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Table 4.
Agriculture and Forestry Technical Work Group
Summary List of Pending Policy Options

#	Policy Name	2012 GHG Savings ($MMtCO_2e$)	2020 GHG Savings ($MMtCO_2e$)	2007-2020 GHG Savings ($MMtCO_2e$)	Cost-Effectiveness ($/$MtCO_2e$)
F-1	Forestland Protection from Developed Uses	0.08	0.13	1.2	22
F-2a	Forest Health & Restoration - Residential Lands	0.18	0.18	2.5	-21
F-2b	Forest Health & Restoration - Other Lands	0.45	0.45	6.3	-21
A-1	Manure Energy Utilization (dairies)	0.35	0.90	7.5	3
A-1	Manure Energy Utilization (feedlots)	0.001	0.002	0.02	320
A-2	Biomass Feedstocks for Electricity or Steam Production	0.93	1.87	15	-77

#	Policy Name	2012 GHG Savings ($MMtCO_2e$)	2020 GHG Savings ($MMtCO_2e$)	2007-2020 GHG Savings ($MMtCO_2e$)	Cost-Effectiveness ($/$MtCO_2e$)
A-3	Ethanol Production	0.7	1.7	12	0
A-4	Nutrient Management	0.004	0.012	0.08	-46
A-5	Manure Management - Land Application	TBD	TBD	TBD	TBD
A-6	Conservation Tillage/No-Till	0.03[a]	0.08[a]	0.60[a]	15
A-7	Convert Agricultural Land to Grassland or Forest	0.36[b]	0.36[b]	4.0[b]	7
A-8	Reduce Permanent Conversion of Ag & Rangeland to Developed Uses	0.12	0.20	1.6	62
A-9	Programs to Support Organic Farming	0.62	0.39	6.2	0.5
A-10	Programs to Support Local Farming/Buy Local	0.32	1.1	5.9	0.2
A-11	Biodiesel Production	0.12	0.31	2.3	0

[a] The GHG benefits have been adjusted to account for overlap with the soil carbon benefits derived from Option A9 on Organic Farming.

[b] Emission reductions are taken against emissions that have not been built into the existing forecast for NM. They refer to emissions associated with acreage assumed to be coming out of the Conservation Reserve Program and returned to active cultivation.

F-1, Forest and Rangeland Protection from Developed Uses

Policy Description

Reduce the rate at which existing forest and rangeland are cleared and converted to developed uses.

Policy Design

- **Goals:** The CCAG recommends that New Mexico reduce by 50 percent the total acres of forestland expected to be lost from land clearing and converted to developed uses by 2020. By 2030, achieve no net loss of forested lands.
- **Timing:** Policy initiation by 2010; 30% reduction achieved by 2012; 50% reduction achieved by 2020.
- **Coverage of parties:** Local governments, Forest Legacy program (NM EMNRD), Natural Lands Protection program (NM EMNRD), private non-profit land trusts, non-profit organizations.
- **Other:** Criteria for land protection have been established by existing public land protection programs such as the federal/state Forest Legacy program and the federal. Grassland Reserve Program. Private land trusts, local governments and other private non-profit organizations may have different criteria. Current or proposed programs may provide tax relief and tax incentives for landowners.

Implementation Mechanisms

i. Information and education/ Research and development

(1) Development of a carbon sequestration assessment program that would assess and assign carbon sequestration value to the state's natural, working agricultural (see Option #A8), as well as native prairie and grasslands. This carbon sequestration map and ancillary data could support a variety of GHG reduction policies.

ii. Technical assistance—Mechanism (4) under Funding Mechanisms below would enhance technical assistance from DFA for Transfer of Development Rights programs. Technical assistance to land owners regarding existing federal and state programs.

iii. Funding mechanisms and or incentives

The following mechanisms may be appropriate to decrease the rate at which natural lands are converted to developed use:

(1) Enhancement of incentives for placement of no-development easements on private land through existing or future programs. Possibly through establishment of limited-term carbon sequestration leases whose cost is linked to the "carbon sink" value of natural lands.

(2) Establishment of an "Agricultural/Conservation Land Reserve" that would establish a pool of permanently protected forest, agricultural or other conserved lands. Owners of natural/agricultural land would be provided with tax incentives to join the reserve.

(3) Enhancement of the existing programs which allow purchase and trade of development rights between high density and low density areas to conserve open space, agricultural land and forest

land on the margins of growing urban areas. Devoting additional staff and funding to the existing program within the Dept of Finance and Administration is needed.

vi. Reporting

Mechanism (1) under Information and Education would enable reporting from the agricultural and forestry sectors, widening market participation in a carbon restricted economy

vii. Administrative/ Funding/ Codes/ Market Based Mechanisms

Development of a state-based, comprehensive "Road Pricing Policy" including measures such as pay-as-you-drive insurance, weight-distance road user fees, congestion pricing, high occupancy toll lanes, etc. Each of these measures would generate revenue for road maintenance, reduced congestion and vehicle miles traveled reduction programs.

Related Policies/Programs in Place

Natural land protection is currently accomplished at the state level through acquisition of conservation easements and fee title by the NM EMNRD (through the Forest Legacy Program) and by private non-profit conservation organizations or private trusts. The NM Land Conservation Incentive Program provides tax relief for landowners who donate conservation easements to qualifying private non-profit land trusts.

Types(s) of GHG Reductions

- CO_2: Carbon savings occur when live carbon stocks (trees, shrubs, and some soil organic carbon) are protected from clearing and the associated decay or combustion of cleared biomass. Carbon losses are offset to some extent by the portion of harvested biomass that is converted to durable wood products (carbon storage in product use), and for that portion converted to renewable energy and displaces fossil energy use that otherwise would be used. Because conversion of forest and rangeland to developed land uses typically is permanent, replacement biomass does not grow back on the site to previous levels to offset removals of live biomass and soil carbon (i.e., to the levels that existed during forest/rangeland use).
- CH_4: New research indicates that about four percent of the carbon storage benefit of live forests is offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- Black Carbon: Emissions of black carbon (soot) result from combustion of biomass from open burning during land clearing, but the heating effect is likely to be offset by the large amount of organic material that is also emitted during biomass combustion.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.1, 0.1
- Net Cost per MtCO2e: $22
- Data Sources: The number of acres that moved from forested land and rangeland to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). Based on comparison of rangeland acreage from NRI and pinyon-juniper acreage from USDA Forest Service, it was determined that roughly 20% of rangeland is pinyon-juniper. For the purposes of this analysis, pinyon-juniper is considered forested land. Forest carbon stock per acre data values were calculated from 1997-1999 USDA Forest

Service carbon stock and acreage data (the latest data available).[1] The above-ground forest carbon density average for NM was estimated to be 28.5 MtC/1,000 acres, and the below-ground density was estimated at 9.7 MtC/1,000 acres (below ground density represent soil organic carbon only). Cost data for conservation easements on forested lands was obtained from the New Mexico Forest Legacy Program and the Nature Conservancy.[2] [3] The mid-point in the range of estimates for purchasing conservation easements was $1,960/acre.

- Quantification Methods: The annual rate of loss from the NRI data was determined to be 3,880 acres/yr (combined forest and rangeland based on loss rates from 1982-1997). The rangeland acreage was adjusted to reflect the amount of pinyon-juniper forest on these lands (20% of rangeland in the NRI was estimated to be pinyon-juniper forest). Reducing the loss rate by 50% yields 1,900 acres/yr protected. Assumptions regarding carbon losses due to development are: for each acre lost to development, 10,000 sq ft (0.23 acre) looses 100% of soil carbon; the remainder of that acre loses 25% of soil carbon; 50% of above ground carbon is lost. The number of acres saved per year was multiplied by the loss of carbon on these acres to estimate carbon savings. Carbon savings were then converted to CO_2e. Costs were estimated by multiplying the acreage saved per year by the cost of conservation easements shown above.
- Key Assumptions: Some rangeland carbon estimates are not currently included in forest carbon estimates due to data limitations; however, “nonstocked” and “pinyon-juniper” forest stands as defined by FIA include many lands classified as “rangeland” by NRI. Forecasted carbon stock measurements from 2002 to 2020 are based on extrapolations of past trends from 1982-2002 and assume a static continuation of all land cover and land use dynamics during that period. Implementation mechanisms are assumed to be “growth neutral” to avoid offsetting development impacts, i.e. land protection does not result in land clearing in other areas (also referred to as “leakage”).

Key Uncertainties

- Benefits: The rate at which live biomass stocks would have declined beyond business as usual due to forest health and forest fire risks may be significant. The rate of offsetting development effects from land protection may be sensitive to the design of policy implementation tools.
- Costs: Cost savings from avoided land clearing costs (not quantified in this assessment) may be contingent on regulatory acceptance of alternative land development approaches, such as conservation design or cluster development.

Contributing Issues

- **Human and social issues**
  - Protection of working lands for sustainable wood products use, recreation, agriculture, cultural and natural heritage.
- **Environmental issues**

[1] Jim Smith, USDA Forest Service, personal communication with S. Roe, CCS.
[2] Bob Sivinski, NM Forest Legacy Program, personal communication with H. Lindquist, CCS, June, 2006.
[3] Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.

- Environmental asset protection, including watersheds (water quality and quantity, biological diversity, wildlife and air quality.
- Reduced transportation emissions from increased location efficiency.

- **Economic issues**
  - Reduced costs of infrastructure and services for dispersed or low density development.
- **Political and regulatory issues –** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

F-2a, Forest Health and Restoration – Residential Lands

Policy Description

Manage sustainable thinning or biomass reduction from residential forestlands (intended to address fire and forest health issues), so that harvested biomass is directed to wood products and renewable energy instead of open burning or decay. Residential forested areas are primarily located at the fringe of development and are often referred to as the wildland-urban interface (WUI).

Policy Design

- **Goals:** The CCAG recommends that New Mexico expand the usage rates of biomass extracted from forested residential lands for wood products and/or energy production to 50% is recommended. The CCAG recognizes that 100% biomass utilization is not achievable due to access to the material or to efficient methods of transporting the material to processors/end users
- **Timing:** Begin ramp up in 2007 and reach full yearly implementation by 2012 and continue through at least 2020.
- **Coverage of parties:** State Forestry Division (NM Energy Minerals and Natural Resources Department), NM Public Regulation Commission, City/County Governments, Private Industry, and non-profit groups.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Mechanisms

i. *Funding mechanisms or incentives/Market based mechanisms*

The following mechanisms function to increase the rate at which the by-products of forest thinning at the wildland-urban interface are used to create wood products (e.g. building materials and furniture) or to generate renewable energy:

(1) Provide tax incentives to reduce the capital costs of biomass energy production and transport for use in electricity generation and the heating of residences and public buildings. This could include tax reductions in state sales tax for a wide variety of biomass-related equipment, including but not limited to biomass harvesting/collection equipment, biomass gasification equipment, biomass electricity generation equipment, and high efficiency wood pellet stoves. Gross receipts exemptions for biomass generation facilities, project construction and related equipment and materials are also recommended.

(2) Establish utility "Buyback Rates" for "Feed-in-Tariffs" for biomass derived energy where utilities offer a standard rate for which they purchase biomass generated energy (electricity and/or heat). This program could be structured in a similar fashion to PNM's existing solar energy buyback program, where they purchase the renewable

energy credits from customer owned solar projects for 13 ¢/kWh for 10 years and apply those credits to their RPS requirements. Buyback rates for biomass projects in other regions of the country generally range from 6-7 ¢/kWh.

(3) Expand the NM Renewable Energy Tax Credit by lowering the eligible threshold capacity from 10 MW down to 1 MW as well as expanding the classification of corporate taxpayers and including general income taxpayers.

ii. *Codes and standards*

a. Work with local communities to develop responsible ordinances that allow the use of EPA-certified wood/pellet burning equipment (instead of broad burn bans that apply to all wood-burning equipment).

b. Expand existing net-metering regulations to enable projects up to 2 MW in size to net-meter at retail energy rates.

Related Policies/Programs in Place

Current residential/municipal fire risk and forest health initiatives oriented toward density reduction include the multi-agency National Fire Plan, Western Governors Association 10-Year Comprehensive Strategy for Implementation of the National Fire Plan, federal Collaborative Forest Restoration Program, NM Forest and Watershed Health Restoration Plan, the federal FIREWISE program, various FEMA programs for fire risk mitigation on private residential lands, and the establishment of the NM Forest and Watershed Restoration Institute, and many other local, state and federal initiatives too numerous to list.

Current programs designed to increase market use of small diameter trees for energy and wood products include various Department of Energy and USDA Forest Service grant programs, Collaborative Forest Restoration Program, and others. Various incentives exist to promote the development of renewable energy in New Mexico, including the Renewable Portfolio Standard, which requires that 10% of IOU energy supplied to in-state consumers come from renewable sources by 2011. This requirement grants a 2x credit multiplier to biomass related projects and has established a Reasonable Cost Threshold of (6-8 ¢/kWh) for biomass projects. Any subsequent tax credits will better enable biomass projects utilizing forest and agricultural waste to compete within this arena. Currently, there exists a NM production tax credit (PTC) for large scale renewable projects 10 MW in capacity and greater, as well as compensating tax deductions for biomass equipment. Additionally, the state enables net-metering at retail rates of renewable projects 10 kW in capacity and smaller.

Types(s) of GHG Reductions

- CO2: Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest, or be left for decay and or open burning following harvest, are harvested and converted to: 1) durable wood products that store carbon; 2) to low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) to renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass.

- CH4: New research indicates that about four percent of the carbon storage benefit of live forests is offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- Black Carbon: Emissions of black carbon (soot) result from combustion of biomass from open burning of land clearing, but the heating effect may be offset by the large emissions of organic material associated with biomass combustion.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.2, 0.2
- Net Cost per MtCO2e: $-21

  Benefits and costs were estimated by assuming that all of the biomass energy would be utilized in commercial/municipal boilers or residential space heating equipment (e.g. pellet stoves). Benefits are estimated by quantifying the CO2e reduced by offsetting an equivalent amount of energy from natural gas combustion. However, it should be noted that this policy supports all beneficial energy uses of biomass.
- **Data Sources:** CCS obtained data on both mechanical and fire treatments conducted in NM from 2001 – 2006.[4] These data contained information on treatments that had occurred on both wildland-urban interface (WUI) lands and non-WUI lands. The WUI lands are those considered to be residential areas applicable to this option. The average acres treated during these years was used as the starting point for analysis. The average carbon stocking on NM forestlands was taken from the USFS data that underlie the AZ Inventory & Forecast (i.e. USFS FIA). Estimates of the fraction of biomass to be removed in WUI and non-WUI areas were taken from an assessment by a researcher at Colorado State University.[5] A reduction in basal area of 42% associated with an "Intermediate Restoration Level" was selected for WUI lands. The reduction in basal area was assumed to be representative of a reduction in biomass density. The cost of producing pelletized fuel ($134/ton) was taken from a Canadian study.[6]
- Quantification Methods: The amount of biomass removed during forest health projects was calculated by multiplying the annual acres treated by the above ground carbon density and the treatment fraction (0.42). CCS assumed that 50% of the biomass from both mechanically-treated and fire-treated areas would be diverted to energy use (pelletized fuel for space heat for the purposes of this analysis). The heat content associated with the diverted biomass was then used to estimate the equivalent amount of natural gas offset (with no adjustment for potential differences in energy efficiency between gas-fired and pellet-fired equipment). Emissions from this offset natural gas were quantified as the benefit of this option. No effort was made to quantify the embedded energy (and CO2e) associated with

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[4] J. Roland, USFS, email communication with S. Roe, CCS, 4/26/06. Data from the National Fire Plan Operations and Reporting System (NFPORS) database.

[5] Brett Dickson, CO State Univ.; Data on forest restoration levels provided to George Koch of the AZ AF TWG on 4/05/06; "Intermediate Restoration" level of treatment selected for WUI areas; reduction in basal area assumed to be representative in reduction of above-ground biomass.

[6] Based on REAP-Canada presentation (mid-point of 2 values provided for pelletizing wood residue (also representative of costs for pelletizing switchgrass). This value includes costs for transport, pelletizing, bagging and shipping, http://www.reap-canada.com/bio_and_climate_3_2.htm.

biomass diversion (e.g. CO_2e associated with transport of biomass, pelletizing, and product transport). These were not considered since the life-cycle emissions associated with natural gas production and delivery were not included. The cost savings for this policy were estimated as the costs for offsetting the natural gas.

- Key Assumptions: Current use of forest biomass from mechanical treatment projects in WUI areas is 30% (mainly for residential firewood). Historical treatment areas are representative of future treatment programs and are the only source of forest biomass. The average NM forest carbon density is representative of areas requiring treatment (areas requiring treatment could be stocked at levels higher than the state average). Energy diversion (50%) and treatment levels selected for analysis are representative of those to be achieved in future practice. The cost of producing and distributing pelletized fuel is representative of what can be achieved in NM.

Key Uncertainties

- Benefits: The market demand for new supplies of wood products and renewable energy is dynamic and not likely to fully absorb all new supply sources without support from policies that expand the market and, potentially, establish preferential treatment of these products in comparison to conventional supplies. The rate of biomass replacement growth in thinned stands could be less than full due to ecological barriers (precipitation) and forest health issues, but the exact rates of replacement are estimated based on expert field judgment. The increased carbon sequestration potential of thinned stands has not been incorporated into this assessment.
- Costs: Future production cost reductions for wood product development and biomass energy recapture technologies are likely to fall with market expansion and "learning by doing" but are difficult to estimate at this time. Demand for biomass energy products is likely to remain strong and continue to grow with increasing fossil fuel costs (e.g. recent surge nationally in residential pellet stoves).

Contributing Issues

- **Human and social issues**
  - Protection of residential and or municipal lands from fire risk.
- **Environmental issues**
  - Environmental asset protection, including watersheds, wildlife and air quality. Lower air emissions occur from energy utilization, as compared to open burning.
- **Economic issues**
  - Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of New Mexico jobs in the associated forestry management industries.
- **Political and regulatory issues –** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

F-2b, Forest Health and Restoration – Other Lands

Policy Description

Increase sustainable thinning of biomass for ecological restoration of forests, and direct the harvested wood and wood waste to wood products and renewable energy. This policy focuses on areas beyond the wildland-urban interface (WUI or "other areas"). However, much of the background material developed for Option F-2a is applicable to this option.

Policy Design

- **Goals:** The CCAG recommends that New Mexico expand the usage rate of biomass extracted from forested non-residential lands for wood products and/or energy production by 50% is recommended. The CCAG recognizes that 100% biomass utilization is not achievable due to access to the material or to efficient methods of transporting the material to processors/end users.
- **Timing:** Begin ramp up in 2007 and reach full yearly implementation by 2012 and continue through at least 2020.
- **Coverage of Parties:** USFS, plus the additional parties listed in the applicable section under Option F-2a.
- **Other:** For the purposes of estimating GHG benefits and costs, biomass is assumed to be utilized for the production of commercial steam/space heat or residential space heat. As stated above, other end uses (electricity generation, liquid fuels, durable wood products) should also be targeted by this policy.

Implementation Mechanisms

See discussion under Option F-2a.

Related Policies/Programs in Place

Current residential/municipal fire risk and forest health initiatives oriented toward density reduction include the multi-agency National Fire Plan, Western Governors Association 10-Year Comprehensive Strategy for Implementation of the National Fire Plan, federal Collaborative Forest Restoration Program, NM Forest and Watershed Health Restoration Plan, the federal FIREWISE program, various FEMA programs for fire risk mitigation on private residential lands, and the establishment of the NM Forest and Watershed Restoration Institute, and many other local, state and federal initiatives too numerous to list.

Current programs designed to increase market use of small diameter trees for energy and wood products include various Department of Energy and USDA Forest Service grant programs, Collaborative Forest Restoration Program, others.

Types(s) of GHG Reductions

- CO_2: Carbon savings occur when live and dead carbon stocks (trees, shrubs) that otherwise would decay or burn in the forest are harvested and converted to: 1) durable wood products that store carbon; 2) to low embedded energy wood building materials that substitute for high embedded energy conventional building materials (steel and concrete); or 3) to renewable energy that displaces fossil energy use. Sustainable management ensures that replacement biomass grows back to the maximum extent on thinned sites to offset removals of live biomass.

- CH_4: New research indicates that about four percent of the carbon storage benefits of live forests is offset by methane release. Methane can be released from land filled biomass under anaerobic conditions.
- Black Carbon: Emissions of black carbon (soot) result from combustion of woody biomass from open burning of land clearing, but the heating effect may be offset by the cooling effect of this particular type of black carbon.

Estimated GHG Savings and Costs per $MtCO_2e$

- GHG potential in 2012, 2020 ($MMtCO_2e$): 0.45, 0.45
- Net Cost per $MtCO_2e$: $-21
- Data Sources: See discussion under F-2a above.
- Quantification Methods: See discussion under F-2a above. For non-WUI lands, a treatment fraction of 0.21 was selected ("Fuels Reduction" level of restoration). This led to a 21% reduction in biomass (and carbon) density on the treated acres. Otherwise, the methods used to estimate benefits and costs are the same as the WUI areas under F-2a.
- Key Assumptions: See discussion under F-2a above.

Key Uncertainties

- Benefits: See discussion under F-2a above.
- Costs: See discussion under F-2a above.

Contributing Issues

- **Human and social issues**
  Protection of working lands and associated industries for sustainable wood products use, recreation, cultural and natural heritage.
- **Environmental issues**
  Environmental asset protection, including watersheds, wildlife and air quality. Lower air emissions occur as a result of energy utilization, as compared to open burning.
- **Economic issues**
  Expansion of markets for industrial producers of sustainable wood products and renewable energy use. Creation of New Mexico jobs in the associated forestry management industries.
- **Political and regulatory issues –** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A-1, Manure Digesters or Other Energy Utilization

Policy Description

Reduce CH_4 emissions from livestock manure through the use of manure digesters or other energy capture technologies installed at dairies. Gas captured from the manure digester/other energy capture technology is used to create heat or electricity, which offsets fossil fuel-based energy production and associated CO_2 and black carbon emissions.

Policy Design

- **Goal levels:** The CCAG recommends that programs are adopted to ensure that by 2050 50% of dairy cattle are participating in alternative energy generation programs or other projects that extract the stored energy and reduce methane emissions. Goals for dairy cattle in 2012 and 2020 are provided below. For beef feedlots, work by the TWG found that the potential emission reductions were too low and cost effectiveness too high to recommend goals for beef feedlots.
- **Timing:** Head of dairy cattle affected from 2006-2050, including head of cattle affected in 2012 and 2020. Number of dairy cattle in future years based on estimates for the Dairy Producers of New Mexico (DPNM):
    - 2012 – 15% of total dairy cattle (58,000 out of 390,000)
    - 2020 – 35% of total dairy cattle (140,000 out of 400,000)
    - 2050 – 50% of total dairy cattle (205,000 out of 410,000)
- **Coverage of Parties:** NM Environment Department, NM Energy Minerals and Natural Resources Department for incentives for biomass energy production, New Mexico State Engineer, NM Department of Agriculture.

Implementation Mechanisms

- Information and education – materials and talks throughout state from EMNRD/ NMDA/ NMED on opportunities for farmers
- Technical assistance – technology/ implementation assistance from EMNRD (1 FTE)
- Funding mechanisms and or incentives – (with market based mechanisms vi.), increase eligible equipment to receive tax compensating tax deduction, gross receipts tax deduction for biomass related equipment, agricultural grant program for clean energy development. EMNRD/NMDA/NMED should monitor the costs for implementing energy recovery projects. If available technologies are found not to be economically feasible these agencies should assist producers in identifying available grants and identify other funding opportunities, including industrial entities both within and outside of the state interested in purchasing renewable energy credits.
- Voluntary and or negotiated agreements – commitments from NM agricultural leaders, partnerships between dairies and utilities

- Codes and standards – air standards and permitting for GHG emissions (NMED) should only be considered if market-based mechanisms have been exhausted and failed
- Market based mechanisms (above)
- Pilots and demos – memorial/ state funding for partnerships between universities and industry
- Research and development – necessary R&D for dry waste/ open corral feedlots, thermophilic plug flow digesters in southwest and other innovative energy utilization technologies
- Reporting – as a NM industry generating GHGs
- Regulatory – net-metering, interconnection standards, special buy-back rates for biomass kWh or biomass RECs

Related Policies/Programs in Place

- Pending/Pilot Projects:
  - The DPNM with the Pecos Valley Biomass Coop have submitted permit application to the Chaves County Commission and received a $250,000 grant from the State for a centralized digester for 25,000 head outside of Roswell, piping methane into PNM's main trunk line.
  - La Mesa Digester Pilot Project with NMSU to process 5,000 tons of manure/year (1,500 kWh/yr), implementing bi-phasic digester technology for dry climate/open corral facilities.
  - An area on the outskirts of Roswell has been zoned to accommodate large digester operations.
- NM Clean Energy Grants through NMEMNR, no monies appropriated in 2006, though seeking recurring revenue stream beginning 2007.
- NM Biomass Equipment and Materials Compensating Tax Deduction: offsets state compensating (sales) tax on equipment and materials for landfill gas, biomass, municipal solid waste, CHP/Cogeneration, hydrogen, anaerobic digestion, ethanol, methanol, biodiesel, and microturbines.
- Federal: State Technologies Advancement Collaborative, Value-Added Grants Program, USDA Renewable Energy and Energy Efficiency Section 9006 Grants, USDA NRCS and EQIP Grants, CIG Awards.

Types(s) of GHG Reductions

- CO_2: Use of methane captured in manure digesters/other energy utilization equipment to generate electricity displaces fossil fuel use and associated CO_2.
- CH_4: Manure digesters/other energy utilization equipment collect and combust the CH_4 produced from anaerobic decomposition during manure storage.
- Black Carbon: Use of methane captured in manure digesters/other energy utilization equipment to generate electricity displaces fossil fuel use and associated BC emissions.

Estimated GHG Savings and Costs per $MtCO_2e$

- GHG potential in 2012, 2020 ($MMtCO_2e$): 0.31, 0.75 (dairies); 0.0003, 0.0006 (feedlots)

- Net Cost per MtCO2e: $3 (dairies); $1,432 (feedlots)

Due to the high cost effectiveness and low benefits associated with application of manure energy utilization at feedlots, the TWG does not recommend extending this option to beef feedlots.

- Data Sources: Data from the GHG inventory & forecast report on methane emissions and dairy/feedlot populations were used as the starting point. Projected future dairy populations were provided by DPNM.[7] Feedlot populations were assumed to remain constant at 2004 levels. Methane emissions at feedlots are much lower than those at dairies due to the differences in manure management and storage at these different operations. As shown in the cost estimates above, an analysis of benefits and costs showed a low potential for GHG benefits and a high cost effectiveness estimate. Due to these findings the TWG decided not to include beef feedlot cattle in this policy option. Consistent with the policy design, manure digesters are assumed to be implemented at dairies covering 15% of the state population by 2010 and 35% by 2020. By 2050, 50% of the dairy cattle population is assumed to be covered.

For each facility that installs a manure digester or other energy capture/utilization technology, it is assumed that 75% of the methane emissions are collected (due to inefficiencies in the manure collection process). This methane is converted to electricity using a heat rate of 17,100 Btu/kW-hr.[8] The annual kW-hrs produced were used to estimate both the costs offset (through avoided electricity consumption), as well as GHGs offset (from grid power). The 2012 and 2020 grid power emission factors were taken from the NM GHG Inventory & Forecast Report (2.01 lb CO2e/kW-hr and 1.81 lb CO2e/kW-hr, respectively). The CO2e reduction benefits were calculated as the sum of the methane emissions reduced, plus the GHG offset from grid-based power. Costs were estimated using data on capital costs from EPA's Methane to Markets report[9] and a recent dairy manure digester application in central California. These data indicate a range of capital costs from about $190 to $450 per head. An annual operating cost of $38/head was also estimated from the central California project.[10] An electricity offset cost of $0.04/kW-hr was also used. High and low annualized costs were estimated using the high and low estimates of capital costs. The reported costs for the policy are based on the mid-point of these estimates. A 15-year project life was assumed along with a 5% interest rate to determine the capital recovery factor.

Because dairy manure management is different in New Mexico than in other areas where anaerobic digesters have been implemented, the TWG compared the cost data above to another study commissioned by DPNM for a dairy manure to energy facility in New Mexico.[11] This study suggested that capital costs for a biomass gasification plant could have similar capital cost on a per head basis as an anaerobic digester facility (about $190/head for a regional plant serving about 20,000 head). CCS believes that the range of costs considered

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[7] Sharon Lombardi, email communication to S. Roe, CCS, September 22, 2006.

[8] Leonard Bull, Animal and Poultry Waste-to-Energy, PowerPoint presentation, North Carolina State University, http://www.cals.ncsu.edu/waste_mgt/waste%20to%20energy.pdf, accessed June 2006.

[9] http://www.methanetomarkets.org/resources/ag/docs/animalwaste_prof_final.pdf, accessed March 2006.

[10] Williams, Douglas, Valley Air Solutions, presentation "Joseph Gallo Farms Dairy Manure Digester", January 18, 2006.

[11] *DPNM Biomass Project Final Report*, prepared by Agri-Energy and the Dairy Producers of New Mexico, 2005.

in this analysis represents, on the low end, manure energy projects implemented for a group of farms (e.g. regional digesters/energy plants) to high end costs, where the digester/energy plant is implemented at a single facility.

- Quantification Methods: See discussion above under Data Sources.
- Key Assumptions: Most applications of manure digesters in the U.S. have been done at dairies with liquid (slurry) manure management systems. For livestock operations that manage manure primarily in a dry solid form like New Mexico, there could be major differences in energy technology selected (e.g. for solid manure, biomass gasification might be a better alternative). These different technology choices could carry higher or lower costs than those used here for anaerobic lagoon digesters combined with an engine and electricity generator.

Key Uncertainties

See Key Assumptions above. The costs associated with anaerobic digester/energy plant application at NM dairies and their representativeness to the energy technology actually selected. Different energy utilization technologies can produce different energy products (electricity, steam, heat, liquid fuels). While each type of project will have GHG benefits, the level of benefit will vary. Anaerobic digester technology was chosen here only as an example of manure energy utilization technologies to be promoted by this policy.

Contributing Issues

- **Human and social issues**
    - Provides odor control, particularly for facilities near urban areas (Portales, Las Cruces, Roswell, Albuquerque Area).
    - Reduces pathogen load, controls flies, reduces fine dust and reduces the spread of weed seeds.
- **Environmental issues**
    - Reduces water quality problems and provides solution for managing nutrients (nitrate saturation occurs in many areas with high dairy density), VOC emissions.
    - Reduces of fossil fuel-based energy consumption.
- **Economic issues**
    - Produces energy in the form of methane, electricity, and/or heat production for on-site use or opportunity to sell energy, keeping energy dollars within that community if farm is locally owned.
    - Turns a waste product that is costly to dispose of into a value added product such as bedding, compost and energy (note that bedding is not used in NM dairies or feedlots).
- **Political and regulatory issues –** none identified.

Feasibility Issues

The TWG found that this option was not feasible for application at beef feedlots due to low emission reductions and a high estimated cost effectiveness.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A-2, Biomass Feedstocks for Electricity of Steam Production

Policy Description

Displace fossil fuel usage through the use of agricultural byproducts (e.g., pecan waste, other crop residue) as a feedstock for electricity or steam production.

Policy Design

- The CCAG recommends that New Mexico adopts methods to utilize 25% of agricultural byproducts by 2012, 50% by 2020, and 75% by 2050.
- **Timing:** see above.
- **Coverage of parties:** NMDA, NMSU, Cooperative Extensions
- **Other:**

Implementation Mechanisms

Additional work is needed to identify the specific implementation mechanisms for this policy option. Mechanisms are thought to fall within the following categories:

i. Information and education
ii. Technical assistance:
iii. Funding mechanisms and or incentives: Monetary incentives may be needed to encourage the first pilot facility for using crop byproduct to generate electricity, steam or fuel for space heating.
iv. Market based mechanisms:
v. Pilots and demos: Some interest has been directed to the implementation of a small electrical generation facility in southern New Mexico using manure and pecan waste as the fuel. Interested parties should encourage development of this facility as a pilot plant through incentive grants.
vi. Research and development: Research directed at: determining the impact of reducing crop residues on subsequent cropping systems and soil erosion; and on maximizing the BTU output of mixed fuel sources (e.g. pecan shells and manure).

Related Policies/Programs in Place

None identified.

Types(s) of GHG Reductions

- **CO2:** Savings occur as a result of displacing fossil fuel use in the production of electricity or steam.
- **CH4:** Reductions are likely in situations where residue is currently burned on-site (pecan waste) due to more efficient methods of combustion associated with energy use. These benefits were not quantified.
- **N2O:** Not applicable (savings only occur if it can be demonstrated that biomass combustion produces less N20 than fossil-based combustion)

- **HFC's, SFC's:** Not applicable
- **Black Carbon:** Potential for a reduction in BC emissions to the extent that coal-based combustion is offset. These benefits were not quantified.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.93, 1.87
- Net Cost per MtCO_2e: -$77
- Data Sources: Estimated biomass byproducts for primary crops are provided in Table 1 below. New Mexico's agricultural crops are concentrated in only a few regions of the state. Availability of irrigation water (surface or ground) limits the state's agriculture to several regions along the Rio Grande and Pecos rivers and the northwestern region of Farmington. Due to adequate groundwater availability, the Estancia Valley (central) and the eastern region of the state also have principal farming areas. In general, the eastern side of the state has the largest concentration of croplands.
  Availability of combustible byproduct estimates may be lower than those printed in other sources. Amounts included in the table below account for irrigation methods and for a 50% harvestable product rather than 100% (grain crops). Estimates for pecan related byproducts are derived from a percentage of the acres pruned in a single year and a percent of the nuts shelled instate.

Combustible Agricultural Byproduct and Feasibility of Use from Principal NM Crops

Crop	Acres (1,000)	Major Production Area	Byproduct Available (Tons)	Feasibility[3]
Wheat (Dryland)	217	Eastern /North Western	75,950[1]	Low
Wheat (Irrigated)	83	Eastern	120,350[1]	Low
Sorghum (Dryland)	75	Eastern	42,750[1]	Low
Sorghum (Irrigated)	17	Eastern	21,930[1]	Low
Corn	58	Eastern	156,600[1]	Low
Pecans (wood)	33	Southern	4,752[2]	Low
Pecans (shell)	-	Southern	2,640[2]	Medium

1. Result from adjusted Kansas State University crop residue index based on production of grain.
2. Unpublished measured amounts from New Mexico State University.
3. Availability of product for other uses not currently incorporated in a producer's practices (no financial incentive).

Feasibility index represents the practicality of using a specific byproduct for space heating or electrical generation. National Resource Conservation Service policies increased minimum tillage practices, soil moisture conservation requirements, improvements to soil structure, grazing benefits, and added costs to harvest all contribute to the indexes associated with grain crops. The classification as an "agricultural byproduct" does not preclude beneficial use by a producer. With respect to pecan prunings, the largest wood is removed by firewood contractors with the remaining branches pushed to the end of the orchard and burned or chipped in the orchard and allowed to decompose. Labor constraints dictate the handling and movement of branches be conducted by machine. Due to the potential labor associated with handling tree branches or investment by producers for chippers, the feasibility of using pecan wood for the generation of electricity, steam, or space heat is low without financial incentives for the producer. New Mexico has one large pecan sheller located in Las Cruces. As a byproduct of the shelling process, pecan shells are trucked from the plant back to orchards for placement on farm roads to reduce dust or as a soil amendment to the orchards. The trucking and ease of handling of shells elevates their Feasibility Index to "medium".

The limited amount and seasonal availability of pecan waste and other agricultural crop byproducts necessitate their coupling with other combustible agricultural byproducts and some financial incentives to offset increased costs associated with their harvest and loss of on-farm benefits, if they are to be incorporated in the production of electricity, steam or space heat. Due to the limited quantities and seasonal availability, the TWG estimated benefits for using the residue to produce pelletized fuel for use in commercial/municipal boilers or residential space heaters (e.g. pellet stoves). Pellet stoves, in particular, have shown a recent surge in popularity in the United States due to the recent increase in fossil heating fuels. However, the technical feasibility of pelletizing each of the crop residues produced in NM requires additional study. Cost information on pelletizing agricultural residues was taken from a Canadian study ($134/ton).[12] The energy content of pelletized agricultural residue was taken from the same source, while the energy content for pelletized wood (for assessing pecan residue) was taken from a pellet stove manufacturer.[13] The cost of natural gas was taken from the U.S. Energy Information Administration ($12.20/MMBtu) and represents the current average of commercial and residential costs.

- Quantification Methods: Estimates of the energy content for switchgrass pellets (19.3 MMBtu/ton for crop residues) and wood pellets (16.4 MMBtu/ton for orchard trimmings) were used to estimate the total energy that could be generated by producing biomass pellets. The amount of CO2e generated from the combustion of an equivalent amount of natural gas was estimated using the residential natural gas emission factor (116.7 lb CO2e/MMBtu) minus the biomass emission factor (14.96 lbsCO2e/MMBtu). No adjustments were made for the potential differences in efficiencies between the natural gas-fired and biomass-fired equipment. The GHG benefit was estimated as the difference in CO2e produced by combusting the pelletized fuel versus an equivalent amount of natural gas.
- Key Assumptions: The estimates of available future supplies of biomass residue assume no change from current levels. The energy content and pelletizing costs for NM crop residue were assumed to be the same as for an analysis of pelletized switchgrass conducted in Canada. There are no technical issues associated with pelletizing residue from any of the principal NM crops.

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[12] Based on REAP-Canada presentation (mid-point of 2 values provided for pelletizing wood residue (also representative of costs for pelletizing switchgrass). This value includes costs for transport, pelletizing, bagging and shipping. http://www.reap-canada.com/bio_and_climate_3_2.htm, accessed May 2006.
[13] http://www.pelletboiler.com/mh_the_fuels.asp, accessed May 2006.

Key Uncertainties

Technical feasibility of converting agricultural residues from all principal NM crops to pelletized fuel or other energy source. The TWG recognizes that there could be continued expansion of the dairy industry in NM, which could affect the availability of residue in the future (e.g. as acres devoted to wheat are converted to alfalfa). The pecan industry could also see continued growth leading to additional residue supplies. However, the estimates of available future supplies of biomass residue assume no change from current levels. CO_2e emissions associated with the processing (chipping, pelletizing) and transporting of pelletized fuel were not incorporated into the benefits assessment (the embedded CO_2e associated with offset natural gas or propane was also not included). Cost information taken from a Canadian study might not be representative of production costs from all types of NM crop residues.

Contributing Issues

- **Human and social issues:** none identified.
- **Environmental issues:** Lower emissions of criteria and toxic air pollutants than those associated with the open burning of residues.
- **Economic issues:** none identified.
- **Political and regulatory issues:** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A-3, Ethanol Production

Policy Description

Provide incentives for the production of ethanol from crops, agricultural byproducts, or other materials (forest treatment biomass, manures, municipal solid waste). Use of the ethanol will offset fossil fuel use (gasoline) and decrease GHG emissions. Different incentive programs will be needed for crop (starch-based) ethanol production versus cellulosic ethanol production processes.

This option is linked with TLU Option 6 on Biofuels Consumption. This option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of ethanol using feedstocks and production methods with greater GHG benefits than the likely business as usual national market production methods (conventional starch-based ethanol).

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs that align in-state production with TLU ethanol renewable fuels goals of 10% of NM gasoline consumption by 2012, 20% of gasoline consumption by 2020, and 50% of gasoline consumption by 2050. The CCAG recognizes that in-state production goals could be limited by available cropland and waste feedstocks (including agricultural residue, forest biomass, manure and municipal solid waste; see quantification below). Careful planning and monitoring of the ethanol production industry will be needed.

  Based on the NM I&F report, current ethanol usage in NM is about 1.5% of gasoline by volume (where oxygenated fuel is required in the state, ethanol is 7.7% of gasoline by volume). To meet the policy goals, significant increases in ethanol production will be needed.

  Due to the current production methods (starch-based) and primary U.S. geographic production regions (mid-western states), incremental GHG benefits can be achieved if the ethanol consumed in NM is produced within NM using methods with lower carbon intensity. The benefits associated with starch-based ethanol production have been incorporated into TLU Option 6, which promotes increased use of ethanol in the state. Because of the fossil fuels used in producing starch-based crops and in processing these crops, ethanol use from conventional starch-based production achieves only modest GHG reductions relative to gasoline (12-30% based on lifecycle analyses). Hence, the goals of this policy are to incentivize the production of ethanol from feedstocks and processes that achieve significant incremental benefits. For example, lifecycle analyses have shown that cellulosic ethanol consumption can produce GHG benefits of up to 85% relative to gasoline consumption. Measured increases in corn, sorghum, and other grains should be achievable and will supplement ethanol production from starch in New Mexico. However, any increase in grain production will have to be balanced by demand of grain crops by the agricultural industry (dairy, high-fructose corn syrup products); use of limited water resources to grow crops and produce ethanol; on input of petroleum chemical based products (fertilizers, herbicides, pesticides) needed to increase grain production; and transport of feedstock and finished product to market. In addition, significant increases are needed in ethanol processing capacity.

While this policy is meant to be technology neutral, due to the production issues, demand for starch-based products by the agriculture industry, and important GHG benefits, cellulosic ethanol production is the most likely technology to produce the quantities of ethanol required in the longer term (beyond 2012). Efficient cellulosic methods are becoming available, possibly by the 2010 timeframe. These include biomass gasification with subsequent production of biofuels, including ethanol. However, starch-based production is expected to remain the dominant production mode through 2020. Due to the current high wholesale price of ethanol, many starch-based ethanol plants are under construction or are planned in the U.S. As such, additional incentives from the state for conventional starch-based ethanol production do not appear to be needed. Instead, New Mexico should promote low-GHG ethanol production methods from starch.

One promising idea is the use of biogas derived from manure to energy projects, such as those envisioned in the dairy sector (see Option A-1). The methane from such projects could offset the use of natural gas to run boilers and dryers at the ethanol plants, which would greatly increase the overall GHG benefits. New Mexico should promote these production methods at both planned and current ethanol plants to achieve optimum GHG benefits.

Increased use of municipal solid waste, forestry residue, and agricultural byproducts (e.g. manure, crop residue) for cellulose conversion to ethanol should be economically attractive in the next few years when the costs of enzymes are sufficiently reduced or biomass gasification projects have been shown to be economically feasible. Required research and development for economical and efficient conversion processes of cellulose to ethanol are simultaneously required (e.g. pilot scale commercial plants), but should be available through private funding and federally funded programs. See additional background information under the Feasibility Issues Section below.

New Mexico should promote projects such as these that produce greater GHG benefits than those achieved by utilizing ethanol from the national market. Depending on project design (e.g. primary fuel source), these projects could be either starch-based or cellulosic plants.

Policies to increase either starch feedstock or cellulosic feedstock for ethanol production must evaluate potential adverse impacts on established industry within New Mexico. For example, using corn or sorghum stover for cellulosic ethanol production could adversely impact the dairy industry which uses these byproducts for feed. While the debate about growing crops for food or for fuel is long and will not be settled in New Mexico, careful consideration of economic impacts must be considered when adding ethanol capacity to New Mexico production.

- **Timing:** By 2012, add 124 MMgal/yr of additional production capacity using methods that achieve significantly better GHG benefits than conventional starch-based ethanol (achieves the 10% renewable goal). By 2020, the TWG estimates that an additional 163 MMgal/yr will be needed to get to the 20% renewable goal. The TWG recommends promoting the establishment of both alternative starch-based and cellulosic production capacity to meet these production goals, using feedstocks produced in state and processes that achieve significant

GHG benefits. Additions of alternative starch-based projects should show similar GHG benefits to cellulosic production.

- **Coverage of Parties:** New Mexico Department of Agriculture (NMDA), New Mexico Agricultural Extension Services (NMAES), and New Mexico Energy, Minerals, and Natural Resources Department would be the lead agencies. Also included are private agencies and agricultural producers and processors.

Implementation Mechanisms

Information and education: NMDA and NMAES would develop guidance for grain growers to convert current crops to biofuels-compatible crops and practices to grow these crops. NM Energy, Minerals, and Natural Resources would provide guidance on biofuels, electricity and hydrogen production and use in the state and nation.

Life-cycle costs and benefits of starch-based and cellulose-based ethanol need to be developed and compared using New Mexico feedstocks, production, and distribution. These also need to be compared to gasoline as a fuel to show GHG and fuel quality differences.

Education on the current demands by various agricultural industries for starch-based crops/feedstocks should be provided to ensure ethanol production either minimizes or does not affect established industries that rely on grain crops.

NMDA and NMAES would develop guidance for growers to convert current crops to starch-based ethanol-compatible crops or cellulose crops and practices to grow these crops.

New Mexico Energy, Minerals, and Natural Resources Department would provide information on emerging technologies in cellulose conversion based on gasification, or enzymatic/acid hydrolysis technologies. It will be important for state government to be well versed on these technologies in order to ensure that New Mexico makes its production goals and balances competing demands.

NM Energy, Minerals, and Natural Resources would provide guidance on plant capacities, biofuel production processes and use in the state and nation, and the carbon content of biofuels produced by various processes.

Technical assistance: Technical assistance on conversion of cellulose to ethanol is required. At current gasoline/oil prices (approximately $2.50 per gallon of gasoline September 29, 2006), acid hydrolysis of cellulose to produce the sugars that are fermented to ethanol is attractive and could find a way into the production market. Enzymatic hydrolysis of cellulose, though, offers high potential to convert cellulose without the wastes of acid hydrolysis and at significantly less energy input. Biomass gasification also offers substantial opportunity and benefits for biofuels production from cellulose, including the potential for other energy end uses (hydrogen production, electricity production, gaseous fuels). Technical assistance in cellulosic production should be available from programs named in the Energy Policy Act of 2005, and New Mexico should be involved as a partner in developing this research and its applications. Alternative starch-based production, such as processes fueled by alternative fuels, could also achieve significant GHG benefits relative to conventional starch-based production.

Funding mechanisms and or incentives/Market based mechanisms:

(1) Expect private investment (e.g., Abengoa and others) and federal and state tax incentives to produce ethanol from cellulose and starch crops. Extend incentives to either starch or

cellulosic feedstock conversion projects that demonstrate significantly better GHG reduction than conventional starch-based production.

(2) Create a NM production tax credit for the creation of renewable fuels (to include sustainable starch based-ethanol, cellulosic ethanol, renewable based hydrogen) on a per gallon gasoline equivalent output basis.

(3) Enable gross receipts tax exemptions on construction/ production of renewable fuels facilities.

(4) Recognize the need for renewable fuels consumption incentives (as outlined by the TLU TWG in Option 6). These could include a sliding scale "fee-bate" program to incentivize low emissions/flex fuel ready vehicles in the market at the time of purchase. Also, an exemption of vehicle registration fees for low emissions/flex fuel vehicles to incentivize increased ethanol ready vehicles in the market.

(5) Recognize the need for incentives for cellulosic feedstock producers to implement cost effective methods for gathering, processing, and transporting feedstocks to biofuels producers. These incentives could come in the form of low interest loans, grants, or other incentives.

Codes and standards: As outlined by the TLU TWG, establish a NM based Renewable Fuels Standard (RFS) that would mandate by 2009, 5% of gasoline would be replaced biofuels (ethanol), rising to 10% by 2012, 20% by 2020, and 50% by 2050. Government vehicle alternative fuel use should provide a model for the state to follow.

Pilots and demos: Provide incentives for the first cellulosic ethanol facility in NM to become operational by 2009. Investigate the advantages and disadvantages of a consortium of New Mexico universities (NM State, NM Mining and Technology, and University of NM) to lead pilots and demos using different emerging technologies. Consider partners with New Mexico's national laboratories as well.

Demonstration projects featuring readily-available cellulosic-based feedstocks used for ethanol production would be useful to test the economics of cellulosic ethanol production.

Demonstrations of locally-produced alternative fuels (including biodiesel, solar power and hydrogen) for local use would help spur rapid public acceptance of the technologies. The initial pilot for cellulose conversion to ethanol is needed to show that the technology works and can be implemented.

Research and development: As mentioned above, additional research on cellulose conversion to ethanol is needed to demonstrate the economic feasibility of different conversion processes. At current prices ($2.00/gallon or more for wholesale ethanol) assessments of cellulosic ethanol production in NM have been shown to be cost effective.[14]

Related Policies/Programs in Place

New Mexico currently has production capacity of approximately 30 million gallons (30 MMgal) of ethanol in 2005 from a single production plant. This production capacity ranks 17th in the nation compared to 21 states that produce ethanol. National ethanol production was about 3.4 billion gallons in 2004 whereas, 140 billion gallons of gasoline was produced in the same year.

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[14] Charles Bensinger, Sunbelt Biofuels, personal communication with S. Roe, CCS. Based on conversion of either manure or municipal solid waste feedstocks. These plants are profitable at an ethanol wholesale price of $1.90/gallon.

Plans have also been announced for additional ethanol production capacity in the state, including a 105 MMgal/yr plant in Clovis projected to begin operation in late 2007. All of the aforementioned production is conventional starch-based production, which is consistent with the bulk of current national production.

For conversion of starch (grains) to ethanol, the federal Energy Policy Act of 2005 calls for a 7.5 billion gallon capacity nationally by 2012. In addition, New Mexico should have a role in new Energy Policy Act programs to market 1 billion gallons of ethanol from cellulose (ag/forestry/municipal waste) conversion by 2015.

Albuquerque currently requires that E10 be available during the winter months (Nov-Feb). Also, New Mexico currently provides compensating tax exemptions for renewable fuels, and alternative fuel vehicles are exempt from the state excise (sales) tax.

Types(s) of GHG Reductions

- CO2: Emissions are reduced by offsetting the use of petroleum-derived gasoline and diesel. In order to assess the CO2 benefit, energy requirements of producing ethanol from starch and cellulose need to be compared to the energy requirements of producing gasoline. Current research indicates that cellulose-based ethanol production provides up to 72-85% reduction in GHGs compared to gasoline, whereas an 18-29% reduction is measured from starch-based ethanol production compared to gasoline.
- Black Carbon: While differences in BC emissions between gasoline and ethanol-blended gasoline are likely to be negligible, a small gain from reduced particulate emissions could be realized by conversions of fuel to blended ethanol/gasoline.

Estimated GHG Savings and Costs per MtCO2e

- GHG reduction potential in 2012, 2020 (MMtCO2e): 0.7, 1.7
- Net Cost per MtCO2e: $0
- Data Sources: In-state production targets were estimated based on the TLU Option 6 renewable fuel standards (10% offset of gasoline by 2012, 20% by 2020, and 50% by 2050). The in-state production targets are shown in the table below along with BAU ethanol and gasoline consumption.

Parameter	2007 (MMgal)	2012 (MMgal)	2020 (MMgal)	2050 (MMgal)
BAU Ethanol Consumption	7.3	8.0	9.3	17
BAU Gasoline Consumption	1,028	1,127	1,306	2,421
Future Ethanol Consumption (based on NM TLU Goals)		124	287	1,331

Emission factors for reformulated gasoline, starch-based ethanol, and cellulosic ethanol were taken from a General Motors/Argonne National Lab study.[15] These emission factors incorporate the GHG emissions during the entire life-cycle of fuel production (e.g., extraction, transport, refining, distribution, and consumption for gasoline; crop production,

[15] *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.

feedstock transport, processing, distribution, and consumption for ethanol). These life-cycle emission factors are referred to as "well-to-wheels" emission factors.

Cost information on cellulosic ethanol production plants in NM was provided by a TLU work group member.[3] Based on a variety of feedstocks, the current production cost using biomass gasification and subsequent ethanol production is estimated to be about $1.30/gallon.

Because ethanol production either by starch-based or cellulosic technology is considered to be profitable, there are no societal costs associated with new processing facilities beyond any incentives used by the state to attract these facilities or support pilot projects. Therefore, the estimated cost effectiveness is $0/Mt reduced.

- **Quantification Methods:** Well-to-wheels CO_2e emission factors from a recent General Motors/Argonne National Laboratory Study were used to estimate the benefits of offsetting conventional gasoline with enough ethanol produced in state to fulfill the policy goals. Well-to-wheels emission factors take into account the energy required to produce, process, and transport each fuel type (i.e., starting with the oil well for gasoline and the crop for starch-based ethanol). These emission factors are output from Argonne National Lab's GREET Model.

  For the purposes of this analysis, ethanol production resulting from incentives from this policy option is assumed to occur using cellulosic ethanol technology, which has higher life-cycle GHG benefits than conventional starch-based ethanol production. For comparison purposes, benefits associated with conventional starch-based ethanol would be about 25% of those estimated for cellulosic ethanol. Because detailed facility-level analyses were not available for alternative starch-based processes, such as those using renewable fuels, CCS assumes that a similar benefit to cellulosic production can be achieved.

  To meet the goals of this policy option, the following GHG benefits were estimated based on the ethanol production volumes shown above. The GHG benefits are based on the incremental benefit achieved using production methods that achieve high GHG benefits over those processes that dominate the national market (conventional starch-based ethanol). This incremental benefit of 66% is based on the results of the ANL study referenced above and is incremental to the benefit calculated for TLU Option 6.

Year	Production (MMgal/yr)	Incremental GHG Benefit ($MMtCO_2e$)
2012	124	0.7
2020	287	1.7
2050	1,331	7.7

  As mentioned above, the cost effectiveness is based on the level of incentives put in place by the state to support feedstock producers and attract private investment (including pilot commercial-scale plants).

- **Key Assumptions:** These include – the increases in in-state production capacity achieve the GHG benefits estimated by ANL for cellulosic technology (including any alternative starch-based production); the life-cycle emission factors are accurate for in-state ethanol production (these were developed at the national level; potentially the benefits could be even higher, since the embedded energy in feedstock transport is lower); current cost estimates for cellulosic ethanol production are accurate and not expected to change considerably over the policy period (thru 2020); current ethanol prices will not fall substantially to the point of making near term cellulosic or alternative starch-based plants economically infeasible.

Key Uncertainties

Several uncertainties remain and include ethanol production life-cycle emission factors, cellulosic ethanol production costs, and the amount of starch-based versus cellulosic ethanol production that can be accomplished in the state. The TWG performed an initial assessment of cellulosic feedstock availability, which is provided under the Feasibility Issues section below. Additional uncertainties include: GHG and net usable fuel benefits that can be gained by moving to cellulose based ethanol production and away from starch-based production; the timing of applied, efficient processes for acid-hydrolysis, enzymatic hydrolysis, or biomass gasification of cellulose feedstock; the resilience of the agricultural industry in New Mexico to competing demands on starch-based products and/or cellulose based products for ethanol.

Contributing Issues

- **Human and social issues**

  Socioeconomic factors related to disrupting the established industries in New Mexico need to be considered. Removal of all or part of the starch based product from industries like dairy and high-fructose corn syrup products could offset social stability in order to provide fuel sources.

  New technologies entering the state need to consider creating jobs as they create new markets. For example, the announcement of new production plants with few jobs attached for the local workforce carry social cost as well as environmental benefit.
- **Environmental issues**

  Gasoline-ethanol blends may increase or decrease emissions of some criteria (e.g. oxides of nitrogen increases) and toxic air pollutants.

  Environmental impacts of increased production of grains for ethanol need to be assessed and compared to benefit in decreased gasoline production and use.

  Increased use of forest land, agricultural land, range land, etc. to procure cellulosic feedstock should be evaluated and compared to potential benefits in decreased consumption of gasoline.
- **Economic issues**

  Ethanol production increases from starch may require additional water use and/or additional input of petroleum based products (fertilizers and herbicides) that may make the increased production more expensive. Similar impacts on water resources from cellulosic ethanol production must also be evaluated.

  Increased ethanol production could provide new markets for grains grown in New Mexico as long as critical resources (water) and established markets were not impacted disproportionately.
- **Political and regulatory issues**

  Additional in-state biofuel production increases can lower the amount of imported petroleum which increases energy security.

Feasibility Issues

Ethanol Pricing: The current wholesale ethanol pricing makes starch-based and cellulosic ethanol plants very attractive. A sharp drop (e.g. below $1.90/gallon) could have a strong negative effect on private investment.

Feedstock Availability: Concerns have been raised regarding the availability of feedstocks within NM to achieve the proposed levels of production. Concerns have also been raised in the agricultural community regarding the use of agricultural residues (e.g. corn/sorghum stover) as feedstocks to ethanol production, given that these feedstocks are currently used as feed to dairy cattle. The TWG conducted a preliminary investigation into the availability of cellulosic feedstocks for conversion to ethanol which is summarized in the table below.

As shown in this table, feedstocks are available to meet the in-state production goals for 2012 and 2020 considering five potential sources of biomass. The conversion rates in this table assume biomass gasification with subsequent liquid fuels production, but ethanol yields from processes using cellulose hydrolysis followed by fermentation to ethanol should provide similar yields. Additional sources targeted by this option include corn/other starch crops (for use in alternative starch-based plants that achieve similar GHG benefits to cellulosic plants). Note that there would be additional significant production needed in the 2030 – 2050 period to meet the TLU consumption goals with in-state production, since over 1,000 MMgal/yr is estimated to be needed based on current fuel consumption projections. Based on this preliminary analysis, it does not appear likely that feedstocks will be available in-state to achieve production levels too much greater than 500-600 MMgal/yr.

NM Biomass Feedstocks

Feedstock	Ethanol Production (MMgal)	Comments
Municipal Solid Waste Fiber	153	Based on 2005 NM Solid Waste Summary and EPA solid waste characteristics. Conversion of waste via gasification at 80 gal/ton waste (Sunbelt Biofuels, personal communication with CCS). Assumes no growth in resource beyond 2012.
Dairy/Feedlot Manure	40	Based on manure available from 50% of the dairy herd (to avoid overlap with Option A-1) and the beef feedlot population. Conversion via gasification at 55 gal/ton manure (Sunbelt Biofuels, personal communication with CCS). Assumes no growth in resource beyond 2012.
Switchgrass or Other Biomass Grown on CRP-Retired Acres	26	Conversion of 375,000 tons/yr of biomass feedstock at 70 gal/ton. See description below.
Forest Residue	32	Assumes that half of the biomass generated under Option F-2 (400,000 ton/yr) is diverted to ethanol production. Biomass conversion rate is 80 gal/ton (Sunbelt Biofuels, personal communication with CCS).
Crop Residue	160	Available crop residue from wheat (2,000,000 tons). Corn and sorghum stover excluded based on their need as animal feed. Conversion rate is assumed to be 80 gal/ton.
Total	**411**	Other potential feedstocks include additional starch-based crops, waste tires, biosolids, and landfill mining.
In-State Production Targets (2012; 2020)	**248; 359**	The derivation of these targets was described above under Quantification Methods.

As shown in the table above, one potential source of biomass as a feedstock is the current lands enrolled in the USDA CRP program. New Mexico has about 590,195 acres in the CRP program, and about 90% these acres are set to expire in 2007. If these acres were converted to production of feedstock for cellulosic ethanol production, the benefits of CRP protection (i.e., no cultivation or agricultural production) could be extended while harvesting the above-ground biomass for ethanol production and/or generation of electricity (as described under Option A-2). The estimated biomass harvested from expiring CRP land amounts to about 375,000 tons of biomass feedstock (assuming that half of the expired CRP acres are converted to biomass production). Using a conversion rate of dry cellulose feedstock to ethanol of 65 - 75 gallons/ton (from U.S. DOE, at web site genomicsgtl.energy.gov/biofuels/transportation.shtml; 9/17/06), the 375,000 tons of biomass could be used to produce 48.8 MMgal/y to 56.3 MMgal/yr of ethanol.

Additional assessment of feedstock availability is needed. For example, some of these feedstocks, such as manure, also have other beneficial uses. Potential impacts for these other uses need to be considered.

Additional benefits associated with the conversion of cellulosic feedstocks to ethanol shown in the table above include a reduction of future methane emissions associated with decomposing MSW in landfills. For forestry and agricultural residue, CH_4 and N_2O emissions would be reduced in instances where these residues are burned. Emissions of CH_4 from dairy and feedlot manure would also be reduced.

Monitoring needs: Monitor grain crop production and conversion to ethanol, compare against state and federal guidelines on ethanol production.

Monitor agricultural residues available, those used to produce ethanol, and competing needs for these byproducts.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A4, Nutrient Management

Policy Description

Between 0.2% and 3% of applied nitrogen in agricultural fields is estimated to be lost as N_2O directly from soil emissions. These N_2O emission rates are directly related to the rates, placement, and timing of applied fertilization. The challenge is to reduce total application of nitrogen without reducing yields or total production.

Agronomic practices that tighten the coupling between soil nitrogen availability and crop growth will improve nutrient use efficiency and reduce the likelihood that nitrogen will escape as N_2O, leach as nitrate into groundwater systems, or be transported to surface water systems. Better synchronization of nutrient applications with active crop needs can be achieved with improved nutrient management. The development and promotion of '*nutrient management guidelines and strategies*' along with support for enhanced extension and outreach of these guidelines can increase adoption of improved nutrient planning and practices, leading to both lower N_2O emissions and lower fertilizer costs.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to achieve measured reductions in total fertilizer use (on a per acre basis) – and consequently in the N2O and nitrate flux from agricultural soils – are achievable with improved nutrient management and adoption of specific nutrient management strategies (as described below). An initial policy goal is proposed that aims to reduce excessive fertilization by reducing average annual per acre nitrogen fertilizer use by 10% by 2020.
- **Timing:** ½ % incremental reduction from 2006 levels in each year from 2006-2015 and 1% incremental reductions from 2015-2020.
- **Coverage of Parties:** New Mexico Department of Agriculture (NMDA) in conjunction with the New Mexico Agricultural Cooperative Extension Service (NMCES) would be lead agencies.

Implementation Mechanisms

- Information and education
  a. NMDA and NMCES would develop fertilization guidance for each major New Mexico crop.
  b. NMCES would promote adoption through county extension agents and regional workshops.
  c. NMDA would monitor progress and performance toward goal through direct questioning of nutrient management practices during annual NASS survey of state farmers.

Related Policies/Programs in Place

None identified.

Types(s) of GHG Reductions

- N_2O: Savings occur through the reduction in the use of nitrogen fertilizers that lead to N_2O emissions. N_2O is produced naturally by microbial processes in the soil. Application of synthetic nitrogen and organic fertilizers leads to increased emissions by augmenting the microbial processes.
- CO_2: Reduced rates of fertilizer application could reduce total CO_2 emissions that result from fertilizer manufacture and application – assuming that manufacturing levels are consequently reduced i.e., production is not shifted onto other buyers.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.004, 0.012
- Net Cost per MtCO2e: -$46
- Data Sources: Currently the only annually tracked measure of nutrient usage by the NMDA is 'fertilizer shipped into New Mexico' – in 2003 this amount was estimated to be 63,844 tons of nitrogen materials (this figure is gross weight and is not adjusted for nitrogen composition of various materials such as anhydrous ammonia, urea, ammonium sulfate etc.). The amount of nitrogen fertilizer shipped into New Mexico was obtained from the USDA's National Agricultural Statistics Service (NASS; http://www.nass.usda.gov/nm/nmbulletin/07_04.pdf). The nitrogen content of each fertilizer came from the Arizona Department of Agriculture (http://www.azda.gov/ESD/UFTRSCodes.pdf). Costs for the five fertilizers with the highest usage rates were obtained from the USDA's Economic Research Service (ERS).[16] The average of these costs was used for the less used fertilizer types.
- Quantification Methods: The reduction in nitrogen applied to NM soil was estimated by multiplying the amount of fertilizer shipped into NM by the nitrogen content (%) of each fertilizer type by the percent reduction for that year. The reduction in nitrogen was estimated using the method from EPA's SGIT. The reduction in nitrogen was multiplied by 90% to estimate the amount of unvolatilized nitrogen not emitted as NH_3 or NO_x. The amount of nitrogen emitted as N_2O was estimated as 1.25% of the unvolatilized nitrogen.
  Costs were estimated as the sum of fertilizer savings (negative cost); costs for soil testing; costs for staff, overhead, and travel; and guidance document preparation costs. Soil testing would be required for each crop field once every 4 years. The number of fields was estimated as 11,416 (856,166 harvested acres divided by 75 acres per field). The cost for each soil test was estimated to be $10. Costs for 2 FTEs of additional staff, overhead, travel, lab, and associated costs was estimated at $250,000 per year, and preparation of guidance documents was assumed to be $75,000 in the first year.[17]
- Key Assumptions: The amount of nitrogen shipped into New Mexico in a particular year was assumed to accurately reflect the usage of fertilizer on New Mexico fields in that year. This amount of fertilizer shipped into the state is also assumed to cover all agricultural nitrogen fertilizer consumption in the state.

[16] http://www.ers.usda.gov/Data/FertilizerUse/Tables/Fert%20Use%20Table%207.xls.
[17] Brian Hurd, NMSU Agricultural Economics, personal communication with H. Lindquist, CCS, June, 2006.

Key Uncertainties

- Benefits: Difficult to measure and monitor adoption rates and management effectiveness of nutrient management guidelines. Measures such as 'fertilizer shipped into New Mexico' is a very crude and unreliable performance measure but is the only one presently available to proxy and estimate for total nitrogen use within the State.
- Costs: Soil testing costs can range from $5-$15 per sample. Nutrient management guidance documents could be prepared based on existing research for most major crops, perhaps at a cost of $50,000-$75,000. Printing and distribution would likely add to this cost. Extension training and regional workshop costs would also add some cost and could vary significantly depending on scope, frequency, and other factors.

Contributing Issues

- **Human and social issues:** none identified.
- **Environmental issues**
  - More efficient use of nitrogen fertilizer reduces potential for runoff and leaching into surface- and ground-waters that diminish water quality.
- **Economic issues**
  - More efficient use of fertilizer could reduce farm operating costs with lower purchases of applied materials; however, there may be increased costs associated with required activities such as soil testing and monitoring.
- **Political and regulatory issues:** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A5, Manure Management

Policy Description

Reduce N_2O emissions from daily spread and other land application of dairy and feedlot cattle manure through the use of better application methods. These application methods are designed to reduce contact of manure nitrogen with air (lowering the rate of denitrification) and the amount of manure nitrogen loss via leaching and runoff. Reduce CH_4 emissions from dry manure storage by promoting composting of these wastes.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico implement composting and land application improvements at dairies and feedlots representing 25% of dry manure storage and treatment processes by 2012 and 90% by 2020.
- **Timing:** see goal levels identified above.
- **Coverage of Parties:** NMDA, NMSU, Cooperative Extension Offices

Implementation Mechanisms

Additional work needed to identify appropriate mechanisms for implementing this policy.

Related Policies/Programs in Place

None identified.

Types(s) of GHG Reductions

- **N2O:** N_2O could be reduced by reducing nitrogen runoff to surface water or leaching to groundwater. Some of this nitrogen is then oxidized to N_2O.
- **CH4:** CH_4 could be reduced through reducing anaerobic decomposition of manure during storage.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): Could not be determined with available data.
- Net Cost per MtCO2e: Could not be determined.
- Data Sources: There are little data available on the reductions of N_2O associated with different manure application methods. Most previous studies have focused on reductions in NH_3 (ammonia) emissions, increased nitrogen uptake by crops, or lower nitrogen runoff. CCS identified one source of information that suggested that subsurface application of manure could lower nitrogen oxide (NO) emissions, but actually raise N_2O emissions.[18] The reduction in CH_4 from composting was assessed by comparing emission factors for stockpiling and composting. The emission factor for manure stockpiling (0.0035 kg CH4/kg

[18] http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/004/Y2780E/y2780e02.htm.

volatile solids) was taken from EPA's SGIT. Manure contains about 10% volatile solids,[19] so the emission factor converts to 0.00035 kg/kg manure. An emission factor for composting was taken from a report on emissions from composting operations.[20] The reported emission factor was 2.23 lb CH4/ton of material for 80% manure, 20% digested biosolids. This emission factor converts to 0.0011 kg CH4/kg manure; which is higher than the emission factor for manure stockpiling. Additional study is needed to determine the relative CH4 reduction benefit of composting manure. It is also not clear whether there could be an N2O benefit or dis-benefit from composting relative to stockpiling (increasing oxygen availability could conceivably increase the rate of N2O production).
The increased cost of composting over stockpiling was obtained from the University of Nebraska Agricultural Research and Development Center.[21] Costs were listed as: $1.25/ton for turning beef feedlot manure and $2.25 to $4.75/ton for spreading, based on labor charges of $10/hour, tractor rental charges of $19.50/hour, $30/hour for a loader and operator, $.60/ton for spreader use, $1/mile for truck usage, and $.50/ton for use of the compost turner. It was assumed that the same costs would apply to stockpiling except for turning; therefore, the cost difference was assumed to be $1.25/ton.

- Quantification Methods: Due to the lack of available data, benefits and costs for reductions in N2O associated with different manure application methods were not quantified.
  CH4 emission reductions achieved through the adoption of manure composting at beef cattle feedlots were also not estimated due to a lack of information on the relative benefits of manure composting.
- Key Assumptions: Beef cattle populations were assumed to remain static at the 2004 level. Other assumptions are discussed under Data Sources and Quantification Methods above.

Key Uncertainties

The major uncertainty is the emission factor for manure composting. Emissions can vary due to factors such as type and amount of bedding material composted with the manure. The lack of data on the merits of manure incorporation compared to surface spreading and manure composting compared to standard storage practices does not allow for a quantification of the benefits for this option.

Contributing Issues

None identified.

Feasibility Issues

None identified.

[19] Cibrowski, P., "Anaerobic Digestion in the Dairy Industry: Pollution Control Opportunities", Minnesota Pollution Control Agency, presented at the Air Innovations Conference, August 10, 2004.
[20] SCAQMD, 1996a. Characterization of Ammonia, Total Amine, Organic Sulfur Compound, and Total Non-Methane Organic Compound (TGNMOC) Emissions from Composting Operations, Source Test Report 95-0032/96-0003, conducted at EKO Systems, South Coast Air Quality Management District, January 1996.
[21] University of Nebraska Integrated Farm at ARDC, Composting, http://www.ianr.unl.edu/ianr/csas/IF/compost.htm.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A6, Conservation Tillage/No-Till

Policy Description

The amount of carbon stored in the soil can be increased by the adoption of conservation tillage. Reducing mechanical soil disturbance reduces the oxidation of soil carbon compounds and allows more stable aggregates to form. In addition to soil carbon benefits, conservation tillage has numerous co-benefits including reduced wind and water erosion, reduced fuel consumption and improved wildlife habitat.

Other management practices such as decreased summer fallow or an increase in winter cover crops could also affect soil carbon levels; however opportunities for significant implementation for these practices in NM were not identified.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to bring 650,000 acres of cropland into new management practices (conservation tillage or no till).
  Note that this option has overlap with Option A9 (Organic Farming). Both options reduce tillage and lead to increases in soil organic carbon. Since the organic farming acreage can be thought of as a subset of the conservation tillage/no-till acreage addressed in this option, the organic farming acreage was subtracted from the conservation tillage/no-till acreage shown below for the purposes of removing double-counting of benefits. The GHG benefits associated with this overlap have been adjusted in the summary table at the beginning of this appendix.
- **Timing:** 650,000 acres of cropland brought into no till management practices from 2007-2015; 1,300,000 acres total by 2025.
- **Coverage of Parties:** Local Agricultural Extension Offices or USDA Soil Conservation Service Field Offices.

Implementation Mechanisms

- **Information and education**- NM Extension and NRCS Field Offices have educational programs in place to encourage farmers to adopt conservation tillage practices.
- **Technical assistance**- There is sufficient technical assistance available in the Extension Service and NRCS Field Offices and in farmer groups.
- **Funding mechanisms and or incentives**- Conservation Security Program incentives provide financial incentives to adopt conservation tillage, however, the funding to extend CSP to cover all cropland is currently lacking.
- **Voluntary and or negotiated agreements**– participation in federal conservation programs is voluntary.
- **Market based mechanisms**- Some NGOs are attempting to organize demonstration projects to deliver carbon sequestration benefits to global markets. The slow rate of accumulation of soil carbon and the uncertainty associated with dryland farming will limit the attractiveness of New Mexico based projects to private sector investors. However, federal programs,

particularly the Conservation Security Program, are intended to expand to cover all eligible land and to provide incentives for adoption of management practices such as conservation tillage.

- **Pilots and demos**- Currently, there is a need to support Pilot projects to demonstrate the technical (measurement, monitoring and verification) feasibility of private sector projects in the state.
- **Research and development**- Improved measurement (direct estimates of soil carbon), monitoring (estimates of acres under different tillage regimes) and verification (model integration of direct measurement estimates and acres of adoption) are required to reduce the uncertainties to an acceptable level.
- **Reporting**- The U.S. DOE Voluntary Greenhouse Gas Emission Reduction Reporting System (1605b) is currently structured to accept conservation tillage as an emission reducing practice.

Related Policies/Programs in Place

Currently, there are about 275,000 acres in conservation tillage. There are no financial incentives to adopt. The Conservation Security Program rewards farmers financially for implementing conservation tillage. CSP is currently limited to less than 5% of New Mexico cropland, but should be expanding over the next decade to include the majority of land.

Types(s) of GHG Reductions

- CO_2: Reducing tillage and soil disturbance slows the breakdown of plant material on the soil surface and in the root zone, accelerating the microbial processes that stabilize carbon and protecting carbon from oxidation, inhibiting the release of carbon back into the atmosphere. Depending on how the adoption of conservation tillage affects the overall crop production process, additional CO_2 reductions can occur through lower fossil fuel consumption in farm equipment. Research also indicates the potential for higher N_2O emissions as soil organic carbon levels increase (see Feasibility Issues Section below).

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.06, 0.13
  As mentioned under Policy Design, an adjustment in the overlap of benefits between this option and Option A9 has been made to the summary table at the beginning of this appendix.
- Net Cost per MtCO2e: $15
- Data Sources: An estimate of the amount of diesel fuel saved by converting to no-till farming (3.5 gal/acre) was obtained from the Conservation Tillage Information Center.[22] A diesel fuel emissions factor was obtained from EPA's SGIT [8.37 MtCO2e/1000 gal (including CO2, CH4, and N2O emissions)]. A soil carbon sequestration rate for adoption of conservation tillage practices of 0.11 ton CO2/acre/yr (0.075 ton C/ha/yr) was provided by a member of the

[22] Value obtained from: http://www.ctic.purdue.edu/Core4/CT/CRM/Benefits.html.

TWG.[23] An estimate of the subsidy needed ($3/acre) to convince those not already practicing conservation tillage to adopt the practice was taken from an Iowa State study.[24] This study states that even when conservation tillage is more profitable than conventional tillage, a subsidy may be needed to overcome the risk aversion of some farmers.

- Quantification Methods: The soil carbon sequestration rate cited above was applied to the acres adopting no-till practices to estimate the amount of carbon sequestered as a result of this program. Soil is assumed to continue sequestering carbon for up to 20 years after no-till is adopted.[7] The amount of diesel fuel emissions avoided was estimated by applying the amount of diesel fuel saved and the diesel fuel emission factor.
- Key Assumptions: Assumptions regarding adoption of conservation tillage practices are based entirely upon the funding and implementation of federal conservation programs such as the Conservation Security Program. If these programs are funded in the 2007 and 2012 Farm Bills, it is assumed that approximately one-half of the eligible acres will be converted to conservation tillage by 2015 (10 years) and the remaining one-half will be converted over the following 10 years. Experience has shown that once conservation tillage has been adopted, there is little return to conventional tillage. A further assumption is that there is year-to-year consistency in the application of tillage practices.

Key Uncertainties

- Funding for federal conservation programs in the 2007 and 2012 Farm Bills.

Contributing Issues

- **Human and social issues:** none identified.
- **Environmental issues**
    - Reduced tillage increases plant cover on the soil surface and reduces wind and water erosion.
    - Crop residue helps hold moisture in the soil and improves water quality by preventing runoff.
- **Economic issues**
    - Reduced tillage saves labor, fuel (and associated emissions), and machinery wear that would be spent tilling the land.
    - Increased carbon content of the soil increases infiltration, water and nutrient holding capacity and improves productivity of cropland.
- **Political and regulatory issues:** none identified.

[23] Joel Brown, Jornada Experimental Range, U.S. Department of Agriculture, paper prepared for the AF TWG on Terrestrial Sequestration in NM, 2005.

[24] Lyubov Kurkalova, Catherine Kling, and Jinhua Zhao. Center for Rural and Agricultural Development, Iowa State University. *Costs and Environmental Effects from Conservation Tillage Adoption in Iowa*, April, 2003.

Feasibility Issues

Research has indicated a potential for increased N_2O emissions as soil organic carbon levels increase.[25] Additional study and field work on NM cropping/soil systems will be needed to verify the GHG reduction potential estimated in this policy analysis.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

[25] Li et al, "Carbon Sequestration in Arable Soils is Likely to Increase Nitrous Oxide Emissions, Offsetting Reductions in Climate Radiative Forcing", *Climate Change*, (2005) 72: 321–338.

A-7, Convert Agricultural Lands to Grasslands or Orchard

Policy Description

Increase carbon sequestration in agricultural land by converting marginal land used for annual crops to permanent cover (grassland/rangeland or orchard). Also, prevent the loss of soil carbon in the future associated with cropland currently in the Conservation Reserve Program (CRP). Adopt mechanisms to either keep these cropland acres in the CRP or prevent them from either returning to conventionally tilled production or to suburban/urban development.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs that would assure that crop acres coming out of the CRP not return to active cultivation using conventional tillage or to urban/suburban development. The TWG found that there was not much potential to convert additional marginal agricultural land to permanent cover beyond what is already being handled in the CRP. Focus was instead placed on policy that would assure that acres coming out of the CRP in future years would not return to production using conventional tillage practices or to suburban/urban development. The goal of the policy is to assure that no soil carbon associated with the acres coming out of the CRP program is lost during the policy period. Based on discussions with the USDA, 145,000 acres in the CRP program will not be extended beyond 2010.
- **Timing:** By 2010, adopt policies to assure no loss of soil carbon from acreage coming out of the CRP program (e.g. no return to conventional tillage, no suburban/urban development).
- **Coverage of Parties:** Additional work is needed to determine the applicable parties.

Implementation Mechanisms

Additional work needed to determine the appropriate implementation mechanisms for this option.

Related Policies/Programs in Place

None identified outside of the Conservation Reserve Program.

Types(s) of GHG Reductions

- CO2: Loss of carbon to the atmosphere from tillage and fallow land is prevented by keeping cropland currently under permanent cover in the same state (i.e. CRP acres).

Estimated GHG Savings and Costs per MtCO2e

- GHG reduction potential in 2012, 2020 (MMtCO2e): 0.06, 0.13
- Net Cost per MtCO2e: $17

- Data Sources: The U.S. Department of Agriculture Farm Services Agency provides data on acreage expiring from the CRP program.[26] Currently, 599,142 acres are in the CRP. As shown below, most of these acres will expire in 2007:
  2006: 4,312
  2007: 533,982
  2008: 36,884
  2009: 12,530
  2010: 524
  2011: 0
  2012: 0
  2013: 1037
  2014 and beyond: 9,873.
  Additional discussions with the USDA indicated that about 145,000 CRP acres statewide will not be extended beyond 2010.[27] Most of this acreage exists in Curry, Quay, Roosevelt, and Harding counties (CRP acreage is limited to 25% of cropland per county). While detailed information on existing NM cropland soil carbon levels are not available, data suggest that soil carbon losses during the first 2 years of tillage would be on the order of 15 tons of carbon per acre (50 MtCO2e/acre).[28] Estimates for the cost of acquiring agricultural land were also provided during these discussions: range $350-$500/acre, depending on proximity to urbanized areas. No data were found on the costs for purchasing conservation easements.
- Quantification Methods: The potential carbon losses (quantified as CO2e emissions) were estimated by assuming that 50% of the expiring 145,000 CRP acres would return to conventional tillage within the 2010 – 2020 time-frame. The carbon loss factor shown above was multiplied by these acreages to estimate total carbon losses. The estimated annual emissions were estimated by dividing this total by 10 years.
  The costs for the policy were estimated by multiplying the mid-range land acquisition cost estimate ($425/acre) by the amount of CRP acres to be conserved (total CRP acres returning to conventional tilling/development divided by 10. The value of 10 reflects the assumption that the expiring acreage would be acquired over a 10-year period from 2010 to 2020.
- Key Assumptions: The fraction of expired CRP acres that returns to production with conventional tilling methods or to development (50%). The carbon loss factor is assumed to be representative of the potential losses on expiring CRP acres. The acquisition costs are assumed to be representative; however costs for purchasing conservation easements could be lower.

Key Uncertainties

See Key Assumptions above.

Contributing Issues

- **Human and social issues**

[26] The Farm Services Agency has a website that tracks CRP by state, year and practice and is updated every month: http://www.fsa.usda.gov/dafp/cepd/crp_statistics.htm.
[27] Andrew Ortiz, USDA, personal communication with S. Roe, CCS and C. Abeyta, AF TWG, June 15, 2006.
[28] Joel Brown, Jornada Experimental Range, U.S. Department of Agriculture, Agriculture Research Service, personal communication with S. Roe, CCS, May 2006.

- **Environmental issues:** none identified.
  - Restoration of native grassland or forest habitat. Improved water quality and air quality.
- **Economic issues:** none identified.
- **Political and regulatory issues:** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A-8, Reduce Permanent Conversion of Farm and Rangelands to Developed Uses

Policy Description

Reduce the rate at which existing crop and rangelands are converted to developed uses. The carbon sequestered in soils and aboveground biomass is higher in crop and rangelands than in developed land uses. Policies are needed to provide incentives for workings farms, ranches and associated land preservation.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to reduce the rate at which agricultural lands are converted to developed uses. These recommendations are aligned with the goals of the analogous option for forested lands (F1). Policy initiation by 2010; 30% reduction achieved by 2012; 50% reduction achieved by 2020.
- **Timing:** Initiation in 2010 and continuing through 2020.
- **Parties:** Public and private partnerships (private agricultural organizations) with: Acequia associations at the local, regional and state levels; County planning and zoning entities; State Cooperative Extension Services, New Mexico Department of Agriculture, New Mexico Energy, Minerals and Natural Resources Department; Federal Natural Resource Conservation Service and Farm Service Agency.

Implementation Mechanisms

- Information and education: NM Extension Service, NRCS Field Offices, land trusts, NM Department of Agriculture.
- Technical assistance: NM Extension Service, NRCS, land trusts, NMSU, NM Department of Agriculture:

  - Development of a carbon sequestration assessment program that would assess and assign carbon sequestration value to the state's natural, working agricultural lands, as well as native prairie and grasslands. This carbon sequestration map and ancillary data could support a variety of GHG reduction policies.

  - Support studies shall be encouraged regarding the depletion of ground water pumped by other states and the impact to New Mexico's aquifers, such as the Ogallalla.
- Funding mechanisms and or incentives: Farm Bill, EQIP, CSP and state funding.

  - Incentives should be developed to encourage the retention of agriculture water rights for production agriculture on working farms and ranches. Such incentives may include, but are not limited to: tax incentives, water banks, technical assistance for implementing water conservation technologies (water right owners shall not be penalized for conserving water, and conserved water shall be allowed to expand the economic base of crop production provided that there is no impact to net depletions), and matching funds for federal programs for rural development in value added industries. The state shall continue as required by statute and the State Constitution to protect senior water right owners.
- Voluntary and or negotiated agreements: Participation in all programs is voluntary.

- Create programs to pair young farmers and ranchers with older landowners with farm and ranch land to allow a transition to new producers when there are no family members wanting to continue farming or ranching.
- Statewide programs should be developed to support local farmers and ranchers in developing value-added agricultural industries and their products, (with additional support for goods sold) for local consumption.

- Codes and standards: Tax codes changes will aid in protecting agriculture land and production for the next generation and slow farmland conversion to other uses.
  - Establishment of a "Working Farms and Ranches Program/Conservation Land Reserve" that would establish a pool of permanently protected forest, agricultural or other conserved lands (each eligible category to be clearly defined in statute). This can be accomplished through voluntarily applying to participate in the reserve. Owners of natural or working agricultural land could opt into the land reserve and qualify for additional tax incentives to protect natural or agricultural lands. Once the land base in the agricultural land reserve (ALR) has been established, no property can be removed from the ALR without transferring an equivalent property into the Reserve. (Identical to policy in F1).
  - Enhancement of the Transfer of Development Rights (TDR) program available to local government which allows purchase and trade of development rights between high density and low density areas to conserve open space, agricultural land and forest land on the margins of growing urban areas. Devoting additional staff and funding to the existing program within the Dept of Finance and Administration is needed. (Identical to policy in F1).
  - Statewide programs should be developed to support local farmers' and ranchers' participation in virtual, vertical supply chain models, with open book management, that will allow producers to receive a higher percentage of the food dollar. Additional supports need to be given for final products produced, processed and sold locally.
  - Water rights appurtenant to agricultural lands are subject to increasing pressures to transfer those water rights out of agricultural production to other uses. Because the transfer of water rights from working farms and ranches may be the initial stage of converting farmland to developed uses, every effort should be made to retain water rights in agricultural uses including the following initiatives:
    - New Mexico should provide incentives that protect agricultural water rights from demands to transfer those rights to other uses. Such incentives should recognize the importance of agriculture to rural economies, agroecological biodiversity, and the cultural heritage of the state. These incentives should ensure that community acequias, irrigation districts, and the agricultural land base are not adversely affected.
    - New Mexico is home to ancient water use traditions, including the custom and culture embodied in the acequias, that should be declared cultural patrimony of the State of New Mexico. Sustaining acequias is important to maintaining existing and future production on working farms and ranches.
    - The state should allocate sufficient resources for technical assistance to build the governing capacity of acequias, irrigation districts, conservancy districts, ditch associations, rural water associations to regulate water transfers in order to provide protections to each community's water supply.

- Watershed protections should be enacted to protect rural, agricultural communities from losing their water rights base as a result of increasing demands to move agricultural water rights to urban uses.
- The state should enact tax incentives so that land that retains its agricultural water rights.
- The state should adhere to the Constitution by protecting senior water rights through priority administration where appropriate and by preventing water uses that cause impairment to senior water rights.

- Inheritance Tax:
  - The New Mexico State Legislature shall pass a Memorial requesting that the New Mexico Congressional delegation study the impacts of eliminating or modifying the Inheritance Tax on working farms and ranches with the intent to reduce or eliminate the necessity of families selling working farms and ranches upon the death of the owner when otherwise the operation would continue.
  - State laws should be reviewed to reduce any additional burden on farm and ranch producers at the time of death of the owner. The value attributed to land must reflect the farming and ranching income potential of the land and not a higher value that could be obtained if the property were sold for development as long as the lands and property remain in production.

- Market-based mechanisms: Incentive based preservation and payment programs to agriculture producers for advanced protection of pristine and productive agriculture resources and to implement BMPs that result in environmental benefits. Such programs: CRP, CREP, and EQIP. State funding.
- Pilots and demos: The NRCS and NM Cooperative Extension Service
- Research and development: Review other states programs such as Idaho Carbon Trading Credits, NM Cooperative Extension Service and NRCS. Review existing local, state and federal policies that result in negative land conversion such as road construction and other infrastructure developments. Review local growth management practices that encourage the development of incompatible land uses and infrastructure services into prime agriculture areas while protecting private property rights and responsibilities.

Related Policies/Programs in Place

Local acequia associations and irrigation and conservancy districts currently have the authority to regulate water rights transfers to uses other than agriculture.

Types(s) of GHG Reductions

- CO_2: Conservation of agricultural lands retains the ability of the land to sequester carbon in soil and biomass.

Estimated GHG Savings and Costs per MtCO2e

- GHG reduction potential in 2012, 2020 (MMtCO2e): 0.1; 0.2
- Net Cost per MtCO2e: $62/MtCO2e
- Data Sources: The number of acres that moved from cropland, pasture, and rangeland categories to developed uses between 1982 and 1997 was obtained from the USDA Natural Resource Inventory (NRI). The amount of rangeland assumed to be pinyon-

juniper (see Option F1) was subtracted from this data. Agricultural land soil carbon data was taken from a study in *Soil Science* that compiled data for cultivated and uncultivated land with various soil types[29]. Estimates of soil carbon on rangeland in the southwest were obtained from the STATSGO/SSURGO soil organic carbon database.
Costs for agricultural land can vary widely from as low as $200/acre in rural areas without significant water supply to as much as $100,000/acre in prime locations with high development potential.[30] Costs were estimated for this option using a cost of $2,000/acre for conservation easement. This cost represents the nationwide average determined by the American Farmland Trust.[31]

- Quantification Methods: The number of acres of cropland/pasture (agricultural land) and rangeland converted to developed uses between 1982 and 1997 was divided by 15 years to give the average number of acres lost each year. The number of acres to be saved in 2010 and 2020 were estimated by multiplying the average rate for 1982-1997 by 20% in 2010 and 50% in 2020. The amount of CO2 emissions savings were estimated by assuming that for each acre lost to development, 10,000 sq ft (0.23 acre) losses 100% of the soil carbon. The remainder of the acre looses 25% of soil carbon.
- Key Assumptions: For each acre of land lost to development, 10,000 sq ft is assumed to loose 100% of the soil carbon. This area represents the area in buildings, streets, and other structures that cover the soil. A loss of 25% of the soil carbon is assumed for the remainder of the acre. These assumptions are based on engineering judgment.

Key Uncertainties

The main areas of uncertainty are the existing soil carbon stocks and the change in soil carbon when land is developed. Additional benefits would be achieved by retaining above ground carbon in preserved rangelands. No data were identified for quantifying these benefits.

Contributing Issues

- **Human and social issues:** The identification and preservation of agriculture land and farms/ranches will protect New Mexico's cultural resources and provide for open space amenity.
- **Environmental issues:** Preservation of agricultural land can reduce suburban sprawl, which decreases transportation-related emissions.
- **Economic issues:** 1) The promotion of value added products will help sustain NM agriculture. 2) Local tax bases can increase when farmers and ranchers participate in the development of value-added businesses to reap a higher percentage of the value of the food products. Accordingly, tax rates at the local level may need adjustment. Consideration of impacts on the local tax base must be considered during further policy development stages.
- **Political and regulatory issues:** none identified.

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[29] Mann, L.K. 1986. Changes in soil carbon storage after cultivation. Soil Science 142(5):279-288.
[30] Bob Findling, The Nature Conservancy, personal communication with H. Lindquist, CCS, June, 2006.
[31] American Farmland Trust, A National View of Agricultural Easement Programs, http://www.aftresearch.org/PDRdatabase/NAPidx.htm.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A9, Organic Farming

Policy Description

Increase acres of farmland using organic farming techniques which improve soil quality and eliminate the use of prohibited chemical fertilizers and pesticides. Organic agriculture significantly increases the organic matter in soil, which increases carbon sequestration in the soils. CO_2 emissions are also reduced because the manufacturing and transportation of prohibited chemical inputs, especially nitrogen fertilizer, have been eliminated, although some transportation is needed for organic inputs. Under some circumstances, with improved soil condition, there can be less irrigation water pumped, which saves on the emissions from energy generation as well as water usage.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to achieve a long-range goal of increasing organic-certified and non-certified-organic acreage to approximately 70% of the cropland used for vegetable and field crop production in the state by 2050.
  Note that there is overlap of this option with Option A6 on Conservation Tillage/No-Till. Both options increase soil organic carbon (sequestration of CO_2). Since the organic farming acreage can be thought of as a subset of the conservation tillage/no-till acreage, the organic farming acreage was subtracted from the conservation tillage/no-till acreage to remove double-counting of benefits. The benefits associated with this overlap have been adjusted in the summary table at the beginning of this appendix.
- **Timing:** The current acreage in New Mexico that is certified organic by the New Mexico Organic Commodities Commission at the beginning of 2006 is approximately 50,000 acres, the predominance of which at this time is ranchland for livestock, cattle, and sheep. By 2012, with sufficient support, the acreage could be at least 179,000 acres for transitioning to certified (a 3-year process), and another 173,000 by 2020. The certified production acreage could therefore increase to 352,000 acres by 2020 depending on drought impacts and the availability of water.
- **Parties:** NM Department of Agriculture, NMSU, NM Organic Commodities Commission, Department of Education, in cooperation with federal and non-governmental organizations**.**

Implementation Mechanisms

- Information and education
  - Conduct a series of workshops and farm tours to ensure Extension Agents and other agriculture professionals can teach effectively about how to transition to organic and how to do Carbon Farming (and Carbon Ranching, when appropriate).
  - Combined with the Buy Local Campaign:

        - Establish a requirement for a state teacher's credential to have 1 or 2 courses in the issue of climate change and agriculture and the utilization of school gardens, and nutrition, integrated into standard curricula.
        - Expand the existing programs: school gardens (mandatory in California), Farm to School, and Cooking with Kids programs in a schedule that by 2012 includes all public schools and a program to share curricula with volunteer private schools.
        - In high school vocational training, incorporate the expanding opportunities in agriculture, food processing including value-added, and food distribution.
- Technical assistance
    - Mentorship programs like California's that join established organic farmers with conventional farmers can successfully support transitioning.
- Funding mechanisms and or incentives
    - Institutional point system purchasing of state agencies in conjunction with the Buy Local Food program.
    - Transition support- tax breaks and incentives for farmers transitioning to organic systems.
    - Assistance for purchasing approved inputs such as pheromones with bulk buying to reduce user costs.
    - Buy-back programs for safe disposal of existing toxic chemicals.
- Codes and standards
    - For Local Food purchasing, an additional point system supporting a continuum from Integrated Pest Management to non-certified organic to certified organic.
- Market based mechanisms
    - Price premiums for organic are a major driver which can be enhanced by institutional point systems for purchasing.
- Pilots and demos
    - Farm tours on organic farms and mentorship programs.
- Research and development
    - No-till organic research is needed, which could be coordinated with research in other states.
    - Research on the best techniques for organic soils to save water.
    - Research and monitoring to verify the net GHG benefits associated with organic farming and higher SOC levels (potential for increase of N_2O emissions).
- Registry
    - Provide additional support for the New Mexico Organic Commodities Commission to expand promotion and transitional support for certification.

Related Policies/Programs in Place

None identified.

Types(s) of GHG Reductions

- CO_2: Organic farming significantly sequesters more carbon in the soils than conventional farming. New techniques are being developed for low/no-till organic farming. For every percentage point of organic matter increase, there is substantial increase in soil carbon (i.e. CO_2 sequestered). Organic farming also reduces emissions of CO_2 through the elimination of petroleum-based chemicals that have to be shipped from long distances. *[Note that in the analysis of benefits below, only the benefits associated with the increase in soil organic carbon have been quantified]*.

- N_2O: Savings occur through the elimination in the use of petroleum-based fertilizer that leads to emissions from soils. Note that research also indicates the potential for higher N_2O emissions as SOC levels increase (see Feasibility Issues Section).
- Black Carbon: To the extent that fossil-based diesel fuel is reduced (in the transport of chemicals), BC emissions will also be reduced.

Estimated GHG Savings and Costs per MtCO2e

- GHG potential in 2012, 2020 (MMtCO2e): 0.21; 0.40
  GHG reductions associated with increases in soil organic carbon only; other potential GHG benefits from lower chemical inputs have not been quantified. The overlap of benefits between this option and Option A6 (Conservation Tillage/No-Till) have been accounted for in the summary table at the beginning of this appendix.
- Net Cost per MtCO2e: $0.54
- Data Sources: Cropland in New Mexico has a wide range of soil organic carbon (SOC) content and the increases from organic farming will also have a range of increases depending on factors such as existing conditions, soil type, weather, crops produced, and tillage practices. To get a reasonable idea of the carbon sequestration possible by organic farming we look at base SOC contents of 0.5% and 1.5% and SOC increase of 20% and 50%. To come up with one figure for comparison with the other agricultural options we use the average of the SOC base content and percent increase. We also assume that 70% of the cropland used for vegetables and field crops are converted to organic. That acreage is 352,000 acres out of the total cropland harvested of approximately 1,000,000 acres. We assumed an S-curve penetration rate for organic farming (slower penetration in early years, followed by rapid increase in midyears and leveling out in latter years).
  For cost data, an estimate by Pimentel[32] of $8.90/acre in the difference in revenue between conventional and organic acreage (conventional being higher) was used to estimate the costs of transitioning from conventional to organic practices.
- **Quantification Methods:** The amount of CO_2 sequestered/acre was computed from the assumed base SOC percentage (0.5% and 1.5%) and the assumed percent increase in SOC (20% and 50%), and assuming a bulk density of 1,000 tons of soil/acre. The range of CO_2 sequestered is shown below:

[32] Pimentel, 2005, *BioScience*, July, 2005.

Base SOC%	Base tons CO2/acre	Tons CO2/acre sequestered	
		20% Increase in SOC	50% Increase in SOC
0.5	18.3	3.7	9.2
1.5	55.0	11.0	27.5

The average of these four variables is 12.8 tons CO2 sequestered/acre. This is remarkably similar to another analysis conducted by the TWG using assumptions of 1.7% base SOC and a 20% increase in SOC and resulting in 12.5 tons CO2 sequestered/acre.
By 2020, the total CO2 sequestered on 352,000 acres would be 4.1 MMtCO2e (35% organic or halfway to the 2050 goal of 70% organic). The amount sequestered in 2012 was computed from the S-curve penetration rate and equals 0.21 MMtCO2e. The amount sequestered in 2020 is estimated to be 0.40 MMtCO2e.

- **Key Assumptions:** The base SOC and percent increases are assumptions but within the parameters expected for New Mexico. Until a much more complete analysis is performed these numbers are considered reasonable. The acreage assumed to be converted to organic practices is also a key assumption and it would take an economic analysis coupled with a survey of farmers about the rate of adopting new practices to give a more accurate number. The cost data by Pimentel are also not specific to southwestern agricultural practices.

Key Uncertainties

As stated in the key assumptions above, SOC increases for organic farming practices holds the largest uncertainty. The amount of acreage that can be transitioned to organic farming and the cost data (revenue differences between organic and conventional practices) is also uncertain. Additional benefits from organic practices have not been quantified due to a lack of data. These include reductions in GHGs associated with the manufacture and transport of synthetic fertilizers, herbicides, and pesticides. There could also be lower water consumption associated with organic practices (and associated GHG emissions for pumping water); however the TWG was unable to find data to demonstrate this benefit.

Contributing Issues

- **Human and social issues**
  - The values of traditional agriculture in New Mexico can be supported.
- **Environmental issues**
  - The elimination of chemical pesticides and herbicides yields improvements in water quality. The California State Water Resources Control Board conducts programs to convert farmers to organic.
  - Pesticides and herbicides can drift, impacting human health, killing beneficial organisms, and harming wildlife.
  - New research comparing organic fertilizing practices (using manure) to conventional (synthetic) practices has shown the potential for lower rates of nitrate

leaching to groundwater. Emissions of N2O were similar between organic and conventional practices.[33]

- **Economic issues**
  - New Mexico's Secretary of Agriculture has declared that more New Mexico farms need to transition to organic to meet demand. National demand for organic products is growing at rapid rates, with the demand exceeding production. Converting to organic provides increased opportunities for farmers, processors, and distributors of organic products.
  - Organic products garner a premium in the marketplace, and the added income helps farmers be sustainable. In some areas, the only farms that are doing well financially are the organic farms.
  - Carbon sequestration in organic farming improves soil quality, allowing for better retention of water, critically important under drought conditions.
  - With increased prices of fossil fuels, the use of petroleum-based chemical inputs is becoming more expensive. The elimination of petroleum-based inputs will yield an increasing economic advantage over the years.
- **Political and regulatory issues:** none identified.

Feasibility Issues

Research has indicated a potential for increased N2O emissions as soil organic carbon levels increase.[34] Additional study and field work on NM cropping/soil systems will be needed to verify the GHG reduction potential estimated in this policy analysis.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

[33] Kramer, SB et al, "Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils", *Proceedings of the National Academy of Sciences*, v103, no. 12, 4522-4527, March 21, 2006.
[34] Li et al, "Carbon Sequestration in Arable Soils is Likely to Increase Nitrous Oxide Emissions, Offsetting Reductions in Climate Radiative Forcing", *Climate Change*, (2005) 72: 321–338.

A10, Programs to Support Local Farming/Buy Local

Policy Description

Local food is a cross-cutting issue, with potential to reduce enormous amounts of transportation and manufacturing emissions. The food system in the United States accounts for approximately 15% of the total energy consumed. [35] While increasing amounts of our food comes from overseas with huge, unsustainable embodied energy, even U.S. foods travel thousands of miles before reaching a grocery store- flour in a packaged product over 5,000 miles, with 6 trips between the field and the store. [36] These figures do not include the additional backhauling miles. Currently locally grown foods typically leave the state. Increasing the percentage of "local food for local people" can significantly reduce fossil fuel use and its associated GHG emissions.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to increase the amount of food consumed in the state to be produced locally. The amount of local food consumed in New Mexico is estimated to be about 3 percent, and organizers of farmers' markets suggest that 35% of our food could be produced and consumed locally. In the longer range, with some commitment, we could increase this further**.**
- **Timing:** From today's approximate 3 percent consumption of local food (much of this is dairy products), by the year 2012, we need to build the systems to shift to 8 percent, and to 25% by 2020. Projections to 2050 would depend on the degree that inevitable increased fuel costs forces rises in food prices shipped long distances, and the number and magnitude of extreme weather threats to global and national food supplies. These factors could accelerate the commitment for higher levels of utilization of local farmers' products, possibly leading to 50% or more of New Mexican food being produced and consumed in state.
- **Coverage of Parties:** NMSU College of Agriculture and Home Economics, and NM Department of Agriculture, NM Public Education Department, NM Environment Department, state institutions in cooperation with federal and municipal agencies, and non-governmental groups.

Implementation Mechanisms

- Information and education
  - Have the Governor perform television Public Service Announcement's to promote local food (done previously in California) for the BUY LOCAL FOOD campaign.
  - Establish a requirement for a state teacher's credential to have 1 or 2 courses in the issue of climate change and agriculture and the utilization of school gardens, and nutrition, integrated into standard curricula.

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[35] This is probably too low since the data are 20 years old and food miles have increased drastically. http://www.cias.wisc.edu/pdf/energyuse2.pdf#search=%22Hendrickson%20Energy%20use%22

[36] From the database of AgInfoLink, Global, Inc., http://www.organicconsumers.org/2006/article_711.cfm

- Expand the existing programs into a continuous K-12 program: school gardens, Farm to School, and Cooking with Kids programs in a schedule that by 2012 includes all public schools and a program to share curricula with volunteer private schools.
- In high school vocational training, incorporate the expanding opportunities in agriculture, food processing including value-added, and food distribution.
- Develop a labeling system for supermarkets to identify local foods that travel less than 500 miles
- Conduct a campaign with public and private sectors on the benefits and importance of supporting local food systems. Even some churches promote local food.

- Funding mechanisms and or incentives
  - Create compensating or GRT tax credits for corporations purchasing an incremental minimum of local food purchases.
  - Create tax credits for the establishment of local production projects which would phase out over time
  - Support the Farm to Cafeteria program by provide an additional 10 cents per meal for purchasing local fresh fruits and vegetables for at least 2 lunch meals a week
  - Support continued development of NM Farmers' Markets
  -Create a program "Safe Local Food for Strong Local Economies" for shorter food chains, integrated with health, education, land-use and transportation agencies which will increase food security, increase food-based businesses which support the local economy, and protect environmental quality
  -Develop urban agriculture projects that utilize composted organic wastes and waste water from the city to grow food produced by students getting credit, local volunteers, offenders assigned to community service, able recipients of food assistance, people wanting their own plots, and farmers. Some cities have three types: people wanting to have a garden plot for home use, for profit CSA's whose members pay, and community gardens that provide food for food banks, shelters, low-income families and worked by those who have incentives and mandates to help produce food for others.
  -Conduct training in season extension, organic soil building, water efficiency, safe pest control, and organic certification.
  -Overcome obstacles including providing insurance programs, post-harvesting handling systems, and transportation and storage facilities.
- Voluntary and or negotiated agreements
  - FARM TO RESTAURANT: Expand the existing program for voluntary commitment from corporations (restaurants, hotels, etc) to buy increasing percentages of local food.
  - FARM TO STORE: Work with grocery stores to increase local food purchasing by eliminating price barriers such as slotting fees and by promotional campaigns for local foods. If voluntary arrangements are not successful, regulations should be considered.
- Codes and standards
  - BUY LOCAL FOOD CAMPAIGN: The Governor's Executive Order to all state institutions (state buildings/cafeterias, schools, universities, prisons, hospitals, etc.) will be to purchase an increasing amount of local food according to a table for minimum purchases, creating the demand side for local food. The state institution local purchasing needs to, at a minimum, parallel the state goals for increase in local consumption of local food.

- To prepare the local supply side, the Governor shall notify the Board of Regents that building the local food systems is a major priority. A working session with the Board of Regents on climate change and sustainable agriculture will initiate the new campaign, setting clear goals. The College of Agriculture and the Department of Agriculture will conduct an assessment of the requirements, define and plan the educational needs. Topics will include carbon farming and carbon ranching methods, and the range of sustainable agriculture, from the initial IPM through to certified organic. Also there will be support for implementing solutions to defined needs such as increased cold storage, allowing improved distribution. Research needs also must be met to assist farmers in improved methods for meeting the increased demands.

-Review local, county and state regulations to both add support for local production, processing, storage, distribution and sale of local foods and to remove or adapt barriers to same.

- Pilots and demos
  - Expand the existing Farm to Table and Farm to Cafeteria programs to conduct demonstrations projects at schools, colleges and other public facilities promoting local food production and processing and local food utilization.
  - Create an incubator organic farm program to support development of new farmers to replace the current aging farmer population.
  - Establish model Urban Agriculture projects based on U.S. urban projects that include greenhouses and utilize treated waste water and composted wastes for waste reduction and reduction of out of state inputs.
- Research and development
  - Conduct market surveys to facilitate customer demand for increased local food.
  - Conduct research to document total miles and energy used for a selection of food products, followed by public education.
  - Conduct monitoring of in-state food production & consumption versus out of state food importation.
- Reporting
  - Assess the need for reporting mechanisms to assess program progress.

Related Policies/Programs in Place

None identified.

Types(s) of GHG Reductions

- CO_2: Savings occur as a result of shorter haul distances and modification of freight modes (air to ground), which would reduce diesel fuel use. Methane and nitrous oxide emissions from fuel combustion are also reduced.
- Black Carbon: Reductions in diesel fuel use result in a reduction in BC emissions.

Estimated GHG Savings and Costs per $MtCO_2e$

- GHG reduction potential in 2012, 2020 ($MMtCO_2e$): 0.32, 1.1
- Net Cost per $MtCO_2e$: $0.17

The method we used was based on a study conducted in the Netherlands using both process analysis and input-output analysis. The results indicate that a large fraction of the benefits are realized by offsetting imports of processed foods by producing and processing these foods in state.
• Data Sources: GHG emissions per unit cost for several food categories from a 1998 Dutch study[37] were used along with data on NM food expenditures.[38]
• Quantification Methods: *Method* - Emissions per unit cost from the Dutch study were multiplied by the applicable estimate of NM food expenditures to estimate CO2e emissions. Because the study authors pointed out that 25% of the CO2e was associated with CH4 and N2O emissions from livestock and crop production, the total CO2e was adjusted downward by 25% to better reflect the emissions associated with transport and processing of food. The estimated emission reductions were then estimated by multiplying the emissions by the fraction of food offset by local food production, 8% in 2012 and 25% in 2020).
• Key Assumptions: Food production and processing emissions in the Netherlands are similar to those in NM. Costs for different types of food are similar in these two areas.

Key Uncertainties

The applicability of the GHG profile for the Netherlands for use in NM is a significant uncertainty. Further, the use of cost data to derive CO2e emission estimates for these two different areas provides an additional degree of uncertainty.

Contributing Issues

- **Human and social issues**
  - Improved public health from increased consumption of fresh local foods, including a higher percentage of produce, helping reduce obesity, diabetes and other health issues.
  - Amplify the benefits to the health of children begun with the Governor's banning of junk food in schools, and the Wellness Policies that have been established.
  - Increased food security, especially when families are allowed to have plots in community gardens and food banks can be supplied with fresh, nutritious garden food
  - Preservation of open spaces utilized for farming.
  - Urban agriculture can provide the fewest food miles, provide jobs right next to where people live (no commuting required), take advantage of reusing water (important in droughts), and reusing wastes that have been composted. Vacant city lots, rooftops, and other areas can provide a significant amount of food production.
  - Reduction of waste: both when safe solid wastes are composted and return to food producing areas, and when the heavy packaging required for long-distance travel is avoided. Local foods can reuse containers repeatedly.
  - Promote cultural heritage. Both Native and Hispanic cultures were self-sufficient in food production, and retaining some aspects of those ties has cultural meaning
  - Preservation of open spaces utilized for farming.
- **Environmental issues**

[37] Kramer et al, "Greenhouse gas emissions related to Dutch food consumption", *Energy Policy*, 27, 203-216, 1999.
[38] http://www.ams.usda.gov/statesummaries/NM/MSAData.htm.

- Today's food has enormous hidden embodied energy in its travel and processing from farm to table in current industrial food systems, typically traveling from one to over five thousand miles for food from the United States, and 8,000 miles or more for imported foods. Backhauling- trucks returning empty- can add another 25% to 50% more miles. With only approximately 10% of our foods being fresh produce, the embodied energy from heavily processed, heavily packaged foods is a major contributor to greenhouse gases. Estimates of 20% of total emissions are from our centralized food systems. Local food can not only reduce food miles but also food processing and packaging. Increasing the percentage of "local food for local people" can reduce significant amounts of fossil fuel use and its associated GHG emissions with greatly reduced miles, less packaging and less processing.
- New Mexican's spend about $6 billion dollars for food each year. About 60% is food at home and 40% away from home. Fifty percent of those expenditures are for meat, fresh vegetables, bakery products, and poultry. Cattle represent the second largest source of cash receipts for New Mexico agriculture but only six percent of the beef consumed in the state is slaughtered here. Cattle can travel 3,500 miles in the "chain" from birth to a New Mexico supermarket. Wheat is the major food grain grown in New Mexico yet most of the wheat products are produced out of state. Wheat can travel over 5,000 miles from field to a New Mexico supermarket, when it is flour in a packaged product. Hence, there are substantial CO_2e emissions associated with out of state fresh and processed food transport, processing, and packaging.
- Local food can not only reduce food miles but also food processing and packaging. Increasing the percentage of "local food for local people" can reduce significant amounts of fossil fuel use and its associated GHG emissions. Local food also increases food security, and can buffer impacts of rising fuel costs and possible fuel shortages.

- **Economic issues**
  - Increased job opportunities in producing, processing, distributing, and selling food.
  - Strengthened local economies and reduction of local dollars leaving the state.
  - Increased food security, especially for low-income families who will suffer disproportionately when food prices rise due to extreme weather events and to increased prices for fossil fuels. Local food can buffer travel costs.
  - Increased local business opportunities, including for food processing.
  - Preservation of disappearing farmlands with improved farm income through specialty crops, institutional contracts, and higher profits through improved integration of the entire chain.
  - Cost: more reliance on local production may reduce the variety of foods available to all consumers throughout the year.
  - Cost: (potential cost): decrease in food security due to local drought conditions and/or local/regional climatic variation—supplemental food supplies and emergency plans can be developed for the proportion of food from local sources.
- **Political and regulatory issues:** none identified.

Feasibility Issues

None identified.

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

A11, Biodiesel Production

Policy Description

Provide incentives for the production of biodiesel from crops or waste vegetable oil. Biodiesel use will offset diesel fuel derived from fossil fuel and will lead to decreased fossil fuel-based CO2 emissions.

This option is linked with TLU Option 6 on Biofuels Consumption. This option seeks to achieve incremental GHG benefits beyond the TLU option by promoting in-state production of biodiesel using feedstocks with greater GHG benefits than the likely business as usual national production methods. NM consumption of biodiesel produced in-state will produce better GHG benefits than biodiesel obtained from a national market due to lower embedded CO2 associated with transportation of biodiesel from distant sources.

Policy Design

- **Goal levels:** The CCAG recommends that New Mexico adopt programs to increase the amount of biodiesel produced within the state. The goals are to produce enough biodiesel to meet 10% of NM diesel consumption by 2012, 20% by 2020, and 50% by 2050. This option is paired with TLU Option 6, which targets methods to increase biodiesel consumption in the state. Optimum GHG benefits are achieved when the biodiesel consumed in the state is produced in-state. This is because less fuel is used to transport crops to processing facilities and to transport fuel to dispensing facilities.

  With BAU production very low in the state, increased use of locally-produced biofuels should be relatively easy to attain. New production of biodiesel in New Mexico is targeted by several private companies. For example, ARES Corp announced a 15 million gallon/year biodiesel plant that will be operating by mid-2007 in Clovis (N Mex, 9/11/06). Feedstocks proposed for immediate conversion to biodiesel are soybeans and waste vegetable oil; with current research into other feedstocks such as algae that produce more vegetable oil, the New Mexico production goals stated here should be met. A preliminary assessment of in-state crop potential for biodiesel production is provided in the Feasibility Issues section below.

  This policy seeks to provide incentives for producing vegetable oil crops for biodiesel production at a level which will replace 10% of New Mexico's petroleum diesel consumption by 2012, increasing to 20% by 2020. A combination of readily available waste vegetable oil, increased use of crops such as soybeans and other crops conducive to cultivation in NM, and research and development of algae to biodiesel technology will help meet this schedule.

  Further into the future, the in-state production volume necessary to continue the support of the TLU TWG's renewable fuels proposals is targeted. This creates the need for 50% fossil diesel offset by 2050. These targets are subject to adjustment up or down based on several economic and environmental factors including the sustainability of using New Mexico crops for biodiesel at the expense of other industries (e.g., dairy, other crop producers); the availability, economical transportation, and efficient conversion of waste vegetable oil; and development and deployment of other technologies for biodiesel production (including Fischer-Tropsch biodiesel from cellulose and algae biodiesel production technology). Additional objectives of this policy are to increase biodiesel production to the above levels without a negative impact to agricultural interests. Biodiesel production and substitution into the New Mexico fuel supply is an important issue in decreasing carbon impacts on the environment and moving to a more independent energy position. However, there is increasing evidence that the magnitude of local biodiesel production is not the only consideration in the larger scheme of environmental stewardship (e.g., Hill et al, 2006; PNAS 103:11206-11210). Life-cycle energy inputs, outputs, costs, and benefits (economic and sociological) must be analyzed in order to claim legitimate energy independence.

- **Timing:** In-state production equivalent to 10% of New Mexico's petroleum diesel consumption by 2012, and increasing to 20% by 2020. The goal for 2050 is 50% of projected fossil diesel consumption.
- **Coverage of Parties:**
  New Mexico Energy, Minerals, and Natural Resources department should lead the evaluation of biodiesel consumption and projections into the 2012 to 2020 time-frame. Energy, Minerals, and Natural Resources should also lead the development of the necessary infrastructure for production and distribution of the locally-produced biodiesel.
  New Mexico Department of Agriculture (NMDA) and New Mexico Agricultural Extension Services (NMAES) should lead the evaluation of appropriate crops and also balance the resource used to grow new crops for biodiesel. NMDA and NMAES must work with competing consumers of agricultural crops to determine the best use of this valuable resource. For example, soy growers will be in high demand if biodiesel conversion nets more income than supplying the dairy industry, and these demands will need to be balanced. NMDA and NMAES would also lead the transition to crops for fuel that would be needed to make the proposed plan effective.
  The above agencies and New Mexico universities should take the lead on investigating the potential for alternative biofuel production processes, including algal production of biodiesel (including pilot scale facilities). Active engagement by state government of private agricultural businesses and private fuel production interests will be needed.

Implementation Mechanisms

Implementation shall be through private development of the various technologies to produce biodiesel without significant negative economic impact to existing agricultural interests and to ensure energy independence in the State. Private industry should be encouraged to build and operate within New Mexico using local resources and providing locally-available product. For example, the ARES Corp. proposed a new biodiesel plant in Clovis that was likely attracted to the area by city government, potential within the state, a solid resource base and customer demand, and, possibly, tax incentives. New Mexico state government should actively evaluate the benefits and costs of incentive programs for new businesses entering the state for biodiesel production [For example, the ARES plant apparently plans to use soybean oil to produce biodiesel, which is not produced in the state and would likely need to be transported 1,000 miles or more to the site]. The costs should include the impacts to the environment as a whole as the fuel production cycles change, also the impacts to local and regional agricultural businesses (farming and dairy) as the demand for feedstock crops increase. In short, biodiesel production should begin only after the life-cycle of the fuel source is considered in economic and environmental terms.

Implementation will likely require that agricultural feedstocks such as soybeans or other oil-producing crops be produced on land already in cultivation. Some conversion of idle land to new cropland could also occur which will decrease the overall carbon benefit to be gained from producing biodiesel [as soil organic carbon and soil nitrogen (as N2O), both GHG sources, will be lost to the atmosphere when the land is converted to new cultivation].

Related Policies/Programs in Place

The renewable fuels standard from the Energy Policy Act of 2005 requires 7.5 billion gallons of renewable fuel in the U.S. by 2012, including biodiesel.

Types(s) of GHG Reductions

- CO2: CO2 emissions are reduced by offsetting the use of petroleum-derived diesel fuel. Overall energy required to produce biodiesel (e.g., life-cycle costs and benefits) need to be compared to the energy requirements of producing fossil fuel diesel in order to completely assess the CO2 benefit of biodiesel production and substitution. From a recent report (Hill et al., 2006)[39], 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 CO2e of biodiesel compared to importation of out of state vegetable oil supplies.
- Black Carbon: BC emissions could be lower between biodiesel and fossil diesel, based on some recent test data for particulate matter; however, the differences are probably negligible (information on the BC content of particulate emissions from biodiesel combustion might not be available).

Estimated GHG Savings and Costs per MtCO2e

- GHG reduction potential in 2012, 2020 (MMtCO2e): 0.12; 0.31
- Net Cost per MtCO2e: $0
- Data Sources: Data from the NM Inventory & Forecast was used to quantify the benefits of offsetting fossil diesel consumption with biodiesel produced within the state. Fossil diesel consumption estimates are:

Year	Amount (1,000 barrels)
2007	11,870
2012	14,158
2020	18,771

The policy design calls for 10% of the fossil diesel consumption to be offset by 2012 from in-state production and 20% offset by 2020.

[39] 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.

The CO2e emission factor used in the inventory and forecast is 10.04 Mt/1,000 gallons. A new study on lifecycle GHG benefits for biodiesel production and use was used to estimate the CO2e reductions for this option (see Quantification Methods below). Although this study covered biodiesel production from soybean production (which might not be the crop of choice in NM), it is the best study identified for estimating lifecycle benefits.

- Quantification Methods: The amount of fossil diesel offset in each year was calculated from the diesel consumption estimates and the fraction to be offset in that year. The fossil diesel offset quantities (biodiesel production quantities) are shown below:

Year	Amount (MMgal)
2012	59
2020	158

As with Option A-3 covering ethanol production, this option is also linked to TLU Option 6, which provides mechanisms to increase biofuels consumption in the state. For TLU Option 6, the fossil diesel offset quantities were multiplied by the fossil diesel CO2e emission factor and the lifecycle GHG reduction for biodiesel (41%) to estimate the GHG reductions in each year. The lifecycle GHG reduction, taken from a recent study published in the Proceedings of the National Academy of Sciences, takes into account emissions associated with biodiesel production, processing, and transport.[40]

For this option, the incremental benefit of in-state production is derived from the lower embedded GHG content of biodiesel feedstocks (vegetable oil) avoided from having to transport the feedstocks from their likely source region. For this assessment, the likely source regions for soybean or canola oil are the U.S. mid-west or northern plains regions. Using South Dakota as a potential source region, rail transport would require shipments to central New Mexico of about 1,200 miles.[41] Rail fuel consumption is about 400 ton-miles/gallon.[42] The density of vegetable oil is about 3,700 tons/MMgal. From these inputs, a GHG emission rate of 112 MtCO2/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. The results are shown below.

Year	Biodiesel Imported (MMgal)	Embedded CO2 (Mt)
2012	59	3,276
2020	158	14,193

Additional and potentially more significant GHG reductions can be achieved from biodiesel produced with in-state feedstocks to the extent that these feedstocks are produced with lower embedded GHG (assuming soybean oil is the baseline). As shown in the Feasibility Issues section below, sunflower yields about 80 gal/acre of oil and canola yields 127 gal/acre

[40] Hill, J et al, "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels", *Proceedings of the National Academy of Sciences,* v103, no. 30, 11206-11210, July 25, 2006.
[41] U.S. National Atlas, http://nationalatlas.gov/natlas/Natlasstart.asp.
[42] U.S. National Atlas, http://nationalatlas.gov/articles/transportation/a_freightrr.html.

compared to soybean yields of about 48 gal/acre. Research on oil production using algae has shown potential yields of 4,000 gal/acre.

Using the data from the Hill et al (2006) study cited above, the CO2e emissions associated with on-farm soybean production are 3,849 Mt/MMgal. Assuming similar cultivation practices (including fossil energy consumption) for other oil crops, production of sunflower oil would produce 2,309 MtCO2e/MMgal [3,849 Mt/MMgal x (48 gal soybean oil/acre ÷ 80 gal oil/acre)]. Similarly, for canola production, the CO2e emissions would be 1,455 Mt/MMgal.

Assuming equal amounts of sunflower and canola production in NM instead of soybean production to produce the vegetable oil targeted by this policy, the lower GHG emissions associated with these crops would save 0.12 MMtCO2e in 2012 and 0.31 MMtCO2e in 2020. Conceivably, much higher emission reductions could be achieved by production of biodiesel with algae. The Feasibility Issues section below provides additional details on the vegetable oil production potential in NM.

- Key Assumptions:
  - New production of crops for biodiesel on previously uncultivated land (e.g. CRP acres) can be done without significant losses of soil carbon and additional N2O emissions.
  - Oil production will occur using crops that are more productive than soybeans or otherwise have much lower embedded CO2e. Other biodiesel feedstocks (e.g. methanol or ethanol) could also be produced from local in-state feedstocks resulting in lower GHG emissions.
  - Distance from source of feedstock to production facility ("farm-to-fuel pump") should be kept small in order to maximize the GHG benefit of biodiesel production.
  - Crop production for fuel will not adversely impact other agricultural industries such as dairy. This assumption must be tested in the life-cycle development of biodiesel sources.

Key Uncertainties

The GHG benefits estimate was developed based on the embedded GHG difference between soybean production and two more productive crops (for oil production). Different crops such as other oil producing seeds and plants or algae might be better suited for vegetable oil production in NM, and these feedstocks could produce biodiesel with lower or higher GHG benefits. Also, the lifecycle GHG benefit for biodiesel assumes that the fuel is derived from crops already in production. Converting intact ecosystems to production would reduce the GHG benefit by oxidizing soil carbon and potentially increasing N2O emissions. The source of oil as a feedstock for conversion to biodiesel is a critical issue. Soybeans are currently the primary source of vegetable oil used for biodiesel production, but oil production can improve with other crops such as jojoba or mustard. Algae are a possible source of oil and are the highest potential producer (and potentially well-suited for southern NM), but research and development is required before oil from algae is viable.

Contributing Issues

- **Human and social issues:**
  - Competition for feedstock between the energy sector (biodiesel producers) and agricultural sector (dairy, soy oil producers) must be optimized to the benefit of each industry. New Mexico has grown into one of the leading dairy producing states in the country in a short time, and could experience similar growth in fuel production. These potentially competing demands should be balanced.
- **Environmental issues:**
  - Biodiesel is thought to lower emissions of some criteria air pollutants (e.g. sulfur dioxide, particulate matter, volatile organic compounds), but could result in slightly higher emissions of nitrogen oxides.
- **Economic issues:**
  - Use of crops for biodiesel at the expense of other industries (e.g., dairy) could be detrimental to the State's economy and that of local farmers and dairy producers and needs to be monitored.
- **Political and regulatory issues:**
  - Tax and financial incentives to build and operate biodiesel production facilities are attractive. However, state and local governments as well as private groups should consider factors that include social issues and economic issues as listed above as new policies are considered.

Feasibility Issues

Additional research is needed in NM to identify the most appropriate crops for vegetable oil production, areas of the state suited for production, and the vegetable oil production potential in the state. Current information on new biodiesel production suggests that 2.7 to 3.0 gallons of biodiesel can be derived from each gallon of process water that is needed using a soybean feedstock. The water will be required from local sources, and thus its supply and potential duration should be a feasibility issue in evaluating the benefits and costs of particular plants and their locations.

Applicability of new biodiesel technology, such as algae production should be considered as a potentially lucrative way to produce vegetable oil for conversion to biodiesel.

Energy efficiency gains at all levels of fuel production should be evaluated and factored into the life-cycles of biodiesel production in New Mexico. Life-cycle modeling from production of crops to use in the fuel supply should be the driving model to evaluate total environmental and economic costs and benefits of all fuel production technologies.

The TWG prepared a preliminary assessment of vegetable oil production in the state. For this assessment no conversion of existing crop land to additional oil production was assumed. The TWG assumed that half of the expiring CRP acreage (250,000 acres) as well as 50,000 acres from the Navajo Irrigation Project would be converted to active oil crop production. For these 300,000 acres, the potential annual oil production is summarized in the table below.[43]

[43] Sources: Oilseed yields: Greg Pahl, 2005, *BioDiesel*, Chelsea Green Publishing, White River Junction, VT. Tyson, K. S., et al., 2004. *Biomass Oil Analysis: Research Needs and Recommendations*, National Renewable Energy Laboratory, NREL/TP-510-34796.

Crop	Oil Yield (MMgal)	Comments
Soybeans	14.4	Yield is 48 gal/acre
Sunflower	24.0	Yield is 80 gal/acre
Canola	38.4	Yield is 127 gal/acre
Algae	150 – 1,200	Yield is 500 to 4,000 gal/acre

As shown in these results, significant additional acreage will need to be brought into new vegetable oil production to meet the in-state production goals of this policy option, unless new crops/technologies such as algae production are successful. Even the 2012 goal of 59 MMgal could not be met with 100% planting of the 300,000 acres with canola. Hence, the support of research and development for new crops and production technologies is an extremely important aspect of this policy option. For example, jatropha plantations could produce 250 gal/acre.[44]

Status of Group Approval

Pending

Level of Group Support

Pending

Barriers to Consensus

Pending

Sheehan, J., et al., 1998. *A Look Back at the US Department of Energy's Aquatic Species Program: Biodiesel from Algae*, National Renewable Energy Laboratory, NREL/TP-580-24190.

[44] http://www.jatrophabiodiesel.org/index.php.