diesel is estimated starting with the lifecycle soybean emission factor (7,261 MtCO$_2$e/MMgal from the Hill et al study). As mentioned previously, the benefits of the biodiesel component of the TLU biofuels option is based on displacement with soybean-based biodiesel. Hence, this analysis was designed to only account for the incremental benefit of in-state feedstock (oil) production using GHG preferential feedstocks. These include vegetable oils that produce greater volumes of oil per unit of energy input (e.g., canola), 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$_2$e/MMgal. So the incremental benefit of canola over soy is 7,261 - 2,744 = 4,517 MtCO$_2$e/MMgal. Sunflower produces 102 gallons of oil per acre resulting in an incremental benefit of sunflower over soy of 3,488 MtCO$_2$e/MMgal. For waste and algal oils, CCS assumes that these have negligible embedded energy. So, the incremental benefit over soy equals the lifecycle fossil diesel EF (12,306 MtCO$_2$e/MMgal) minus the soybean based EF (7,261 MtCO$_2$e/MMgal), which is 5,045 MtCO$_2$e/MMgal.

To meet the in-state production goals for 2012, 2015, and 2028, the table below provides the mix of oil feedstocks assumed in this analysis. The assumed mix relies heavily on new technologies (e.g., algal oil) to produce feedstocks in the post-2010 period. The net production data summarized below exclude BAU production, which is estimated to be 8 MMgal/yr.

| | | | |
|---|---|---|---|
| 2012 | Oilseed | 500,000 | 33% soy, 33% Sunflower, 33% canola |
| | WVO | 500,000 | |
| | | 1,000,000 | |
| 2015 | Oilseed | 2,000,000 | 33% soy, 33% Sunflower, 33% canola |
| | Algal oil | 12,000,000 | |
| | WVO | 500,000 | |
| | | 14,500,000 | |
| 2028 | Oilseed | 4,500,000 | 33% soy, 33% Sunflower, 33% canola |
| | Algal oil | 45,000,000 | |
| | WVO | 500,000 | |
| | | 50,000,000 | |

GHG reductions were estimated by multiplying the production of each oil feedstock by

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

*Biodiesel Costs*

Costs were estimated using information from an analysis of biodiesel production costs from the US DOE.[53] The value of incentives needed is assumed to be equivalent to the difference in the costs of producing fossil diesel and soy-based biodiesel ($0.34/gallon). This value is very close to the incentive offered in a State of Missouri incentives program.[54] This program offers production incentives of $0.30/gallon to producers up to 15 million gallons of production/yr. The incentive grants last for five years. CCS assumed a similar incentive structure and that these would cover the costs of all grants or tax incentives associated with this policy (all other implementation mechanisms are assumed to be achieved within existing programs). The cost estimates are based on multiplying the amount of biodiesel produced in each year by the production incentive. This assumes that all production occurs at production facilities of less than 15 million gallons/yr. The production incentive runs out after five years of production.

*Ethanol GHG Reductions*

The benefits for this option are dependent on developing in-state production capacity that achieves benefits above the levels of existing and planned (BAU) starch-based production in the U.S. Emission factors for reformulated gasoline, starch-based ethanol, and cellulosic ethanol were taken from a General Motors/Argonne National Lab study.[55] These emission factors incorporate the GHG emissions during the entire life-cycle of fuel production (e.g., for gasoline: extraction, transport, refining, distribution, and consumption; for ethanol: crop production, feedstock transport, processing, distribution, and consumption). These life-cycle emission factors are referred to as "well-to-wheels" emission factors:

Fuel Emission Factor (grams $CO_2e$/mi)

- Reformulated gasoline 552
- Starch-based ethanol 451
- Cellulosic ethanol 154

Based on the emission factors shown above, the incremental benefit of the production targeted by this policy over conventional starch-based ethanol is 66% (reduction of $CO_2e$ by offsetting gasoline consumption). This value was used along with the lifecycle emission factor for gasoline[56] and the production in each year to estimate GHG reductions.

*Ethanol Costs*

Costs for the incentives needed by this policy option are based on the difference in estimated production costs between conventional starch-based ethanol and cellulosic ethanol. The DOE

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

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

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

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

EIA estimated that the cost to produce starch-based ethanol is $1.10/gal compared to $1.29/gal, or a difference of $0.19/gal (in $1998).[57] In 2006 dollars, the difference is $0.23/gal. These incentives are considered necessary in the near term (up to 2015) to help commercialize technologies that produce ethanol from cellulose or produce starch-based ethanol using renewable fuels. The incentives should also help to establish the infrastructure to deliver biomass to bio-refineries, since producers will seek the local feedstocks or renewable fuels for their operations.

By 2015, it is assumed that advances in cellulosic ethanol production (e.g., enzyme costs, production processes) will make cellulosic ethanol production cost competitive with starch-based production. Hence, the incentives are discontinued beginning in 2015. Note that there is currently federal legislative proposal to offer cellulose an incentive of $0.765/gallon compared to the $0.51/gallon currently offered for ethanol production.[58] If enacted, this $0.255/gallon premium could cover the additional incentives that are assumed to be needed by the State of Vermont. Obviously, the federal incentives do not assure that production facilities would locate in VT. These federal incentives have not been factored into the cost estimates for this option.

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

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

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

## Key Uncertainties

TBD

## Additional Benefits and Costs

TBD

## Feasibility Issues

Vermont uses approximately 234,000,000 gallons of distillates (heating oil and on and off-road

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

[58] 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.

diesel) and 328,000,000 gallons of gasoline per year[59].

Biocardel Vermont, Inc., located in Swanton is due to begin production of biodiesel from soy oil in early 2007 with 4 mgy (million gallon per year) capacity and increase to 8 mgy by 2010. One commercial biodiesel producer is in operation in Winooski, with an annual capacity of just 50,000 gallons. Several other small producers may be approaching commercial status for an additional 150,000 gallons of capacity in 2007-2008.

- Eighteen Vermont farms are currently showing interest in growing oilseed crops for biofuel (soy, sunflower, canola) and a few have begun producing biodiesel. The Vermont Biofuels Association (VBA), UVM Extension, UVM Ctr for Sustainable Agriculture and VT Sustainable Jobs Fund (VSJF) are collaborating on several integrated research and demonstration projects with several of these farms to assess the feasibility of increased oilseed production to meet both farm livestock feed and fuel (biodiesel) need. Vermont's farms use a total of 6.4 mgy of petrodiesel and heating oil distillates and the VBA estimates that by 2015 over half of Vermont's farm distillate use plus an additional 6 mgy will be produced in state, on 100,000 acres (or 17% of cropland[60]).
- With seed funding from the Vermont Agency of Agriculture, a Montpelier company is working with the VBA and Gund Institute (UVM) researchers to optimize the production of algae in *photobioreactors* to be located on dairy farms. Using a patented, but as yet untested technology, the systems are two to three years from being commercially viable. It is estimated that over 100 VT dairies would provide a suitable location for the commercial units. Once established a single *photobioreactor* may be capable of producing above 500,000 gallons per year of high quality biodiesel feedstock (oil) as well as cellulosic feedstock as a 'by-product'.

Numerous government studies confirm microalgae organisms' ability to sequester abundant amounts of $CO_2$ through photosynthesis and other biological processes.[61] This potential should also be examined and evaluated as a component of the Governor's Commission on Climate Change.

There is currently no commercial production of ethanol from cellulosic feedstock in the United States. However, recent announcements by New England based cellulosic biomass-to-ethanol company Mascoma Corp. (a national leader in this technology), point to a 15,000 sq.ft. test facility planned for the Rochester, NY area. The facility, to be constructed over the next 12 to 15 months, is expected to operate using a number of agricultural and/or forest products as biomass, including paper sludge, wood chips, switch grass and corn stover. At the New York demonstration facility the company and its strategic partners "will demonstrate the commercial scale production of ethanol from biomass", according to a statement issued by the company

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[59] Source: U.S. Dept of Energy, Energy Information Administration. Report: Adjusted Sales of Distillate Fuel by End Use/Vermont. URL: http://tonto.eia.doe.gov/dnav/pet/pet_cons_821dsta_dcu_SVT_a.htm.

[60] Source: U.S. Dept of Agriculture, 2002 Census of Agriculture – Vermont. Table 9. URL: http://www.nass.usda.gov/census/census02/volume1/vt/index1.htm.

[61] Source: U.S. Dept of Energy, National Renewable Energy Laboratory. Report June 2001, Kiran L. Kadam; Microalgae Production From Power Plant Flue Gas: Environmental Implications On A Life Cycle Basis. Contract DE-AC36-99-GO10337

president in December 2006.

Vermont has an opportunity to position itself as a creator of sustainably produced biofuels by focusing on cellulosic ethanol and biodiesel derived from stringent agricultural and forestry practices. VSJF, the VBA, the Vermont Alternative Energy Corporation (VAEC), and other organizations have already completed preliminary research on the potential of cellulosic ethanol in Vermont. However, biofuels research and development is still at an early stage in Vermont. Tapping the capacity of these and other organizations, including Vermont's educational institutions and the cellulosic ethanol expertise at Dartmouth College should help to accelerate the development of the cellulosic ethanol sector.

Which cellulosic feedstocks grow best in Vermont? VAEC's cellulosic ethanol feasibility study concludes that wood, lumber, forest residue, and grass straw would make up the most likely ethanol feedstocks in Vermont. VAEC believes that10 million gallons of cellulosic ethanol can be produced, with about 60,000 acres of land devoted to hay. This is equal to 17 percent of the land currently devoted to forage in Vermont (and 4.8 percent of all agricultural land in Vermont). According to the Vermont Division of Forestry, there are over 140 million tons of wood in Vermont's forests. The McNeil Generating Station in Burlington uses 180,000 tons of wood per year (less than one percent of the total). Statistics for 2003 show that less than one percent (1,096,382 tons) of Vermont's total amount of wood was harvested.

- With a yield of 66 gallons of ethanol per bone dry ton of forest residues, 151,515 tons of residue (less than one percent of the total amount of wood in Vermont's forests) would be required to produce 10 million gallons of cellulosic ethanol.

## Status of Group Approval

TBD

## Level of Group Support

TBD

## Barriers to Consensus

TBD