Expanding Bioenergy Crops to Non-traditional Lands in Michigan
FINAL REPORT

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MICHIGAN STATE UNIVERSITY | Extension

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Introduction

This project builds on Phase I, "Exploring the Feasibility of Growing, Harvesting and Utilizing Bioenergy Crops on Non-traditional Land in Michigan." The report, released on November 12, 2010, included a detailed analysis of the potential acres of non-traditional land available and useable to grow bioenergy crops on freeway right-of-ways, airport and vacant urban lands. It also included an economic analysis of potential crops that can be grown on these marginal sites. In partnership with the Michigan Department of Transportation, regulations and safety issues were identified along with other potential hurdles to utilizing these lands.

Specific objectives for this project are listed below:

Task 1: Expand Partner Network and Linkages

A cross section of public and private sector entities will strengthen this project by offering complementary skills, resources and linkages. Industry representatives include bioenergy crop experts from all stages of the supply chain, production though processing, and both existing and new customers, linking bioenergy producers to customers to increase the production and use of bioenergy.

Task 2: Bioenergy Crop Production on Roadway Right-of-Ways

Expand the growth and use of bioenergy crops (switchgrass and canola) for bioenergy utilization at Power Plants, residential and farm heat, farm equipment and transportation vehicles.

Task 3: Bioenergy Production and Use at Michigan Airports

Increase airport transportation use of bioenergy crops (Oriental mustard and canola utilized for biofuel) through on-site airport biofuel production and use at Detroit, Grand Rapids and Muskegon airports.

Task 4: Expand Bioenergy Crops Grown in Urban Areas

Expand bioenergy crop production of switchgrass and canola at Flint urban areas on vacant and abandoned lands to supply local Genesee Power plant utilization.

Task 5: Expand Bioenergy Crops Grown on Marginal Farmland

Ramp up and diversify farm scale bioenergy feedstock crops to include additional oilseed crops, such as canola and Oriental mustard to supply on-site farm use biofuels.

Task 6: Preprocessing Bioenergy Crops.

Purchase a hammer mill and pelletizer to grind and pelletize switchgrass harvested from roadways and urban areas. Pellets will be delivered to the MSU Power Plant and Genesee Power Station (Mid-Michigan Recycling). An extruder/biodiesel unit will extract oil from the Oriental mustard and canola harvested from roadways, farmlands and airports. Oil will then be used to create biodiesel via the biodiesel production unit and utilized on site. The Power Alternative (TPA), Warren, Mich., will process some of the seed from the farm sites.

Task 7: Energy and Economics

The MSU Product Center will evaluate the project. A project summation will include production, economic data, energy use and savings.

The knowledge learned from Phase I was used to develop Phase II. Demonstration sites were established on highway right-of-ways (ROW), airports, urban lots and farm-scale sites. These sites were used to verify the production and economic data presented in Phase I. Phase II also examined pelletizing and extrusion of oil from oilseed crops. Phase II was designed to set up Phase III, which will establish a biomass supply system that is sustainable and economical. Phase II took the next step to demonstrating the biomass production system. It is intended that Phase III (next step) will look more broadly at the supply chain and devising a system that connects producers of biomass with the end user (processor).

Phase I: Determine feasibility of production (Project #BES 10-60, January – August 2010)

Phase II: Demonstrate bioenergy production and conversion technology that addresses key issues and validates outcomes described in Phase I and provide preliminary data on pre-processing to be used in Phase III (Project #BES 11-01, October 2010 – February 2012)

Next Step (Phase III): Develop the biomass supply chain including harvest, storage, handling and logistics (USDA-AFRI Sustainable Bioenergy Coordinated Agricultural Project, submitted December 15, 2011). The MSU-led project could bring the expertise to the table to develop the supply chain. Additional resources are needed to evaluate the feasibility, design and construction of the facility, and deploy the renewable energy production industry. We will need to find industry partners to develop the process technology and logistics of converting the biomass to a drop in fuel.

TASK 1: Expand Partner Network and Linkages

A cross section of public and private sector entities were convened on three occasions to strengthen this project by offering complementary skills, resources and linkages. Industry representatives included bioenergy crop experts from all stages of the supply chain—production through processing—both existing and new customers, linking bioenergy producers to customers to increase the production and use of bioenergy. Members of the Partner Network and their affiliations are listed in Table 1.

This group provided valuable insight that guided the development and implementation of the project. Face-to-face meetings in combination with conference calls were held in January 2011, June 2011 and November 2011. Items discussed included project goals, management, economic development potential, identification of additional partners, regulatory compliance, related national initiatives and economics of production/processing.

Partners in this project are interested in continuing to meet after the grant is completed. Project Partners are interested in moving forward with Phase III, pending additional funding. They identified several issues that need to be further explored related to production of bioenergy crops on non-traditional lands, including the following:

- Production challenges of bringing lower productivity soils into production including soil fertility, drainage, water holding capacity and topography.
- Economic evaluation of conversion processes and related bioenergy and bioproducts is needed. Transesterification, fast pyrolysis, gasification and other conversion processes are technically feasible processes. Each method provides alternative feedstocks and capital costs for processing facilities.
- Utilization of urban parcels has potential to supply bioenergy, but has challenges with access; smaller parcels require smaller equipment, which drives up the cost per acre to produce bioenergy crops.
- Financing conversion/processing facilities will be a challenge. Government, airports and airlines do not have extra capital to invest right now. Linkages need to be made to seek out sectors that have investment capital.

Reports from the project management team to each Partner Network meeting can be found in Appendices A, B and C.

Table 1. Partner Network members and their affiliation.

Name	Organization
Steve Barker	Air Transport Assoc. of America
Dale Feldpausch	Capital Region Airport Authority
Steve Montle	City of Flint
Rich Altman	Commercial Aviation Alt. Fuels Initiative (CAAFI)
Marc Kemper	Delta Airlines
Costa Apostolakos	Delta Airlines
Dave Blakeny	Farmer
Ernest Gubryl	Federal Aviation Administration
Christina Kelley	Genesse County Land Bank Authority
Ted Barrett	Genesee Renewable Power Plant
Joel Burgess	Gerald R. Ford International Airport
Jason Hazen	Husky Energy
Scott Howard	Husky Energy
Bennie Hayden	Marketing for Green
Bob Batt	Michigan Department of Transportation
Terri Novak	Michigan Energy Office
Bill Knudson	MSU Extension Product Center
Terry McLean	MSU Extension
Dennis Pennington	MSU Extension
Charles Gould	MSU Extension
Mark Seamon	MSU Extension
Marty Piette	Muskegon County Airport
Joe Tesar	Quantalux
Dennis Miller	Solena Group
Mary Vibilante	Synergy Consulting
Jim Padilla	The Power Alternative, Start Detroit
Lance Stokes	The Power Alternative
Dan Angell	The Power Alternative
James Rekoske	UOP Honeywell
Rick Vanderbeek	USDA Rural Development
Michelle Plawecki	Wayne County Airport Authority
Jeff Bryant	Wayne County EDGE Development Office
Bryan Wagoner	Wayne County Airport Authority
Wendy Sutton	Wayne County Airport Authority

TASK 2: Bioenergy Crop Production on Highway Right-of-Ways

Background

Phase I of this project sought to understand the feasibility of growing, harvesting and utilizing bioenergy crops on non-traditional cropland for energy use such as biofuel, heat and electricity production. In the Phase I report it was estimated there is between 9,516 and 11,895 acres of limited access highway Right-of-Way (ROW) areas that could be utilized for bioenergy crop production.

Phase II of this project sought to build on Phase I. Highway ROW demonstration sites were identified across the state. Bioenergy crops were planted and harvested at each site. Results from each site are reported on in the next two sections.

Michigan Department of Transportation (MDOT) permit and approval process

From the onset of this project it was recognized that working with MDOT was the key to a successful highway ROW demonstration project. Meetings were held with MDOT personnel to ensure communication was taking place. The morning of June 2, 2011, MDOT notified the MSU Extension project leader that the Federal Highway Administration (FHWA) had stopped any further progress of the project because they needed more project background information as there was no current guidance in the MDOT real estate procedures manual. FHWA identified six issues MDOT needed to address before they would allow the project to continue. These six issues were never provided to the project leader. However, MDOT did say that addressing the six issues meant a revision to the real estate procedures manual. FHWA strongly recommended that MDOT get input from Michigan Department of Environmental Quality, Michigan Department of Natural Resources and Michigan Department of Agriculture and Rural Development throughout the revision process.

On the afternoon of June 2, based on new information and a new commitment from FHWA and MDOT leadership, a new plan was set in motion. The new plan was to issue permits for each highway ROW demonstration site. Accordingly, four permits were applied for and obtained (see Appendix E for an example of a permit). Each permit included all of the general conditions for the specific permit (see Appendix F). Permits varied in price based on location, but the unaccounted cost for all four permits totaled $505.

Each permit stipulated there be specific signage and safety equipment whenever work was being done at a site (see Appendix C for more information). This was another unexpected cost of $1,893.35.

Safety equipment necessary for highway sites.
Photo courtesy of Dennis Pennington.

It should be pointed out that by law the FHWA requires compensation for use of Federal Government land outside its intended use. Those fees were waved in lieu of state permits for this project, but in the future, entities wanting to grow bioenergy crops on highway ROWs will have to pay a fee to do so. The state will also collect a rental fee on state land used to grow bioenergy crops.

Highway right-of-way sites

Demonstration sites were established at four locations across the state (I-69 Exit 16 [Branch County], I-69 rest stop [Lapeer County], I-75 Exit 279 [Otsego County] and M-6 Exit 5 [Kent County]). Appendix D contains maps for each site.

Purpose

The purpose for the demonstration sites was to grow bioenergy crops under highway ROW conditions. At each site, one acre each of canola and switchgrass were planted. Seeding, fertilizer and herbicide application rates were based on published literature values for switchgrass and canola (see Table 2).

Table 2. Crop data for four highway right-of-way sites.

<table>
<tr><th>Location</th><th>Crop</th><th>Planting Date*</th><th>Planting Rate</th><th>Fertilizer Rate (lb) (N-P-K)</th><th>Herbicide Rate</th><th>Harvest Date</th><th>Yield Data</th></tr>
<tr><td>I69 Exit 16</td><td>Canola</td><td>6/14/11</td><td>6 lb/A</td><td>102-32-32</td><td rowspan="8">1 qt glyphosate + 1 qt LI900J + 1 pt ChoiceJ was applied on all sites prior to planting.</td><td rowspan="8">All sites were harvested in Sept. 2011.</td><td rowspan="8">No yield data available.</td></tr>
<tr><td>I69 Exit 16</td><td>Switchgrass</td><td>6/14/11</td><td>7 lb pls**/A</td><td>42-42-42</td></tr>
<tr><td>I69 Rest Stop</td><td>Canola</td><td>6/9/11</td><td>6 lb/A</td><td>102-32-32</td></tr>
<tr><td>I69 Rest Stop</td><td>Switchgrass</td><td>6/9/11</td><td>7 lb pls/A</td><td>42-42-42</td></tr>
<tr><td>I75 Exit 279</td><td>Canola</td><td>6/10/11</td><td>6 lb/A</td><td>102-32-32</td></tr>
<tr><td>I75 Exit 279</td><td>Switchgrass</td><td>6/10/11</td><td>7 lb pls/A</td><td>42-42-42</td></tr>
<tr><td>M6 Exit 5</td><td>Canola</td><td>6/13/11</td><td>6 lb/A</td><td>102-32-32</td></tr>
<tr><td>M6 Exit 5</td><td>Switchgrass</td><td>6/13/11</td><td>7 lb pls/A</td><td>42-42-42</td></tr>
<tr><td colspan="8">* Recommended planting date in Michigan is from mid-April to May 1.
** pls means “pure live seed.”</td></tr>
</table>

Soil test results

Soil samples were taken from random highway ROW sites across the state to determine soil fertility. Highway ROWs are by nature disturbed soils. It was assumed soil fertility would be low and salts high. Table 3 shows that these soils need nutrients, but are remarkably low in sodium content.

Table 3. Soil sample test results from 18 median and limited access highway sites across Michigan.

Soil Sample	pH	P (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	Na (ppm)	CEC (meq/100 g)	Organic Matter
SS_01	5.7	42	24	52	337	18	3.4	2.3
SS_02	6.8	47	38	88	475	7	3.2	1.9
SS_03	7.7	14	96	213	1391	9	9.0	4.5
SS_04	7.7	36	43	117	748	42	4.8	1.9
SS_05	8.2	7	32	73	992	76	5.7	1.9
SS_06	7.9	34	50	116	1191	17	7.0	2.8
SS_07	7.7	49	118	156	1425	37	8.7	3.4
SS_08	8.1	42	68	138	1490	184	8.8	3.3
SS_09	7.0	33	26	37	428	36	2.5	1.9
SS_10	7.5	8	86	340	1364	21	9.9	5.4
SS_11	7.8	6	44	176	1833	13	10.7	4.3
SS_12	7.9	25	67	159	1480	291	8.9	3.1
SS_13	8.4	10	35	101	1396	104	7.9	1.6
SS_14	7.5	8	50	112	1008	9	6.1	2.0
SS_15	8.1	5	59	133	2110	391	11.8	3.0
SS_16	7.9	6	52	124	1619	198	9.3	2.6
SS_17	8.1	15	71	159	1720	36	10.1	2.3
SS_18	8.2	15	89	135	2623	210	14.5	3.0

Canola and switchgrass highway right-of-way sites

Table 2 provides crop data for each site. The crops were planted between June 9 and 14, seven to eight weeks later than the recommended planting date for Michigan. There were two reasons for the delayed planting. First, Michigan experienced an unseasonably wet, cool spring. All field crops across the state were planted late. Second, when soil temperatures were high enough for planting to begin, the Michigan Department of Transportation (MDOT) instituted additional permit requirements for all four highway ROW demonstration sites. Working through the permit process pushed planting into mid-June. Canola and switchgrass were planted anyway, even though it was beyond the recommended planting time. Both the canola and switchgrass seed germinated, but

Drilling canola at Coldwater site.
Photo courtesy of Dennis Pennington.

weather conditions turned hot and dry, resulting in poor stand growth. Harvesting of both crops was attempted at each site; however, yields were either so poor they were deemed not reportable or it was determined a site was not worth harvesting.

In accordance with the permits issued for each site, all canola demonstration sites were reseeded to a grass mix specified by MDOT. The switchgrass sites were left as is.

Fertilizing the Gaylord site.
Photo courtesy of Dennis Pennington.

Reseeding grass seed at end of season.
Photo courtesy of Dennis Pennington.

Existing vegetation highway right-of-way sites

At the Branch, Lapeer and Otsego county sites, existing vegetation was harvested using the quadrat method to determine how much biomass was there already. This was done because there was some discussion about collecting existing biomass rather than mowing, which might save MDOT some money. Based on yields in Table 4, the amount of biomass collected probably isn't cost effective (even if the contractor was paid current mowing rates).

Table 4. Yield data on existing biomass at three locations.

Location	Crop	Harvest Date	Yield Data
Branch I-69 Exit 16	Existing vegetation	The 2nd and 3rd week of October	1.1 T/A
Lapeer I-69 Rest Stop	Existing vegetation		0.8 T/A
Otsego I-75 Exit 279	Existing vegetation		1.3 T/A

However, a Wisconsin study conducted in 2010 arrived at the opposite conclusion. The purpose of the pilot project was to test the feasibility of harvesting roadside biomass along Highway 151 in the townships of Sun Prairie and York in South Central Wisconsin. A 2.2 mile section of right-of-way along Highway 151 between County Highway V and VV was harvested on November 4 and 5. Thirty-five large square bales were harvested producing an average yield of 2.03 tons/acre or 5.55 tons per mile. The results of this pilot project showed that harvesting roadside biomass with farm equipment is feasible, and yield and quality was sufficient to warrant further study (Derr, 2011). The knowledge gained from this project could be used for establishing a useful benchmark for road shoulder biomass value in Michigan.

MDOT biodiesel production opportunity

Assuming a canola crop yield of 40 bu/acre on prime cropland and 25 bu/acre on marginal land (see the *Project Summation for Energy and Economics* section for an explanation of where these yields came from), one acre of prime farmland and marginal land will yield approximately 107 and 67 gallons of biodiesel per acre, respectively. In 2010, the MDOT-owned fleet used 1,028,809 gallons of diesel (Gould, 2011). To replace this volume of petroleum diesel with biodiesel would require 9,615 acres of prime farmland or 15,355 acres of marginal land. There is a sufficiently large marginal land base to support growing all of the biodiesel MDOT needs for its fleet (see the *Expand Bioenergy Crops Grown on Marginal Farmland* section for more information).

Lessons learned

1. Permits are expensive, prescriptive and time consuming. Safety equipment, while justified, is also expensive. These requirements will most likely serve as disincentives for farmers to grow bioenergy crops on highway ROWs.
2. Highway ROW soils are low in fertility. It will take several years of management to increase soil fertility levels to maintenance levels.
3. MDOT has other land not associated with highway ROWs that could be available to grow bioenergy crops.
4. The Wisconsin study indicates harvesting highway ROW biomass has potential. Future work should be conducted to determine if their conclusions are valid in Michigan.

TASK 3: Bioenergy Production and Use at Michigan Airports

Background

Three airports—the Muskegon County Airport (MSK), Gerald R. Ford International Airport (GRR) and Detroit Metro Airport (DTW)—agreed to set aside some land to grow bioenergy crops. The Muskegon County Airport (43.161364°N, -86.215853°W), Gerald R. Ford International Airport (42.862817°N, -85.527614°W) and Detroit Metro Airport (42.181728°N, -83.367981°W) have 500, 1300, and 1169 acres, respectively, that could be used to grow bioenergy crops. Due to airport security issues, all sites were located outside the perimeter fence, providing easy access to each site.

The Federal Aviation Administration (FAA) provides oversight of airport activities and as such required a permit at each airport in order to conduct these demonstrations. Permit conditions required a review of intended crops by the U.S. Fish and Wildlife Services to examine if the crops had potential to draw wildlife, large bodied avian species or flocking birds that could cause aircraft safety concerns. Lease agreements were implemented between Michigan State University and each airport to meet legal obligations and indemnification for each party. Fair rental amounts were determined and paid based on 2011 Michigan Land Values and Leasing Rates (Wittenberg, 2011). Upon meeting all of these conditions, FAA approved the use of airport land for these demonstration projects.

Muskegon County Airport (MSK)

On May 17, 2011, Oriental mustard (Pacific Gold) and canola (Hyclass 906RR) were planted at a rate of 6 and 7 lbs/acre, respectively. The site was 140 feet by 600 feet. Planting conditions were warm and dry. Soil was very sandy with little vegetation growing. Fertilizer was applied at a rate of 113, 42.6 and 42.6 lbs/acre of N-P-K, respectively. On June 15, 12 oz Intensity OneJ + 8 oz StingerJ was applied to Oriental mustard and 1 qt. glyphosate/acre was applied to canola.

This site was scouted again 14 days after postemergence herbicide application. Weeds exhibited significant wilting and yellowing from the successful second application. No noticeable damage from wildlife or birds was detected.

This site is on a Rubicon sand, from sandy outwash plain with a land capability class unit of VI (s). This soil has high to very high water infiltration rate (Ksat) of 5.95 to 19.98 inches per hour and a low water holding capacity of 3.8 inches. Regularly scheduled irrigation on this site would be necessary in order to maintain even modest yield goals. See Appendix G, Web Soil Survey Muskegon County Airport for more details.

Gerald R. Ford International Airport (GRR)

On May 12, 2011, Oriental mustard (Pacific Gold) and canola (Nexera 2014CL) were planted at a rate of 6 and 7 lbs/acre, respectively. The site was 260 feet by 300 feet. A no-till drill was used to seed both crops. Planting conditions were warm and dry. Fertilizer was applied at a rate of 113, 42.6 and 42.6 lbs/acre of N-P-K respectively. A burndown application of 1 qt. glyphosate/acre was applied. Upon crop scouting, it was determined that a second herbicide application was needed to control weeds. On June 15, 12 oz Intensity OneJ + 8 oz StingerJ was applied to Oriental mustard and 1 qt. glyphosate/acre was applied to canola.

This site was scouted again 14 days after postemergence herbicide application. Weeds exhibited wilting and yellowing from the second application, but poor to very poor weed control was observed and contributed to reduced crop yields. No noticeable damage from wildlife or birds was detected.

Due to the high level of weed invasion the site was not harvested. By the end of the growing season, perennial weeds had mostly taken over the plot. It was mowed to keep the weeds from setting seed and expanding the weed seed bank.

This site was established on a Blount loam from a loamy till moraine formation. This is a very productive agricultural soil with moderately low to moderately high water infiltration rate (Ksat) of 0.06 to 0.57 inches per hour and a moderate water holding capacity of about 7.4 inches. This soil has a land capability class unit of II (e). Water infiltration and holding capacity is handled well for this soil. Water tends not to pond during heavy rainfall, yet it holds adequate water for crop production. See Appendix H Web Soil Survey Gerald R. Ford International Airport Site for more details.

In order for successful establishment of oilseed crops at this site, fall tillage followed by weed control in the fall would be warranted. In the spring, a finishing tillage to control winter annual weeds just prior to planting should be done with follow-up postemergence weed control. It may take more than one crop year to achieve proper weed control to protect crop yield goals.

Detroit Metro Airport (DTW)

On May 13, 2011, Oriental mustard (Pacific Gold) and canola (Hyclass 906RR) were planted at a rate of 6 and 7 lbs/acre, respectively. The site was 140 feet by 600 feet. Planting conditions were wet; there was some caking on press wheels in certain spots. Fertilizer was applied at a rate of 113, 42.6 and 42.6 lbs/acre of N-P-K, respectively. A burndown application of 1 qt. glyphosate/acre was applied. Upon crop scouting, it was determined that a second herbicide application was needed to control weeds. On June 14, 12 oz Intensity OneJ + 8 oz StingerJ was applied to Oriental mustard and 1 qt. glyphosate/acre was applied to canola.

This site was scouted again 14 days after postemergence herbicide application. Weeds exhibited significant wilting and yellowing from the successful second application. No noticeable damage from wildlife or birds was detected.

This site was established on a Pewamo loam from a loamy till depressions on till-floored lake plains. This is a moderately productive agricultural soil with a severe limitation being a low area with frequent ponding. This soil has moderately high water infiltration rate (Ksat) of 0.20 to 0.57 inches per hour and a high water holding capacity of about 10.0 inches. The depth to water table is about 0.0 inches, meaning it has a high water table. This soil has a land capability class unit of II (w). See Appendix I, Web Soil Survey Detroit Metro Airport Site, for more details. Ponding of water across

Area at Detroit Metro Airport that was drowned out by flooding. *Photo courtesy of Dennis Pennington.*

about half of the demonstration site was noted. Oriental mustard and canola in this area died as a result. Excessive rain events coupled with poor draining had a significant impact on crop yield.

At harvest, samples were collected, dried in plant dryer and yield determined. The average yield for canola and Oriental mustard was 9.5 and 6.5 bushels per acre, respectively. It should be noted that this was a demonstration site, not replicated research plots. When making management decisions, farmers should use data from multiple years and multiple sites. This low yield was a result of the drowned out area in the middle of the site. Proper drainage will be a limiting factor when employing non-traditional lands in growing bioenergy crops.

Test burn information

A test burn using biodiesel at Gerald R. Ford International Airport was conducted for about two weeks in October 2011. Two hundred gallons of B-20 biodiesel were dispensed through an auxiliary tank. The tank had a product filter in line with the nozzle. The B-20 biodiesel and tank were provided by Crystal Flash Energy, a biodiesel provider in Michigan. The fuel was burned in two New Holland tractors (New Holland TV145 and New Holland TV140). Each tractor pulled 20 foot batwing mowers and mowed tall grass (10-15 inches) in outland fields of the airport. Prior to the test burn, the tractors' fuel economy for regular diesel was calculated at 5.1 gallons per hour at 2200 RPM. Fuel filters were changed on each tractor prior to the test burn and changed after the test (see before and after photos). During the test the two tractors were operated at 2200 RPM pulling the batwing mowers. The tractors started normally. The outside temperatures during the test were 65-75 degrees Fahrenheit. The fuel economy burning the B-20 biodiesel was 6.5 gallons per hour. The tractor operators indicated no difference in tractor performance. The tractor operators' comments include:

Ford tractor at Gerald R. Ford International Airport that was used for test burn of biodiesel.
Photo courtesy of Dennis Pennington.

- "Burned cleaner. When I hit the tall grass, the tractor really put out the black smoke with regular diesel, it didn't do it with the B-20."
- "We worked them hard, cut low, outfield mowing at its best."
- "No difference in performance. The same as regular diesel fuel."
- "I really like this, it is so much cleaner. We should burn this more."

Cross section of fuel filters from Tractor 1 before the test burn. *Photo courtesy of Paul Gross*.

Cross section of fuel filters from Tractor 1 after the test burn. *Photo courtesy of Paul Gross*.

Cross section of fuel filters from Tractor 2 before the test burn. *Photo courtesy of Paul Gross*.

Cross section of fuel filters from Tractor 2 after the test burn. *Photo courtesy of Paul Gross*.

Biodiesel is a viable option for use at Michigan airports. The test burn indicated no loss of tractor performance. However, fuel economy was less using the B-20 biodiesel. Another concern with the biodiesel is the performance in cold temperatures in Michigan. Operator observation indicated B-20 burned much cleaner with considerably lower emissions into the environment. Economics and availability will be key factors in the use of biofuels in the future.

TASK 4: Expand Bioenergy Crops Grown in Urban Areas

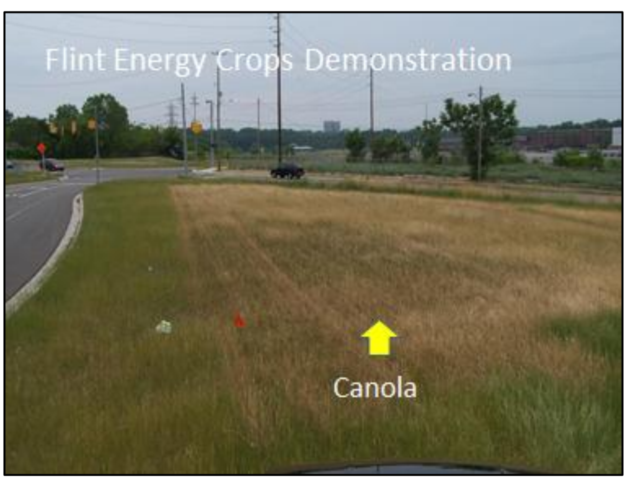
Background

Vacant urban lots are being explored in Michigan as a remediation tool to reclaim the land for productive use. Several private companies are exploring whether this land could be used to produce energy crops. The objective of this task was to demonstrate production of canola and switchgrass on this type of non-traditional land. Two urban sites were secured to establish energy crops within the City of Flint. Flint was chosen because of its quantity of vacant urban land, redevelopment efforts such as the Genesee Land Bank, Flint local food efforts and the network of resources developed by our MSUE collaborator, Terri McLean. One of the sites was located in a northern Flint residential community on Marengo Road. This site was a renovated home site with a small footprint. The energy crop plot utilized an area of 25 feet by 30 feet to grow switchgrass and Miscanthus. The other site was located near Kettering University and adjacent to a brownfield site that was formerly a Chevrolet production facility. This area was used to establish a canola crop. See Table 5 for details of crops at each of the two sites.

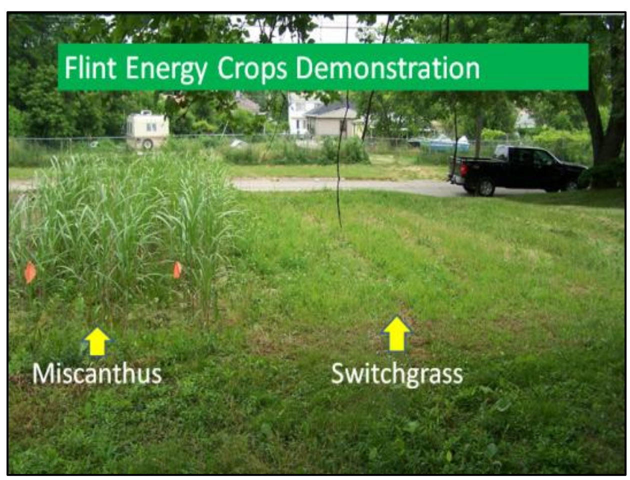
Table 5. Urban bioenergy crop establishment information for two sites in Flint, Mich.

Location	**North**	**Downtown**
Crop	Switchgrass	Canola
Planting date	June 2010	June 6, 2011
Establishment method	Conventional tillage Broadcast seed	No-till Drilled seed
Seeding Rate	6 lbs. pure live seed per acre	6 lbs. per acre
Details	Cave-in-Rock switchgrass variety used at 15 lbs/A. No fertilizer used to discourage weed growth.	NX4-106RR canola was seeded at 7 lbs/A. Total N-P-K was 104-32-32 respectively.
Harvest date	n/a – mowed to manage weed growth	n/a – not harvested due to poor crop and mowing with surrounding grass area.

While urban land represents a significant land area and opportunity for the production of energy crops, the demonstrations helped to identify several challenges associated with this practice. The total land area available in many urban areas can be impressive, but when the vacant parcels are aggregated and evaluated for their individual applicability, the commercial-scale crop production challenges become evident. See Table 6 for issues identified.



Urban site in Flint, Mich., where canola was planted. *Photo courtesy of Mark Seamon.*



Switchgrass planted at urban site in Flint, Mich. *Photo courtesy of Mark Seamon.*

Table 6. Challenges identified at two urban Bioenergy demonstration trial sites.

North	Downtown
1. Parcel size: Very small lot with trees and vegetation pressure from adjacent lots that reduced sunlight and growth, access with farm equipment is limited. Large blocks of contiguous parcels need to be assembled. 2. Physical obstructions: Sidewalks limit useable area; blocks, bricks and partial foundations from previous buildings; low hanging tree limbs from adjacent lots. 3. Ownership: Communications with owner are vital. Land use, maintenance of plot area can affect success. Multiple owners may be likely. 4. Pesticide use: Proximity to homes and sidewalks may limit use or timing of applications. 5. Crop selection: Some tall crops appear to be unkept and unsightly. Switchgrass establishment was slow and appeared weedy. Residents may be concerned about safety if line of sight is obstructed.	1. Parcel size: Half-acre area limits farm equipment use. 2. Physical obstructions: Utility manhole access site with covers missing, sidewalks limit useable area. 3. Ownership: Public triangle area at the convergence of two streets, required approval of Mayor's office. Ownership can be difficult to determine with tax reverted, foreclosed or estate issues. 4. Pesticide use: Proximity to public use areas may limit use or timing of applications. 5. Crop selection: Due to proximity to streets, crop must be short to allow traffic sight distances.

TASK 5: Expand Bioenergy Crops Grown on Marginal Farmland

Background

There are 10,031,807 acres of land in farms in Michigan. Of this land, 6,859,081 acres (68%) were harvested in 2007. That leaves 3,172,726 acres (32%) of non-traditional land available for bioenergy crop production (National Agricultural Statistics Service, 2007, 2009). It is inconceivable to suggest that every available acre could be utilized, but it illustrates the untapped potential of land that does not compete with food crops.

Ottawa County Oriental mustard field.
Photo courtesy of Dennis Pennington.

Farm-scale demonstration sites

The purpose for the demonstration sites were to identify potential issues or problems farmers may face when growing canola and Oriental mustard. Four farmer cooperators willing to dedicate 25 acres of their land to grow oilseed crops were identified. The county they farm in and the crop they grew are as follows:

- Barry County, (42.469787°N, -85.491326°W) Oriental mustard
- Saginaw County, (43.229954°N, -84.252858°W) canola
- Ottawa County, (43.112095°N, -85.974263°W) Oriental mustard
- Osceola County, (43.996036°N, -85.153457°W) canola

Each farmer received $650 per acre payment to compensate for the opportunity lost by not growing another crop. This was calculated by multiplying December 2011 corn futures prices x state average corn yield, then subtracting production expenses ($6/bu x 156 bu/a -$300 = $636/a). This number was rounded up to $650 per acre, which is equivalent to what each farmer would have received if they planted corn as they normally would. Each farmer covered their own production expenses (tillage, planting, fertilizer, weed control, harvest and any other field operations).

Harvesting canola crop at Osceola County farm.
Photo courtesy of Dennis Pennington.

Crop production summary from four sites

Table 7 contains the information provided to each farmer cooperator on planting, seeding, tillage, fertilizer, herbicide and harvesting Oriental mustard and canola.

Table 7. Planting, seeding, tillage, fertilizer, herbicide and harvest recommendations to farmer cooperators.

	Oriental Mustard[1]	**Spring Canola**[2]
Planting date	After soil temp reaches 40-45 degrees F	Last week of April
Seeding rate	5-7 lbs/A drilled ½- to 1-inch deep	4-5 lbs/A drilled ½- to 1-inch deep
Tillage	Conventional, firm seedbed	Conventional, firm seedbed
N (lb/a)	110	110
P (lb/a)	45	45
K (lb/a)	80	80
Herbicide	12 oz. Intensity One + 8 oz. Stinger, PRE	1 qt. glyphosate, POST
Harvest	Must be swathed when field turns from green to yellow/brown. Combine cylinder speed set about 600 rpm.	Must be swathed when 30-40% of seed on each stem turns reddish, brown.

[1]Oplinger, *et al.,* 1991.
[2]Oplinger, *et al.,* 1989.

Table 8. Crop yields and locations on farmland sites.

	Crop	Yield (bu/A)	Acres	Total (bu)
Osceola	canola	26	25	650
Saginaw	canola	23	25	575
Barry	Oriental mustard	0	25	0
Ottawa	Oriental mustard	10	7	40

Opportunities and barriers

Opportunities

1. There is significant interest among farmers to become more self-sufficient in fuel production.
2. Double cropping could provide on-farm fuel production in addition to maintaining existing cropping systems.
3. Fuel costs continue to be one of agriculture's biggest energy expenses, and therefore, farmers are very interested in alternative options to reduce their input costs.

Barriers

1. Opportunity cost of growing energy crops is high compared to existing commodity crops due to high commodity prices.
2. Oriental mustard harbors white mold, which could cause rotation problems with soybeans and dry edible beans.
3. Canola is a host for turnip mosaic yellows virus, which will limit the area where canola can be grown due to the susceptibility of sugar beets to the same virus.

Lessons learned

1. Volunteer Oriental mustard could become a weed problem for future rotational crops.
2. As with any new crop, it might take a few years for growers to learn how to grow new crops and reach maximum yields.
3. Oilseed crops do not mature evenly within the field, causing green seed to be mixed in the combine with dry, mature seed. This inconsistency can cause field loss by seed pod shatter or reduced oil content in the seed.
4. Alternative markets for Oriental mustard don't exist, limiting the flexibility in marketing the crop.

TASK 6: Preprocessing Bioenergy Crops

On-farm pellet production

A hammer mill and pelletizer was used to grind and pelletize switchgrass harvested from roadways and urban areas.

This system was used to produce a biomass pellet that was combusted to produce heat, steam and/or electricity at the MSU T. B. Simon Power Plant, as well as on farms in outdoor wood stoves used to heat homes and farm shops. The demonstration scale of these tools will enable the practical evaluation to optimize pellet quality characteristics for energy use. This will include the addition of binding agents and/or lubricants and blending biomass feedstocks with evaluation of the resulting pellets.

Portable pellet mill constructed for this project.
Photo courtesy of Dennis Pennington.

Several partners were engaged in designing and contributing to the construction of this equipment. MSU University Farms had an old backup generator that was donated to the project to provide power for the system. MSU Biosystems and Agricultural Engineering provided the pellet mill. Grant dollars from this project purchased the hammer mill, trailer, cooling conveyor, surge bin and binding agent tank as well as all of the electronic controls. MSU Biosystems and Agricultural Engineering staff also donated their time and expertise to design and build the electronic controls for the pellet mill. The resulting system is operational and replicates a full-size commercial system. Switchgrass has been the primary biomass feedstock for the pellets. Glycerin, a waste stream product from the biodiesel system, was used as a binding agent.

An educational effort has been integrated into this portion of the project to help Michigan farmers evaluate the production of biomass energy pellets. The pellet system has been mounted onto a trailer that enables on-site production at locations across the state. Economics and pellet utilization accompanied the physical pelleting demonstrations at remote sites.

On-farm biodiesel production

Biodiesel unit and storage tanks mounted inside enclosed cargo trailer.
Photo courtesy of Dennis Pennington.

Biodiesel processing unit

A Genesee model biodiesel processing unit was purchased from OnSite Energy, LLC (Flint, Mich.). The Genesee is an automated unit designed to process 80 gallons of oil into biodiesel in 6-7 hours. More information about the Genesee can be found at http://www.onsiteenergyllc.com/.

Oilseed press

A CLB-300 oilseed press with a 12 HP diesel engine (3 ton/day capacity) was purchased from Cropland Biodiesel (Lynden, Wash.). More information about this model can be found at http://www.croplandbiodiesel.com/products/extruders_motor/clb-300-dmg.html. Unfortunately, this press was not of sufficient quality to warrant use in this project and was shipped back. A CLB-500 oilseed press was secured from MSU Chemical Engineering Professor Dennis Miller and used to crush canola seed harvested from the 25-acre farmer sites. While this press was operational, it had limited ability to extract oil. Oil from this press has fines in it and needed to be filtered. Three separate tests were conducted, where 100 pounds of seed was measured. Oil from each test was weighed separately and then averaged. The press was yielded 12 pounds of oil from each 100 pound batch. Mechanical oil presses should be able to yield 25% oil. Due to the poor performance of this borrowed press, a new KK40 double head press was purchased and employed. To address the dirty oil issue, a centrifuge was purchased to clean the fines from the oil. Filtered oil was then used in the biodiesel unit to make biodiesel.

Oilseed

A total of 57 acres of Oriental mustard and canola (7 and 50, respectively) was harvested from farm sites around the state. Sixteen tons of the harvested oilseed was reserved to be pressed for oil. This oil was used to make biodiesel during the on-farm biodiesel processing demonstrations. An additional ten tons of seed was delivered to The Power Alternative in Warren, MI for crushing and conversion into biodiesel.

On-farm biodiesel demonstrations

An enclosed trailer was purchased and the Genesee bolted in. Three on-farm demonstrations have been conducted to date. The goal of these demonstrations is to teach farmers how to make biodiesel for on farm consumption and the economics associated with making their own fuel. Canola oil and catalysts were transported to each site, where 40 and 80 gallon batches were made. Educational material, including a Cost of Production Worksheet, was developed for use in these demonstration projects (posted at http://bioenergy.msu.edu keyword “Freeways to Fuels”). A video of the oilseed press was made and shown to the farmers. A representative from OnSite Energy attended the farm demonstrations to serve as an additional resource.

Table 9. Biodiesel test runs including cost for catalysts, amount of biodiesel and glycerin produced, and the cost per gallon for the catalysts.

	Cost	Amount		Batch Amt		Cost per batch	Gal biodiesel per batch	Gal glycerin per batch	Cost per gal biodiesel
Run #1									
Methanol	$ 708.90	165	g	16	g	$68.74	64	32	$1.07
KOH	$ 242.51	220	lb	4717	gms	$11.46	64	32	$0.18
Run #2									
Methanol	$ 708.90	165	g	7	g	$30.07	31	11	$0.97
KOH	$ 242.51	220	lb	2063	gms	$5.01	31	11	$0.16
Run #3									
Methanol	$ 708.90	165	g	8	g	$34.37	38	10	$0.90
KOH	$ 242.51	220	lb	2122	gms	$5.16	38	10	$0.14

TASK 7: Energy and Economics

Introduction

The Michigan State University Product Center analyzed the economics of the project. This includes a breakeven analysis for both canola and Oriental mustard—two crops often mentioned for dedicated biodiesel and jet fuel production. Four farm sites of 25 acres each were considered. Two farmers grew Oriental mustard and two other farmers grew canola. Actual results vary from farm to farm, and while these figures can give a producer some idea of what to expect, the actual experience of a particular farmer may be different. A rough energy balance calculation is included for canola. There is less information available for Oriental mustard; however, given the similar oil content and the cost of production figures, the energy balance for Oriental mustard is likely to be similar to that of canola.

Government policies are also considered as well as alternative payment methods. This is particularly important when considering developing a supply chain for dedicated bioenergy crops.

Breakeven analysis for Farmer 1

Table 10 shows the breakeven analysis for Farmer 1 who grew Oriental mustard. The figures are based on an actual farm and consider the level of revenue needed to break even, and rates of return of 5, 10 and 15 percent. Two scenarios are considered: in the first the farmer owns the land, and in the second the farmer pays $75 an acre in rent.

Table 10: Breakeven Analysis—Oriental Mustard—Farmer 1.

Item	Cost per acre ($)
Seed	10.02
Fertilizer (Nitrogen)	25.75
Herbicide	39.12
Fuel	13.00
Utilities	.20
Labor	48.00
Tractor costs	18.00
Planting equipment costs	20.00
Spraying and fertilizer equipment costs	5.00
Harvesting equipment costs	25.00
Property taxes	25.00
Total	**229.09**
Breakeven Revenue	229.09
5% rate of return	240.54
10% rate of return	252.00
15% rate of return	263.45
Breakeven Revenue $75 an acre rent	279.09
5% rate of return	290.54
10% rate of return	302.00
15% rate of return	313.45

If the farmer owns the land, the breakeven revenue is $229.09 an acre; if the land is rented, the breakeven revenue is $279.09 an acre. In the case where the farmer owns the land, the revenue needed for a 5 percent rate of return is $240.54 an acre, $252.00 for a 10 percent rate of return, and $263.45 an acre for a 15 percent rate of return. In the case of land rents, the breakeven level of revenue is $279.09 an acre, the level of revenue is $290.54 for a 5 percent rate of return, $302.00 for a 10 percent rate of return, and $313.45 for a 15 percent rate of return. Major cost items include labor, harvesting equipment costs and nitrogen fertilizers. Property taxes are a major cost item in the case when the farmer owns the land, and rent payments are a major cost item when the farmer does not own the land.

Table 11 shows the price of oil under two scenarios, the first is if the yield is 40 bushels per acre and the second is if the yield is 25 bushels per acre. The crop was managed for a 40 bushel yield goal and fertilized accordingly. If the 40 bushel yield goal was achieved, an acre would produce approximately 107 gallons of biodiesel; if the yield is 25 bushels an acre, an acre produces approximately 67 gallons per acre. Actual oil content was 26.14 percent and there is no market for the meal. If higher concentrations of oil in the seed could be achieved, the breakeven price per pound would be reduced, improving the potential profitability of producing Oriental mustard.

Table 11: Price of Oriental mustard oil to achieve Breakeven, 5, 10 and 15 percent rates of return for Farmer 1.

Price of Oil (cents per pound)		
40 Bushels an acre	**Farmer owned**	**Farmer rents**
Breakeven price	43.8	53.4
5% rate of return	46.0	55.6
10% rate of return	48.2	57.8
15% rate of return	50.4	60.0

25 Bushels an acre	Farmer owned	Farmer rents
Breakeven price	70.1	85.4
5% rate of return	73.6	88.9
10% rate of return	77.1	92.4
15% rate of return	80.6	95.9

The breakeven price ranges from 43.8 cents a pound in the case of 40 bushels an acre and the farmer owns the land to 85.4 cents a pound in the case of 25 bushels an acre and the farmer rents the land. Yields of 40 bushels an acre reduce the necessary price to achieve a given rate of return in excess of 26 cents a pound when the farmer owns the land and an excess of 32 cents a pound when the farmer rents the land. If the oil content of Oriental mustard could increase, either through improved production practices or the development of higher oil content varieties, the breakeven price could be reduced.

Table 12 shows the costs and breakeven revenue for Farmer 2 who grew 25 acres of Oriental mustard.

Table 12: Breakeven Analysis—Oriental Mustard—Farmer 2.

Item	Cost per acre ($)
Seed	10.02
Fertilizer	27.00
Labor	18.00
Tractor costs	22.00
Planting equipment costs	22.00
Harvesting equipment costs	75.00
Property taxes	25.00
Total	**199.02**
Breakeven Revenue	199.02
5% rate of return	208.97
10% rate of return	218.92
15% rate of return	228.87
Breakeven Revenue $75 an acre rent	249.02
5% rate of return	261.47
10% rate of return	273.92
15% rate of return	286.37

If the farmer owns the land, the breakeven revenue per acre is $199.02; if the farmer rents the land the breakeven revenue is $249.02 an acre. In the case of the farmer owning the land the 5, 10 and 15 percent rates of return are $208.97, $218.92 and $228.87, respectively. In the case of the farmer renting the land the 5, 10 and 15 percent rates of return are $261.47, $273.92 and $286.37, respectively.

It should be noted that Farmer 2's cost of production is about $30 an acre lower than Farmer 1. This could be due to different accounting methods as well as different costs of production.

Table 13 shows the breakeven costs per pound under two scenarios, the first if the yield is 40 bushels an acre and the second if the yield is 25 bushels an acre. The oil content is assumed to be the same as Farmer 1, 26.14 percent.

Table 13: Price of Oriental mustard oil to achieve Breakeven, 5, 10 and 15 percent rates of return for Farmer 2.

Price of Oils (cents per pound)		
40 Bushels an acre	**Farmer Owns**	**Farmer Rents**
Breakeven Price	38.1	47.6
5% rate of return	40.0	50.0
10% rate of return	41.9	52.4
15% rate of return	43.8	54.8
25 Bushels an acre	**Farmer Owns**	**Farmer Rents**
Breakeven Price	60.9	76.2
5% rate of return	64.0	80.0
10% rate of return	67.0	83.8
15% rate of return	70.0	87.6

If the yield is 40 bushels an acre, the breakeven price is 38.1 cents a pound if the farmers owns the land, and 47.6 cents a pound if the farmer rents. In order to obtain a 5 percent rate of return the price is 40 cents a pound if the farmer owns the land, and 50 cents a pound if the farmer rents. In order to obtain a 10 percent rate of return the price is 41.9 cents a pound if the farmer owns the land, and 52.4 cents a pound if the farmer rents. In order to obtain a 15 percent rate of return the price is 43.8 cents a pound percent if the farmers owns the land, and 54.8 cents a pound if the farmer rents the land.

The breakeven prices are considerably higher if the yield is 25 bushels an acre. The breakeven price is 60.9 cents a pound if the farmer owns the land, and 76.2 cents a pound if the farmer rents the land. To obtain a 5 percent rate of return the price is 64 cents a pound if the farmer owns the land, and 80 cents a pound if the farmer rents the land. In order to obtain a 10 percent rate of return the price is 67 cents a pound if the farmer owns the land, and 83.8 cents a pound if the farmer rents the land. In the case of a 15 percent rate of return, the price is 70 cents a pound if the farmer owns the land, and 87.6 cents a pound if the farmer rents the land.

Table 14 shows the breakeven analysis for canola for Farmer 3. As is the case with Oriental mustard, these figures represent the costs of a commercial farmer.

Table 14: Breakeven Analysis—Canola—Farmer 3.

Item	Cost per acre ($)
Seed	52.80
Nitrogen Fertilizer	2.16
Phosphate Fertilizer	.58
Potash Fertilizer	2.02
Herbicide	27.96
Fuel	20.00
Utilities	.20
Labor	35.20
Marketing	1.00
Tractor costs	9.00
Planting equipment costs	11.08
Spraying and fertilizer equipment costs	6.00
Harvesting equipment costs	12.00
Other Equipment Costs	2.00
Property taxes	25.00
Total	**207.00**
Breakeven Revenue	207.00
5% rate of return	217.35
10% rate of return	227.71
15% rate of return	238.08
Breakeven Revenue $75 per acre rent	257.00
5% rate of return	267.39
10% rate of return	277.71
15% rate of return	288.06

As is the case with Oriental mustard, two scenarios are considered: one in which the farmer owns the land, and one in which the farmer rents the land at $75 an acre. The breakeven revenue is $207 an acre in the case where the farmer owns the land, and $257 an acre in the rental case. In the case where the farmer owns the land, the level of revenue needed to earn a 5 percent rate of return is $217.35, $227.71 for a 10 percent rate of return, and $238.06 an acre for a 15 percent rate of return. In the land rent case the level of revenue needed for a 5 percent rate of return is $267.39, $277.71 an acre for a 10 percent rate of return, and $288.06 an acre for a 15 percent rate of return. The major cost items for canola production are seed, labor and harvesting equipment costs. Compared to Oriental mustard seed, costs are much higher and fertilizer costs are lower. Other costs are similar for the two crops.

As was the case with Oriental mustard, production figures vary somewhat between the two farms. This may be due to differences in accounting methods as well as actual differences in the cost of production.

Table 15 shows the breakeven price of canola oil when the yield per acre is 40 and 25 bushels and when the farmer owns and rents the land. If the yield is 40 bushels an acre, an acre could produce approximately 115 gallons of biodiesel; if the yield is 25 bushels an acre, an acre could produce approximately 72 gallons of biodiesel. In this case the price of canola meal is estimated to be 11 cents per pound.

Table 15: Price of canola oil to achieve Breakeven, 5, 10 and 15 percent rates of return for Farmer 3.

Price of Oils (cents per pound)		
40 Bushels an acre	**Farmer owned**	**Farmer rents**
Breakeven price	9.2	17.0
5% rate of return	10.8	18.6
10% rate of return	12.4	20.2
15% rate of return	14.0	21.8
25 Bushels an acre	**Farmer owned**	**Farmer rents**
Breakeven price	28.5	40.8
5% rate of return	31.0	43.4
10% rate of return	33.6	46.0
15% rate of return	36.1	48.5

The breakeven price ranges from 9.2 cents a pound in the case of 40 bushels an acre and the farmer owns the land to 48.5 cents a pound in the case of 25 bushels an acre and the farmer rents the land. Yields of 40 bushels an acre reduce the necessary price to achieve a given rate of return by about 20 cents a pound when the farmer owns the land and approximately 25 cents a pound when renting the land. In this case the oil content was 32.29 percent.

Table 16 shows the breakeven analysis of another canola farmer. In this case the oil content was 36.07 percent.

Table 16: Farm Production Costs—Canola—Farmer 4.

Item	Cost per Acre
Seed	49.20
Nitrogen	8.14
Potash	.88
Herbicide	.22
Fungicide	27.38
Fuel	43.44
Utilities	.20
Labor	8.40
Tractor costs	22.40
Planting equipment costs	12.00
Spraying and fertilizer equipment costs	11.85
Harvesting equipment costs	23.00
Rent	30.00
Total	237.11
Breakeven revenue—Rent $30 an acre	237.11
5% rate of return	248.97
10% rate of return	260.82
15% rate of return	272.68
Breakeven revenue—Rent $75 an acre	282.11
5% rate of return	296.22
10% rate of return	310.32
15% rate of return	324.43

The breakeven revenue is $237.11 an acre in the case where the farmer rents the land for $30 an acre, and is $282.11 an acre in the case where the farmer rents the land for $75 an acre. The level of revenue needed for a 5 percent rate of return is $248.97 when the farmer rents the land for $30 an acre, and $296.22 in the case where the farmer rents the land for $75 an acre. The level of revenue needed for a 10 percent rate of return is $260.82 an acre in the case where the farmer rents the land for $30 an acre, and $310.32 an acre if the rent is $75 an acre. In order to earn a 15 percent return, the needed revenue is $272.68 an acre when the rent is $30 an acre, and $324.43 an acre if the rent is $75 an acre.

Table 17 shows the price of canola oil needed to meet the revenue goals in the $30 an acre rental case and $75 an acre rental case.

Table 17: Price of canola oil to achieve Breakeven, 5, 10 and 15 percent rates of return for Farmer 4.

Price of Oils (cents per pound)		
40 Bushels an acre	**$30 an acre rent**	**$75 an acre rent**
Breakeven price	13.5	19.8
5% rate of return	15.2	21.7
10% rate of return	16.8	23.7
15% rate of return	18.5	25.7
25 Bushels an acre	**$30 an acre rent**	**$75 an acre rent**
Breakeven price	33.3	43.3
5% rate of return	35.9	46.4
10% rate of return	38.5	49.5
15% rate of return	41.2	52.6

The breakeven price ranges from 13.5 cents a pound in the case of 40 bushels an acre and the farmer rents the land for $30 to 52.6 cents a pound in the case of 25 bushels an acre and the farmer rents the land for $75 an acre. Yields of 40 bushels an acre reduce the necessary price to achieve a given rate of return by about 20 cents a pound when the farmer rents the land for $30, and approximately 25 cents a pound when renting the land for $75 an acre. In this case the oil content was 32.29 percent.

It should be noted that canola has a definite advantage over Oriental mustard in that there is a well-established market for canola compared to Oriental mustard. There is also a well-established market for canola meal. The value of canola meal was based on 2010-2011 crop year data provided by the Canola Council of Canada. After adjusting for exchange rates and converting from metric to English measurements, the value of the canola meal is estimated to be 10.9 cents a pound. The implication of this is a canola farmer is less dependent on the value of the oil to generate sufficient revenue to cover costs. While Oriental mustard meal has the potential as a natural pesticide, this market has not developed yet.

Given that this project was only a demonstration, yield data may be misleading. Additional yield data that is replicated over more locations and more years is needed. Once this additional information is collected, a more definitive breakeven analysis based on actual yields could be obtained.

Capital costs of crushing oilseeds and producing fuel

Obtaining good cost figures for crushing and producing oil is difficult. Oilseed crushing requires large economies of scale. One estimate for a commercial-sized integrated crush plant and refinery with a throughput capacity of 2,500 tons per day is between $56 and $78 million (Remco, p. 7). Oil from this refinery would not be used for human consumption, so some of the refinery costs are not relevant. For example, bleaching and deodorizing would probably not be necessary in the production of biodiesel or bioaviation fuel. A facility of this size would generate enough oil to produce 45 million gallons of biodiesel a year. A smaller facility processing 600 tons of oilseed per day would cost between $33 and $43 million to build (Remco, p. 37). Such a plant would have much higher operating costs as outlined in Table 18.

Table 18: Cash operating costs of a 2,750 tons per day and 660 tons per day soybean processing plant.

Cost Item (dollars per ton)	2,750 tons per day facility	660 tons per day facility
Fixed Labor Cost	2.35	9.80
Other fixed costs	1.76	7.35
Total fixed costs	4.11	17.15
Variable Costs		
Fuel for oilseed drying	.70	.70
Fuel for steam	4.67	2.35
Electricity	2.40	2.40
Water and sewer	.50	.50
Maintenance	1.69	4.41
Chemicals	2.00	1.20
Total variable costs	11.96	11.56
Total Cash Operating Costs	**16.07**	**28.71**

The primary cost difference is the higher level of fixed costs for the smaller plant. It should be noted that these figures are for a soybean crushing plant, but it is likely that the figures are similar for other oilseed crushing facilities.

Generally speaking, a stand-alone biodiesel facility that produces between 5 and 10 million gallons a year would cost between $7 and $12 million (Remco, p. 12). The figures for aviation fuel are likely to be similar to biodiesel since both fuels are petroleum distillates. The figures for both the crush plant and the stand-alone biodiesel facility do not include interest expense and, therefore, likely understate the actual cost. These figures are for 2005 and may also be somewhat low given a small increase in the price level since that time.

Table 19 outlines biodiesel production costs assuming that the cost of oil is 30 cents a pound and that it takes 7.5 pounds of oil to produce one gallon of biodiesel. The plant under consideration produces 5 million gallons of biodiesel a year. These figures are based on the Remco Feasibility Study carried out on behalf of the Michigan Department of Agriculture in 2005.

Table 19. Costs to produce biodiesel for large- and small- (farm) scale production facilities.

Cost Item	Large Scale ($)	Small Scale ($)
Feedstock costs		
Oil ($ per pound)	0.30	0.20
Oil ($ per gallon of biodiesel)	2.25	1.49
Variable costs (per gallon of biodiesel)		
Catalyst	0.08	0.18
Methanol	0.12	1.07
Natural gas	0.03	0.00
Electricity	0.02	0.02
Fuel treatment (winter)	0.00	0.06
Total variable costs	0.25	1.33
Fixed costs		
Salaries, wages and benefits (per gallon)	0.19	0.19
Maintenance	0.05	0.05
Insurance and taxes	0.02	0.00
Land lease	0.01	0.00
Equipment & other costs	0.15	1.65
Total fixed costs	0.42	1.89
Total costs per gallon	2.92	4.71

It should be noted that a larger fuel processing facility would have slightly lower variable and fixed costs per gallon. However, the dominant cost item is the oil, in this case accounting for more than 77 percent of the total cost per gallon.

This example does not include the value of the glycerin that is produced as a byproduct of the biodiesel process, and as such should be considered a worst-case scenario. If the biodiesel or bioaviation fuel industry becomes established, the glycerin market is likely to become flooded driving the price of glycerin to or near zero.

One alternative is to use a small portable press and extruder to separate the oil from the seed. While this would reduce the upfront capital costs and provide a method to do small-scale processing and show the potential for producing biofuels, its feasibility to process oilseeds on a commercial scale is doubtful.

Alternative payment schemes

Anytime a new commodity is introduced, additional risk is involved. Unlike commodities such as wheat or corn, there are few, if any, established markets. There is a well-established market for canola in Canada which gives canola an advantage over other energy crops. One way to promote the growth of dedicated energy crops is to guarantee price or revenue. This would directly reduce the risk faced by the grower. Providing support in the farm of subsidized seed or other inputs would also enhance the profitability and reduce the risk faced by the farmer.

Another way to address the issue of risk is through contracting. One example of this is a contract between an airport fuel company and growers of biofuel crops. A contract has the potential of insuring a market for the crop for the farmer and a supply of biofuel feedstock for the airport fuel company.

Establishing a supply chain from the farm to the airplane is another important consideration. Of particular importance is processing the oilseed, at least separating the oil from the seed. As is the case with most types of agricultural processing, oilseed processing exhibits economies of scale. In order to take advantage of these economies of scale and to generate enough feedstock to make it worthwhile to airports and other potential users of biofuels, sufficient amounts of the feedstock need to be produced and in a form (oil separated from the seed) that the biofuel producers and consumers find useful. One way to address this barrier is through the use of a cooperative that could own the oilseed press, transportation equipment and other inputs. Another alternative could be some type of joint venture between farmers and other actors along the supply chain. Addressing supply chain issues will be critically important if biofuels are going to be used for air transport.

Government policies

There are two major policies that impact the use of biofuels. The first is the Renewable Fuel Standard 2 (RFS 2) which establishes mandates for the use of both ethanol and biodiesel. The second is the Biomass Crop Assistance Program (BCAP), a program that provides incentives for farmers to grow dedicated biomass energy crops. Each of these policies will be discussed in turn.

RFS 2

The latest Energy Bill that went into effect on July 1, 2010, requires certain levels of fuel to be produced from renewable sources. This is referred to as RFS 2; the first Renewable Fuel Standard was in the previous Energy Bill. Table 20 shows the amount of biofuels that are to be produced from 2008 through 2022.

Table 20. Fuel volumes in the Renewable Fuels Standards 2 (billion gallons).

			Advanced Biofuels			
Year 1	**Conventional (Ethanol)**	**Biomass-based Diesel**	**Non-cellulosic Advanced**	**Cellulosic Biofuels**	**Total Advanced Biofuels**	**Total Renewable Fuel**
2008	9.00					9.00
2009	10.50	0.50	.10		.60	11.10
2010	12.00	.65	.20	.10	.95	12.95
2011	12.60	.80	.30	.25	1.35	13.95
2012	13.20	1.00	.50	.50	2.00	15.20
2013	13.80	1.00	.75	1.00	2.75	16.55
2014	14.50	1.00	1.00	1.75	3.75	18.25
2015	15.00	1.00	1.50	3.00	5.50	20.50
2016	15.00	1.00	2.00	4.25	7.25	22.25
2017	15.00	1.00	2.50	5.50	9.00	24.00
2018	15.00	1.00	3.00	7.00	11.00	26.00
2019	15.00	1.00	3.50	8.50	13.00	28.00
2020	15.00	1.00	3.50	10.50	15.00	30.00
2021	15.00	1.00	3.50	13.50	18.00	33.00
2022	15.00	1.00	4.00	16.00	21.00	36.00
Source: EPA						

Conventional ethanol from corn starch is allowed to increase from 9 billion gallons to 15 billion gallons by 2015. The major increase is in cellulosic biofuels which goes from zero in 2008 to 16 billion gallons in 2022. Non-cellulosic fuels such as fuel from algae and other sources including ethanol from sugar cane, is to increase from 100 million gallons in 2009 to four billion gallons by 2022. Overall, the amount of renewable fuel is to increase from 9 billion gallons in 2008 to 36 billion gallons by 2022. It should be noted that biomass-based diesel, non-cellulosic advanced and cellulosic biofuels are all considered advanced biofuels.

There are also some other changes in RFS 2 compared to the previous standard. Both on-road and off-road uses are included in the new standard. Diesel derived from soy oil, waste oils, fats and grease are classified as biomass-based diesel fuel (EPA). New facilities are also required to reduce greenhouse gas emissions using a lifecycle assessment. In the case of biomass-based diesel and non-cellulosic advanced biofuels, greenhouse gases are to be reduced by 50 percent, and a 60 percent reduction is required for cellulosic-based fuels. Existing facilities are grandfathered and do not have to meet greenhouse gas standards (EPA).

BCAP

The 2008 Farm Bill provides farmers with financial incentives to produce dedicated biomass crops. There are two primary incentives. The first incentive pays producers up to 75 percent of the cost of establishing a bioenergy perennial crop, not including equipment. Eligible crops include but are not limited to switchgrass, Miscanthus, fast growing wood poplar, jatropha, algae, energy cane and pongamia (USDA). The producers are paid annually for up to five years for herbaceous biomass and for up to 15 years for woody biomass. Upon sale of the crop, annual payments are reduced by 1 percent if the biomass is sold for cellulosic biofuels, 10 percent if the biomass is sold for other advanced biofuels, 25 percent if the biomass is sold for heat, power or biobased products and 100 percent if the biomass is sold for anything else (USDA).

The second incentive is assistance for the collection, storage and transportation of biomass-to-biomass conversion facilities (e.g. ethanol facilities, electric utilities) for two years per producer in the form of a matching payment for up to $45 per ton of the delivery cost to the facility (USDA). The payments are based on a matching rate of $1 for every $1 paid by a qualified biomass conversion facility (USDA). Bonus incentives are available for the cultivation of cellulosic biofuel materials that reduce greenhouse emissions by 60 percent.

There are conservation requirements that must be met in order to qualify for the payments. The biomass must be certified to have been collected and harvested only with an approved conservation, forest stewardship or similar plan. Harvesting must occur with an approved harvest plan, and cannot occur on native sod. All crop collection, harvesting and transportation must be done in strict accordance with invasive plant species protection (USDA).

Rough energy balance

Calculating net energy balance is as much art as it is science and is dependent on the assumptions used. The figures below will provide a general outline of calculating the net energy balance of producing biodiesel from canola. Data for Oriental mustard and other crops are more difficult to obtain, but the figures are likely to be similar. Of the crops used for this project, canola is the one that has been used the most to produce biodiesel.

Gross energy

These figures are based on canola. Other crops might be slightly different. The fuel used in this case is diesel; jet fuel is a distillate like diesel fuel and as a result the energy production should be similar.

It takes approximately 7.4 lbs. of canola oil to produce a gallon of biodiesel and there are 130,000 btus per gallon of biodiesel. The gross energy generated per ton of canola oil-based biodiesel is therefore:

$$\frac{130{,}000}{7.4} = 17{,}468 \text{ btus per lb.} \times 2{,}000 \text{ lbs.} = 35{,}135{,}135 \text{ btus per ton}$$

Energy used for crop production

$$\frac{2{,}993 \text{ (btus per kg)}}{2.2} = 1{,}360 \text{ (btus/lb.)} \times .43 \text{ (percentage oil)} = 585 \text{ (btus/lb./oil)} \times 2{,}000 =$$

1,169,991 btus/oil/ton

Energy used for transportation

This is based on energy per mile and assuming the truck gets 5 miles per gallon and the load is 80,000 lbs. Locating a biodiesel facility near the location where the biodiesel will be used will reduce the amount of energy used.

$$\frac{140{,}000 \text{ btus per gallon of petrol diesel}}{5 \text{ MPG}} = \frac{28{,}000 \text{ btus per gallon}}{80{,}000 \text{ lbs. per truck load}} = .35 \text{ btus per lb./mile}$$

This converts to 700 btus per ton per mile.

Alternatively assume 10 MPG and 30,000 lbs. per truck load

$$\frac{140{,}000 \text{ btus per gallon of petrol diesel}}{10 \text{ MPG}} = \frac{14{,}000 \text{ btus per gallon}}{30{,}000 \text{ lbs. per truck load}} = .47 \text{ btus per lb. mile}$$

This converts to 940 btus per ton per mile.

Energy used for processing

The energy used for processing figures is based on soybean crushing and conversion to biodiesel, which is a two-step process. Actual figures may be slightly different based on the feedstock used.

Crushing

$$\frac{3{,}290 \text{ (btus per kg)}}{2.2} = 1{,}495 \text{ (btus per lb./oil)} \times 2{,}000 = 2{,}990{,}909 \text{ btus/oil/ton}$$

Conversion oil to biodiesel

$$\frac{5{,}308 \text{ (btus per kg)}}{2.2} = 2{,}413 \text{ (btus per lb./biodiesel)} \times 2{,}000 = 4{,}825{,}454 \text{ btus/oil/ton}$$

The total energy requirement for biodiesel from canola is:

1,169,991 + 2,990,909 + 4,825,454 + Transportation

This equation is equal to the energy requirement to grow, crush the seeds, convert the oil to biodiesel and to transport the biodiesel to the fueling station.

Example

Example 1: 15 tons of biodiesel transported 40 miles and truck gets 10 miles to the gallon.

$$35{,}135{,}135 \times 15 = \frac{527{,}027{,}025 \text{ btus total energy produced}}{17{,}549{,}865 + 44{,}863{,}635 + 72{,}381{,}810 + 37{,}600} = 3.91$$

Example 2: 40 tons of biodiesel transported 80 miles and truck gets 5 miles to the gallon

$$\frac{1{,}405{,}405{,}400 \text{ btus total energy produced}}{46{,}799{,}640 + 119{,}636{,}360 + 179{,}418{,}160 + 56{,}000} = 4.06$$

In this example the net energy balance is positive. It should be noted that energy used for production and crushing is based on the proportion of oil in the seed. If all of the energy used was applied to the oil, the net energy balance would be lower.

Summary

The primary purpose of this project was to demonstrate that bioenergy crops could be produced on non-traditional land in Michigan and illustrate to farmers and other interested parties the potential to utilize bioenergy on-site and/or within relatively close proximity, thus decreasing our energy footprint and increasing our energy independence. Eleven sites including highway right of way, airport, vacant urban land and marginal farmland were selected to represent the geographic diversity of our state. This report chronicles the experiences, outputs, lessons learned, hurdles an opportunities for bioenergy production on these lands.

Marginal Land

Marginal land has been poorly defined in the literature (Dale, 2010) by generally includes soil structural properties, soil hydraulic properties, soil organic carbon sequestration, water quality, runoff, sedimentation and other biological and chemical properties (Blanco-Canqui, 2010). Campbell (2008) and Perlack (2005) have suggested that marginal land includes idle or fallow cropland, abandoned farmland and abandoned pastureland. We have extended this definition to include airport, right of way and vacant urban land for this project.

Regardless of how you define marginal land, there are some inherent limitations to producing high yielding bioenergy or other crops. Our demonstrations found low water holding capacity, high water holding capacity, poor soil structure, lack of chemical properties (fertility) and high water table/frequent ponding. Most of these limitations can be mitigated or reduced with proper management. However, one growing season is not long enough to address these issues.

Permits and Regulations

Utilizing airport and right of way sites require permits to be obtained and regulations to be followed. The Federal Aviation Administration (FAA) has a set of rules that govern how airport property is to be utilized by airport authorities. The goal of the FAA is to provide a safe environment for air travel. Of particular concern is planting crops on close proximity to flight zones that attract large bodied or flocking avian species that could pose a threat to aircraft. FAA granted permission to use land at three airports for this demonstration project but identified in partner network meetings that additional research would be needed in order to grant long term use for bioenergy crop production.

Michigan Department of Transportation (MDOT) is responsible managing and maintaining roadways that provide a safe travel corridor for motorists. They must manage environmental issues like soil erosion, protection of wetlands where possible and maintaining native species. There are a series of manuals, guides and advisories that contain standard operating procedures for use and access to highway right of way property. We found that production and harvest of any kind of crop is almost exclusively prohibited. Tillage operations, herbicide applications and operating farm equipment are necessary to production of bioenergy crops but strictly banned in the regulations. Permits are issued for projects such as road construction and utility installation or repair. The process for obtaining permits is especially burdensome and time consuming. Permit fees were mostly waived for this demonstration, but would normally be charged for anyone growing a bioenergy crop on the right of way. In addition, land rent is charged at fair market value for comparable agricultural land. Current regulation, permit application process and fees would need to be changed and adapted to allow for utilization of right of ways for bioenergy crop production.

Economics

The four farmer sites were used to determine the breakeven price for either Oriental mustard or canola. Selected cash costs ranged from $199-229 per acre for Oriental mustard and $207-237 per acre for canola. This was on owned land (no rental cost). Costs of processing seed into oil was calculated and added to the cost to produce the crop. The total cost for a farmer to produce oil ranged from 47-53 cents per pound of oil for Oriental mustard to 17-20 cents per pound for canola. The difference in cost per pound of oil was due primarily to higher harvested yields and higher oil content of the canola.

Using previously published reports cash operating costs for an oil processing plant, the cost of a large facility is estimated to be $16.07 a ton and the cost of a smaller facility is $28.71 per ton. The cost per gallon of a large scale biodiesel facility is estimated to be $2.92 of which 78% ($2.25) is the cost of the oil, assuming the price of the oil is 30 cents a pound. The small scale equipment cost of production was $4.67 per gallon. The higher cost for small scale equipment is indicative of the fact that economies of scale help reduce the cost of production as compared to a large scale production facility.

A rough energy balance for canola was also calculated. The results indicate that the net energy balance for canola is positive. Since the production practices for Oriental mustard are similar, it is likely that Oriental mustard would also have a positive net energy balance. These figures need to be interpreted carefully because the results vary based on the assumptions used to calculate the energy balance.

This project shows that bioenergy crops can be grown in the state. However, given the relative rates of return, individual farmers can almost certainly obtain higher profits from growing crops such as corn and soybeans. Also the market and supply chain for bioenergy crops is not well developed. Land currently not used for agricultural production such as airport land, abandoned urban land and highway right of ways offer some potential, although there are problems with this type of land as well. Airport land probably has the greatest potential for dedicated bioenergy crop production.

Opportunities associated with growing bioenergy crops include:

- Non-traditional cropland **does not compete with** land used for the production of food.
- Growing bioenergy crops has the potential to generate **economic activity and jobs** on land that currently does not generate income or jobs.
- Potential revenue for MDOT and airports through land rents.
- There are well **established markets** for some bioenergy crops.
- Potential for Michigan Department of Transportation to **run their fleet on biodiesel** produced from oilseed crops grown on non-traditional cropland.
- Potential for **jet fuel production** from oilseed crops grown on airport property.
- **Reduced dependence** on crude oil-based fuels.
- **Environmental benefits** (soil stabilization, carbon capture, etc.).

Barriers associated with growing bioenergy crops include:

- Getting farm equipment on and off highways.
- Federal and state regulations.
- Fair to poor soils.
- Potential wildlife attractant.
- Undeveloped markets for some bioenergy crops.
- Michigan lacks the capacity to crush canola, camelina and Oriental mustard and densify biomass crops (such as switchgrass).
- For some bioenergy crops there are no registered herbicides for weed control.
- Lack of knowledge about growing some bioenergy crops.
- Limited parcel size in right-of-ways and urban areas.

Authors Note

This project was initiated on October 1, 2010. Work was conducted during the fall and winter months to obtain permits, purchase equipment and inputs, and prepare for the upcoming planting season. On March 31, 2011 work was halted on the project pending review and clarification of eligibility by the U.S. Department of Energy. On May 4, 2011, approval was granted and work resumed. This put the project behind by six weeks which jeopardized successful demonstration of bioenergy crop production on all sites. Typically, oilseed crops would be planted in April and switchgrass in early May. This late start was the biggest contributor to poor crop production at all sites.

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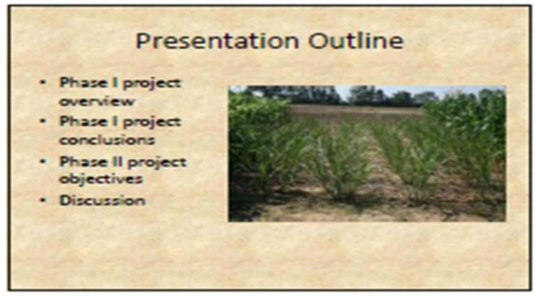
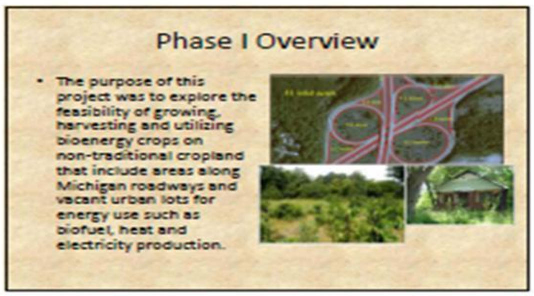
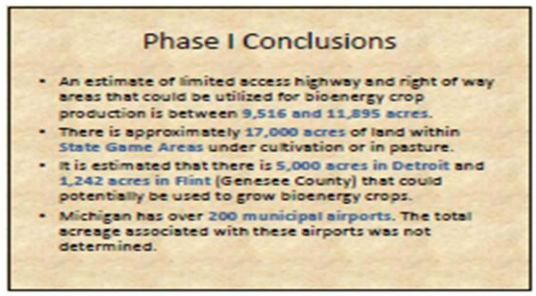
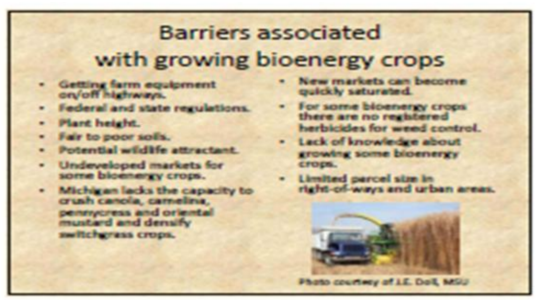
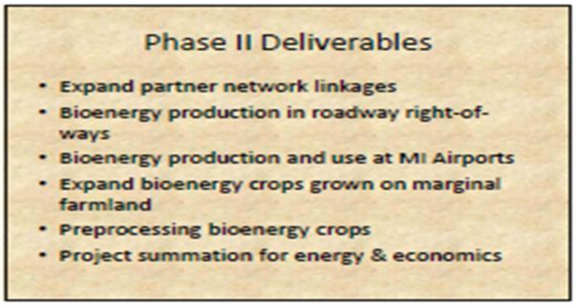
Appendix A. Report to Partner Network Members at January 2011 Meeting.

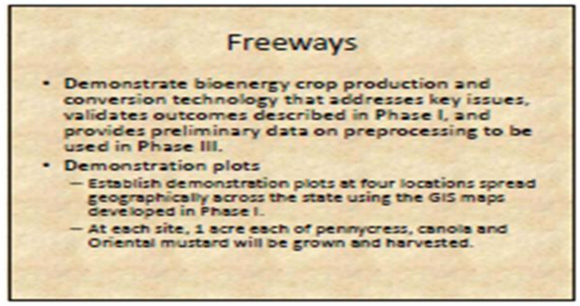


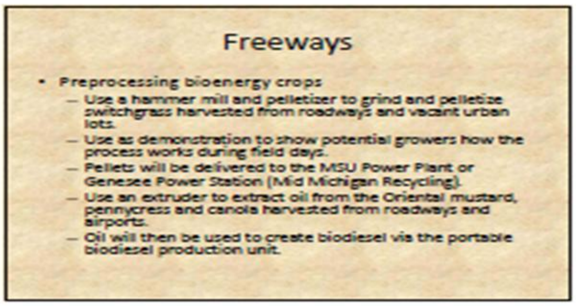







Phase II Deliverables
• Expand partner network linkages
• Bioenergy production in roadway right-of-ways
• Bioenergy production and use at MI Airports
• Expand bioenergy crops grown on marginal farmland
• Preprocessing bioenergy crops
• Project summation for energy & economics

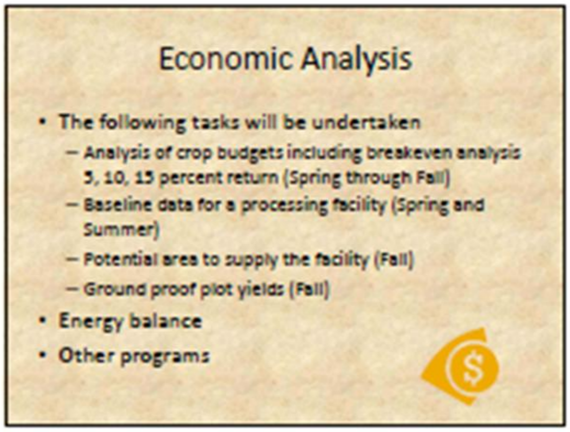

Freeways
• Demonstrate bioenergy crop production and conversion technology that addresses key issues, validates outcomes described in Phase I, and provides preliminary data on preprocessing to be used in Phase III.
• Demonstration plots
– Establish demonstration plots at four locations spread geographically across the state using the GIS maps developed in Phase I.
– At each site, 1 acre each of pennycress, canola and Oriental mustard will be grown and harvested.

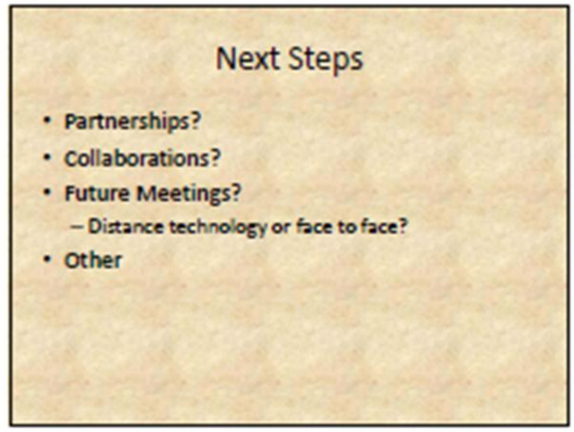

Freeways
• Preprocessing bioenergy crops
– Use a hammer mill and pelletizer to grind and pelletize switchgrass harvested from roadways and vacant urban lots.
– Use as demonstration to show potential growers how the process works during field days.
– Pellets will be delivered to the MSU Power Plant or Genesee Power Station (Mid Michigan Recycling).
– Use an extruder to extract oil from the Oriental mustard, pennycress and canola harvested from roadways and airports.
– Oil will then be used to create biodiesel via the portable biodiesel production unit.


Airports
• Three airports:
– Detroit Metro/Willow Run
– Muskegon County
– Gerald R. Ford
• Three crops at each site:
– Canola, oriental mustard, pennycress
• 1 acre of each crop at each site
• Discussion:
– Site location
– Security access
– Fertilizer and pesticide application

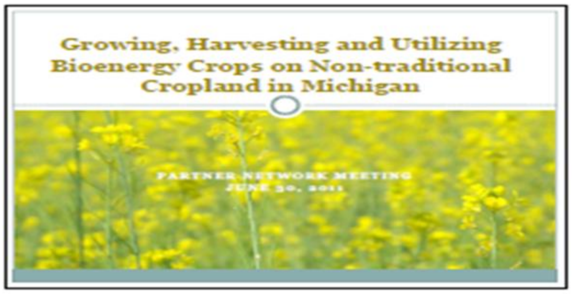

Urban Vacant Land
Flint
Partners:
• Flint office of the Mayor
• Genesee County Land Bank Authority
• Kettering University
Adjacent street corners:
• former building site
• grass lot
Crops: switchgrass, canola or oriental mustard

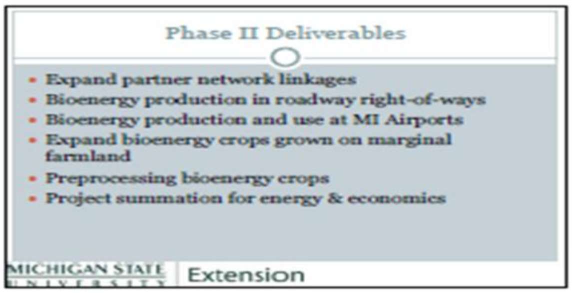

Farm Scale Production Sites
Four sites:
• Barry County – Pennycress
• Ottawa County – Oriental Mustard
• Osceola County – Canola
• Saginaw County – Canola
25 acres at each site
Should provide commercial quantity for processing
Evaluation of the crop productivity potential, agronomics, geographic fit

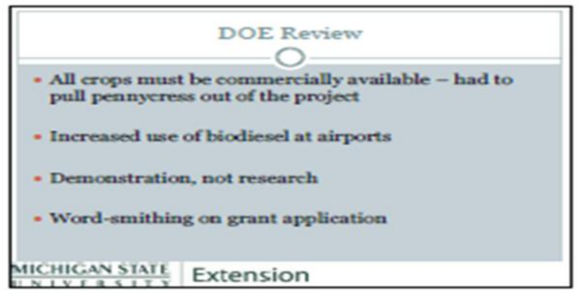

Economic Analysis
• The following tasks will be undertaken
– Analysis of crop budgets including breakeven analysis 5, 10, 15 percent return (Spring through Fall)
– Baseline data for a processing facility (Spring and Summer)
– Potential area to supply the facility (Fall)
– Ground proof plot yields (Fall)
• Energy balance
• Other programs

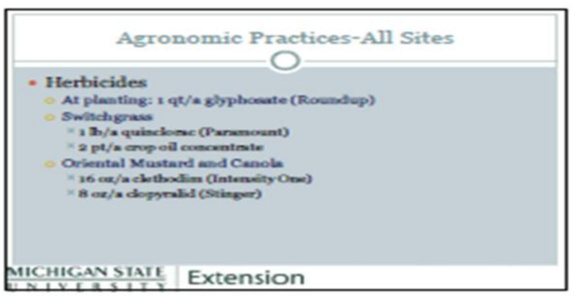

Next Steps
• Partnerships?
• Collaborations?
• Future Meetings?
– Distance technology or face to face?
• Other

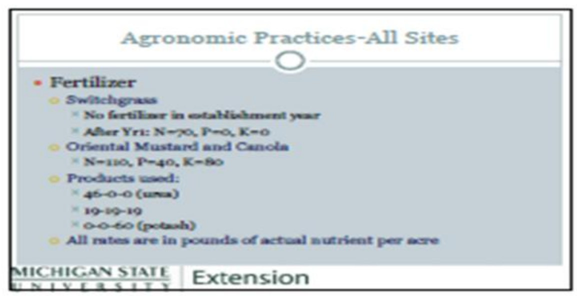
Appendix B. Report to Partner Network Members at June 2011 Meeting.

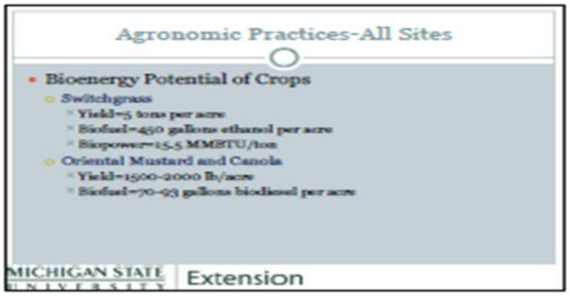











Agronomic Practices-All Sites
Bioenergy Potential of Crops
Switchgrass
Yield=5 tons per acre
Biofuel=450 gallons ethanol per acre
Biopower=15.5 MMBTU/ton
Oriental Mustard and Canola
Yield=1500-2000 lb/acre
Biofuel=70-93 gallons biodiesel per acre
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Planting
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Fertilizing
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Herbicide Application
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Highways
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Highway Sites
I69 at Exit 16
M6 at Byron Center Ave
Five Lakes Rest Stop
I75 at Exit 279 (Gaylord)
MICHIGAN STATE UNIVERSITY Extension


Highways
F2F Activities in other States
North Carolina
Ohio
Oregon
Tennessee
Utah
Washington
North Carolina F2F
Canola
MICHIGAN STATE UNIVERSITY
Extension


Airports
Three airports:
Detroit Metro/Willow Run
Muskegon County Airport
Gerald R. Ford International Airport
Two crops at each site:
Canola, Oriental mustard
One acre of each crop per site
MICHIGAN STATE UNIVERSITY
Extension


Airports
Flooding damage - DTW
MICHIGAN STATE UNIVERSITY
Extension


Airports
Weed Control - GRR
MICHIGAN STATE UNIVERSITY
Extension


Airports
Dry Conditions - MKG
MICHIGAN STATE UNIVERSITY
Extension


Replanting-GRR & MSK
MICHIGAN STATE UNIVERSITY
Extension


Replanting-GRR & MSK
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Replanting – Highways?
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Replanting – Highways?
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Farm Scale Production Sites
Field of Canola, Osceola County, MI
Four sites:
Barry County – Oriental Mustard
Ottawa County – Oriental Mustard
Osceola County – Canola
Saginaw County – Canola
25 acres at each site
Should provide commercial quantity for processing
Evaluation of the crop production potential, agronomics and geographic fit
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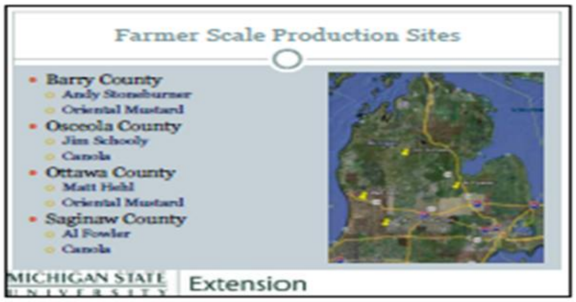
Extension


Farmer Scale Production Sites
Barry County
Andy Stoneburner
Oriental Mustard
Osceola County
Jim Schooly
Canola
Ottawa County
Matt Hehl
Oriental Mustard
Saginaw County
Al Fowler
Canola
MICHIGAN STATE UNIVERSITY
Extension


Vacant Urban Land
Flint, Michigan
Partners:
Flint office of the Mayor
Genesee County Land Bank Authority
Kettering University
Adjacent street corners:
former building site
grass lot
Crops: switchgrass, canola or miscanthus
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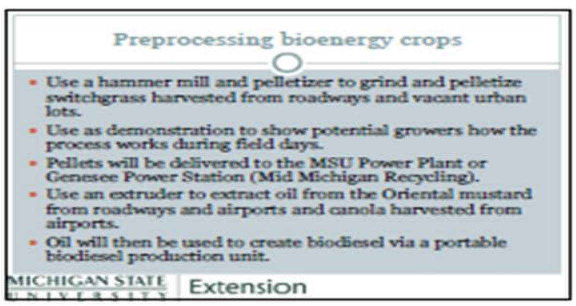
Extension


Vacant Urban Site
MICHIGAN STATE UNIVERSITY
Extension


Urban
MICHIGAN STATE UNIVERSITY
Extension


Preprocessing bioenergy crops
Use a hammer mill and pelletizer to grind and pelletize switchgrass harvested from roadways and vacant urban lots.
Use as demonstration to show potential growers how the process works during field days.
Pellets will be delivered to the MSU Power Plant or Genesee Power Station (Mid Michigan Recycling).
Use an extruder to extract oil from the Oriental mustard from roadways and airports and canola harvested from airports.
Oil will then be used to create biodiesel via a portable biodiesel production unit.
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Economic Analysis
The following tasks will be undertaken
Analysis of crop budgets including breakeven analysis 5, 10, 15 percent return (Spring through Fall)
Baseline data for a processing facility (Spring and Summer)
Potential area to supply the facility (Fall)
Ground proof plot yields (Fall)
Energy balance
Other programs
MICHIGAN STATE UNIVERSITY
Extension

Next Steps

- Develop an economic model for Michigan farmers and entrepreneurs.
- Continue work on demonstration sites.
- Initiate preprocessing component
  - Biodiesel, pelletizing

Harvesting miscanthus. Photo courtesy of J.E. Doll, MSU.

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- **Project Oversight Committee**
  - **Charles Gould**
  - **Bill Knudson,**
  - **Terry McLean**
  - **Dennis Pennington**
  - **Mark Seamon**
  - **Terri Novak**
- **Funding for this project comes from a grant from the Michigan Department of Energy, Labor and Economic Growth.**

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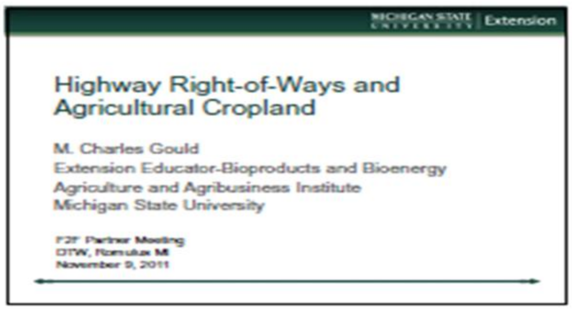
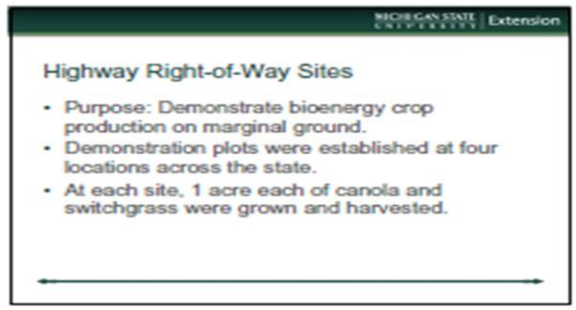
Appendix C. Report to Partner Network Members at November 2011 Meeting.





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Bioenergy Potential of Crops

- Switchgrass
  - Yield=5 tons per acre
  - Biofuel=450 gallons ethanol per acre
  - Biopower=15.5 MMBTU/ton
- Canola
  - Yield=1500-4800 lb/acre
  - Biofuel=75 -240 gallons of biodiesel per acre
- Oriental Mustard
  - Yield=1500-2000 lb/acre
  - Biofuel=70-93 gallons biodiesel per acre

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MDOT Biodiesel Example

- The MDOT-owned fleet used 1,028,809 gallons of diesel and 1,971 gallons of E85 in 2010.
- Assume a yield of 77 gallons of biodiesel/A (from canola).
- Requires 13,361 acres of canola to produce the biodiesel necessary to power MDOT's fleet.

Source: http://www.fapri.missouri.edu/outreach/publications/2006/biofuelconversions.pdf

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MDOT Highway ROW Policy

- MDOT did not have policy in place for the kind of work we wanted to do.
- Each highway site required a permit, plus safety signs and placards when working at a site.
- Permit process required a great deal of paperwork and levels of approval.
- Permits cost a total of $505.
- Recommendations
  - Streamline the permit application process.
  - Amend current policy to allow utilization of HROW for bioenergy crop use.

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Agricultural Cropland Sites

- Purpose: Demonstrate bioenergy crop production and conversion technology.
- Demonstration plots were established at four locations across the state.
- One 5 acre site of Oriental mustard and three 25 acre sites of canola were grown and harvested.

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Preprocessing bioenergy crops

- Use a hammer mill and pelletizer to grind and pelletize switchgrass harvested from roadways and vacant urban lots.
- Use as demonstration to show potential growers how the process works during field days.
- Pellets will be delivered to the MSU Power Plant or Genesee Power Station (Mid Michigan Recycling).
- Use an extruder to extract oil from the Oriental mustard and canola harvested from roadways and airports.
- Oil will then be used to create biodiesel via a portable biodiesel production unit.

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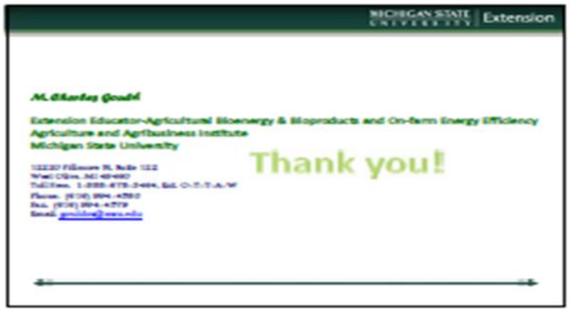
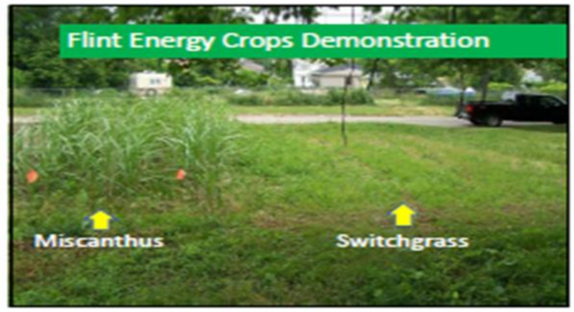
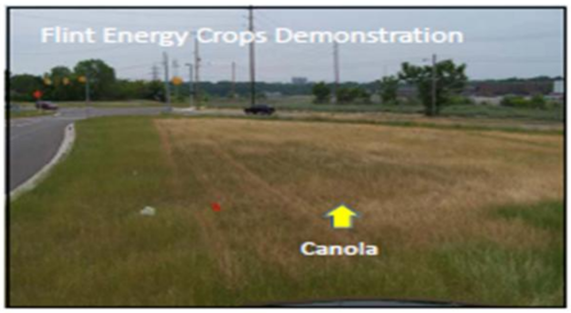
Biodiesel processor and oilseed press

The 80 gallon Genesee Processor.

Able to produce 200-300 gallons per day (2-3 tons p/day), 1500 gallons per week, 90,000 per year.


MICHIGAN STATE UNIVERSITY | Extension
M. Charles Gould
Extension Educator-Agricultural Bioenergy & Bioproducts and On-farm Energy Efficiency
Agriculture and Agribusiness Institute
Michigan State University
Thank you!


Flint Energy Crops Demonstration
Miscanthus
Switchgrass


Flint Energy Crops Demonstration
Canola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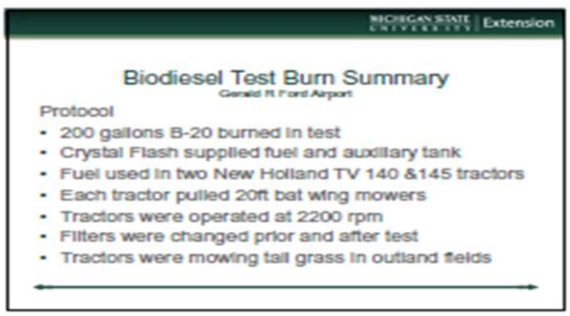
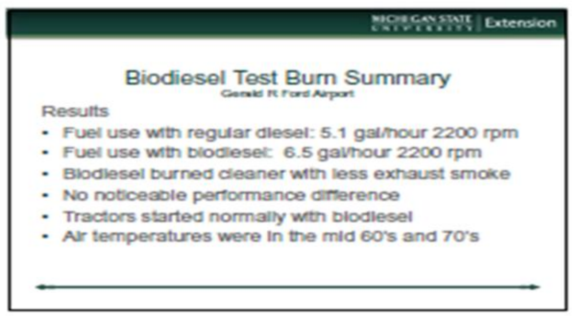
Mobile biomass hammermill and pellet mill


MICHIGAN STATE UNIVERSITY | Extension
Biodiesel Test Burn Summary
Gerald R Ford Airport
Protocol
• 200 gallons B-20 burned in test
• Crystal Flash supplied fuel and auxiliary tank
• Fuel used in two New Holland TV 140 &145 tractors
• Each tractor pulled 20ft bat wing mowers
• Tractors were operated at 2200 rpm
• Filters were changed prior and after test
• Tractors were mowing tall grass in outland fields


MICHIGAN STATE UNIVERSITY | Extension
Biodiesel Test Burn Summary
Gerald R Ford Airport
Results
• Fuel use with regular diesel: 5.1 gal/hour 2200 rpm
• Fuel use with biodiesel: 6.5 gal/hour 2200 rpm
• Biodiesel burned cleaner with less exhaust smoke
• No noticeable performance difference
• Tractors started normally with biodiesel
• Air temperatures were in the mid 60's and 70's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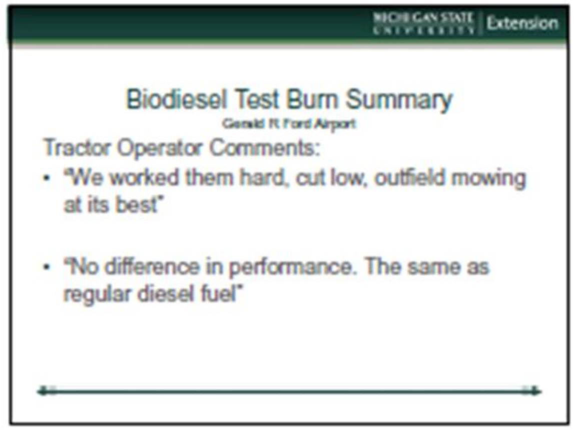
Biodiesel Test Burn Summary
Gerald R Ford Airport
Tractor Operator Comments:
• "Burned cleaner. When I hit the tall grass the tractor really put out the black smoke with the regular diesel, it didn't do that with the B-20"
• "I really like this, it is so much cleaner. We should burn this more"


MICHIGAN STATE UNIVERSITY | Extension
Biodiesel Test Burn Summary
Gerald R Ford Airport
Tractor Operator Comments:
• "We worked them hard, cut low, outfield mowing at its best"
• "No difference in performance. The same as regular diesel fuel"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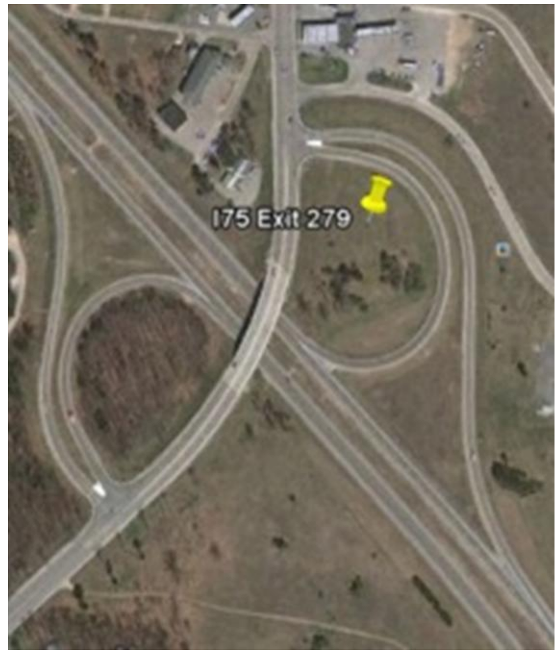
• Project Oversight Committee
• Charles Gould
• Bill Knudson,
• Terry McLean
• Dennis Pennington
• Mark Seamon
• Terri Novak
• Funding for this project comes from a grant from the Michigan Department of Energy, Labor and Economic Growth.

Appendix D. Maps of highway right-of-way sites.

I-69 Exit 16 (Branch County).



I-69 Rest Stop (Lapeer County).

I-75 Exit 279 (Otsego County).

M-6 Exit 5 (Kent County).

Appendix E. MDOT right-of-way permit.

Page 1 of 2

MDOT
Michigan Department of Transportation

INDIVIDUAL CONSTRUCTION PERMIT
For Operations within State Highway Right-of-Way

Issued To:
Michigan State University Extension

12220 FILLMORE ST, STE 122
WEST OLIVE MI 49460-8986

Contact:
Merrill Gould
616-994-4580(O)
gouldm@msu.edu

Permit Number: 69013-004810-11-060311
Permit Type: Individual Application
Permit Fee: $30.00
Effective Date: Jun 03, 2011 to Jun 03, 2012
Bond Numbers
Liability Insurance Expiration Date:

THIS PERMIT IS VALID ONLY FOR THE FOLLOWING PROPOSED OPERATIONS :

PURPOSE:

To demonstrate that bioenergy crops can be grown successfully on highway right-of-ways and verify the production and economic data presented in Phase I. This will be accomplished by establishing demonstration plots at four locations geographically located across the state. The southeast quadrant of the I-75 and Old US 27 interchange is one of the four sites. At each site, one acre each of switchgrass and Oriental mustard will be grown and harvested.

STATE ROUTE: I-75 **TOWNSHIP OF:** Bagley **COUNTY:** Otsego County

TOWN	RANGE	SECTION
T 30 N	R 3 W	21

NEAREST INTERSECTION:	SIDE OF ROAD:	DISTANCE TO (in feet) NEAREST INTERSECTION:	DIRECTION TO NEAREST INTERECTION:
I-75 and Old US 27	East, South	0	North

CONTROL SECTION:	MILE POINT FROM:	MILE POINT TO:	LOCATION: LEFT	MEDIAN	RIGHT	TRANSVERSE
69013	9.590	9.730	☐	☐	☑	☐

REQUISITION NUMBER: **WORK ORDER NUMBER:** **MDOT JOB NUMBER:** **ORG JOB NUMBER:**

This permit is incomplete without "General Conditions and Supplemental Specifications"

I certify that I accept the following:

1. I am the legal owner of this property or facility, the owner's authorized representative, or have statutory authority to work within state highway Right-of-Way.
2. Commencement of work set forth in the permit application constitutes acceptance of the permit as issued.
3. Failure to object, **within ten (10) days** to the permit as issued constitutes acceptance of the permit as issued.
4. If this permit is accepted by either of the above methods, I will comply with the provisions of the permit.

69013-004810-11-060311 Issued To:Michigan State University Extension

5. I agree that Advance Notice for Permitted Activities for shall be submitted **5 days prior** to the commencement of the proposed work.

   I agree that Advance Notice for Permitted Utility Tree Trimming and Tree Removal Activities shall be submitted **15 days prior** to the commencement of the proposed work for an annual permit.

NOTE: Work shall NOT begin until the Advance Notice has been approved. Failure to submit the advance notice may result in a Stop Work Order.

☐ **By checking this box, I certify that I have read and agree to follow the General Conditions, Supplemental Specification, and attached permit requirements. Failure to comply with the conditions of the document may result in a Stop Work Order or the permit may be revoked.**

	Justin Wing	**June 03, 2011**
Property or Facility Owner or Representative	**MDOT**	**Approved Date**

THE STANDARD ATTACHMENTS, ATTACHMENTS AND SPECIAL CONDITIONS MARKED BELOW ARE A PART OF THIS PERMIT.

STANDARD ATTACHMENTS:

1 General Conditions for Permit (General Conditions)

ATTACHMENTS

SPECIAL CONDITIONS

1 The Department of Transportation does not, by issuance of this permit, assume any liability claims or maintenance costs resulting from the Bio Energy Crop facility placed by this permit. The Department reserves the right to require removal of all or any portion of this facility as needed for highway maintenance or construction purposes without replacement or reimbursement of any costs incurred by the permitted or other party. The permitted will defend, indemnify and hold harmless the Department for any claims whatsoever resulting from the construction or the removal of the authorized by this permit.

2 Special Condition 4 This Permit is invalid without the MDOT bio energy general permit conditions and work shall not commence without receipt of the bio energy general permit conditions.

Appendix F. MDOT signed performance agreement and ag land special permit conditions.

Michigan Department Of Transportation
2207E (07/10)

PERFORMANCE AGREEMENT FOR UNIVERSITIES or COLLEGES

Page 1 of 2

This Performance Agreement is required by the Michigan Department of Transportation for purposes of issuing to a University or College an "Individual Permit for Use of State Trunkline Right of Way" (form 2205), or an "Annual Application and Permit for Miscellaneous Operations Within State Trunkline Right of Way"(form 2205B).

WHEREAS, the Michigan State University
(Name of University or College)

hereinafter referred to as the "UNIVERSITY or COLLEGE," periodically applies to the Michigan Department of Transportation, hereinafter referred to as the "DEPARTMENT," for permits, referred to as "PERMIT," to construct, operate, use and/or maintain utility or other facilities, or to conduct other activities, on, over, and under state trunkline right of way at various locations;

NOW THEREFORE, in consideration of the DEPARTMENT granting such PERMIT, the UNIVERSITY or COLLEGE agrees that:

1. Each party to this Agreement shall remain responsible for any claims arising out of its own acts and/or omissions during the performance of this Agreement, as provided by law.

2. Any work performed for the UNIVERSITY or COLLEGE by a contractor or subcontractors will be solely for the UNIVERSITY or COLLEGE and not as a contractor or agent of the DEPARTMENT. The DEPARTMENT shall not be subject to any obligations or liabilities by vendors and contractors of the UNIVERSITY or COLLEGE, or their subcontractors or any other person not a party to the PERMIT without its specific prior written consent and not withstanding the issuance of the PERMIT. Any claims against the State of Michigan, the Transportation Commission, the DEPARTMENT, and all officers, agents, and employees thereof will be the sole responsibility of the UNIVERSITY or COLLEGE. Certificate of insurance shall be provided to the Department by the contractors. The liability policies shall meet the requirements of the Departments Permit.

3. The UNIVERSITY or COLLEGE will, by its own volition and/or request by the DEPARTMENT, promptly restore and/or correct physical or operating damages to any State trunkline right of way resulting from the installation, construction, operation and/or maintenance of the UNIVERSITY or COLLEGE facilities according to a PERMIT issued by the DEPARTMENT.

4. With respect to any activities authorized by PERMIT, when the UNIVERSITY or COLLEGE requires insurance on its own or its contractor's behalf it shall also require that such policy include as named insured the State of Michigan, the Transportation Commission, the DEPARTMENT, and all officers, agents, and employees thereof and those governmental bodies performing permit activities for the DEPARTMENT and all officers, agents, and employees thereof, pursuant to a maintenance contract.

06/08/2011 16:05 1616554372 THE UPS STORE PAGE 01/02

Special Conditions for
Agricultural Use of Limited Access Right-of-Way

1. MDOT does not, by issuance of this permit, assume any liability claims or maintenance costs resulting from the bio-energy crop facility placed by this permit. MDOT reserves the right to require removal of all or any portion of this facility as needed for highway maintenance or construction purposes without replacement or reimbursement of any costs incurred by the permit holder or other party. The permit holder will defend, indemnify and hold harmless MDOT for any claims whatsoever resulting from the construction or the removal of the authorized by this permit.
2. The permit holder shall comply with the MDOT General Conditions and Supplemental Specifications, (Form 2205-1).
3. The permit holder shall comply with all specific special conditions included on each permit.
4. A License Agreement, (Form 2490) and associated fees and rent shall be required.
5. A Performance Resolution for Universities or Colleges, (Form 2207E) shall be required.
6. In subsequent years, all permitted activities shall comply with the following:
   - Context Sensitive Solution (Form 3727)
   - Adopt-a-Landscape Instructions, (3728)
   - Adopt-a-Landscape Site Plan Checklist, (Form 3737)
   - Adopt-a-Landscape Vegetation Management and Work Plan Checklist, (Form 3738)
   - Adopt-a-Landscape Context Sensitive Solutions Checklist, (Form 3739)
   - Adopt-a-Landscape Maintenance Plan Checklist, (Form 3740)
7. Operations require a Road Work Ahead sign or arrow board in bar mode as specified in MD-01 to ensure public safety is assured.
8. The permit holder is responsible for securing the permission of any underlying property owner where easement or statutory Right-of-Way is involved.
9. Only canola and switchgrass planting is permitted.
10. Each site shall only be accessed 4 times each year as follows:
    a. Spring fertilization and seeding using no-till method
    b. Late summer harvest for canola (access is allowed twice)
    c. Fall harvest for switchgrass
11. Permission to access each site is limited to the following vehicles and equipment:
    a. 2 each standard size pickup trucks
    b. 2 each flatbed trailers
    c. 1 each small utility tractor
    d. 1 each ATV with fertilizer broadcast spreader
    e. 1 each 3 point hitch sickle bar type mower
    f. 1 each 5' wide swather
    g. 1 each small plot combine
    h. 1 each JD 330 round baler
    i. 1 each pallet forks
    j. 1 each small skid loader

10\. For the research project only, access to and from Limited Access Right-of-Way will be according to the MDOT agreed upon plan. In subsequent years, access shall only be

Appendix G. Web Soil Survey Muskegon County Airport.

Muskegon County, Michigan

RsB—Rubicon sand, 0 to 6 percent slopes

Map Unit Setting

Elevation: 600 to 1,000 feet
Mean annual precipitation: 30 to 36 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 140 to 150 days

Map Unit Composition

Rubicon and similar soils: 95 percent

Description of Rubicon

Setting

Landform: Outwash plains
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy outwash

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water capacity: Low (about 3.8 inches)

Interpretive groups

Land capability (nonirrigated): 6s

Typical profile

0 to 5 inches: Sand
5 to 28 inches: Sand
28 to 60 inches: Sand

Data Source Information

Soil Survey Area: Muskegon County, Michigan
Survey Area Data: Version 5, Jun 22, 2009

Appendix H. Web Soil Survey, Gerald R. Ford International Airport Site.

Kent County, Michigan

19B—Blount loam, 2 to 6 percent slopes

Map Unit Setting

Elevation: 580 to 1,530 feet
Mean annual precipitation: 30 to 36 inches
Mean annual air temperature: 45 to 48 degrees F
Frost-free period: 140 to 150 days

Map Unit Composition

Blount and similar soils: 91 percent
Minor components: 9 percent

Description of Blount

Setting

Landform: Moraines
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy till

Properties and qualities

Slope: 2 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.57 in/hr)
Depth to water table: About 12 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Moderate (about 7.4 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 7 inches: Loam
7 to 23 inches: Silty clay loam
23 to 60 inches: Silty clay loam

Minor Components

Pewamo

Percent of map unit: 3 percent
Landform: Depressions on till plains, depressions on moraines

Rimer

Percent of map unit: 2 percent
Landform: Drainageways on outwash plains, drainageways on till plains

Belleville

Percent of map unit: 2 percent

Landform: Depressions on till plains, depressions on lake plains

Colwood

Percent of map unit: 2 percent

Landform: Depressions on lake plains

Data Source Information

Soil Survey Area: Kent County, Michigan

Survey Area Data: Version 9, Jun 19, 2009

Appendix I: Web Soil Survey, Detroit Metro International Airport Site.

Wayne County Area, Michigan

Pe—Pewamo loam

Map Unit Setting

Elevation: 570 to 720 feet
Mean annual precipitation: 28 to 34 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 160 days

Map Unit Composition

Pewamo and similar soils: 90 percent
Minor components: 10 percent

Description of Pewamo

Setting

Landform: Depressions on till-floored lake plains
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 10 inches: Loam
10 to 36 inches: Silty clay loam
36 to 60 inches: Silty clay loam

Minor Components

Blount

Percent of map unit: 4 percent
Landform: Flats on till-floored lake plains
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Convex

Corunna

Percent of map unit: 3 percent

Landform: Depressions on till-floored lake plains, depressions on lake plains
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear

Metamora

Percent of map unit: 3 percent
Landform: Drainageways on till-floored lake plains
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Convex

Data Source Information

Soil Survey Area: Wayne County Area, Michigan
Survey Area Data: Version 8, Dec 8, 2011

Appendix J: Evaluation Results from On Farm Biodiesel Demonstrations.

1. As a result of attending this demonstration my knowledge level has: (check one)

3	25%	Considerably Increased
7	58%	Increased
2	17%	Somewhat Increased
0	0%	Not Changed

2. As a result of attending this demonstration, I am confident in making decisions based on the subject matter. (check one)

2	17%	Strongly Agree
5	42%	Agree
5	42%	Neutral
0	0%	Disagree
0	0%	Strongly Disagree

3. As a result of attending this demonstration, I am thinking of making a change in farm practices. (check one)

0	0%	Strongly Agree
2	17%	Agree
8	67%	Neutral
2	17%	Disagree
0	0%	Strongly Disagree

4. I plan to utilize the information gained from this session: (check one)

1	8%	Strongly Agree
7	58%	Agree
4	33%	Neutral
0	0%	Disagree
0	0%	Strongly Disagree

5. Do you plan to produce a bioenergy crop on your farm? (check one)

3	25%	Yes
9	75%	No

6. How likely are you to invest in equipment to produce biodiesel? (check one)

1	8%	Very likely
3	25%	Somewhat likely
8	67%	Probably not
0	0%	Need more information to answer this

7. Have you used biodiesel on your farm in the past or now? (check one)

6	50%	Yes
6	50%	No

8. If you answered yes to question 7, what blend have you used? (Check all that apply)

0	0%	B100
0	0%	B50
5	63%	B20
3	38%	B5
0	0%	Other ___________________

9. Please list up to three reasons for your answer in question 7:

I did up to 2 yrs ago until the price of B20 got too high.
Like it.
Not available.
Wanted to try it.
Use soybean oil for renewable energy.
Environmental.
Cost savings of oil.
Meal bi-product.
Haven't heard a lot of good things about it.
Didn't know much about it.
Increased lubricity of biodiesel.
Reduced maintainance.
Support farmers.

10. Have you encountered problems from biodiesel usage? (If yes, please explain)

2	22%	Yes
7	78%	No

Got some poor quality animal fat.
Dissolved sludge and plugged filters until system was cleaned out.
Also affected some old hoses.

11. Do you plan to use biodiesel on your farm in the future? (check one)

7	70%	Yes
3	30%	No

12. What factors are important to you in determining whether or not to produce biodiesel on farm? (check all that apply)

9	Economics of production
0	Not sure how to grow oilseed crop

4	Land availability
2	Labor to operate equipment
4	Equipment to store and handle seed and oil
2	Prefer to use biodiesel
4	Environmental benefit

13. Do you have any suggestions to improve this demonstration:
    Was great.
    Presenters were very knowledgeable.
    Good demonstration.
    Good job - very informative.

Acknowledgement: “This material is based upon work supported by the Department of Energy under Award Number(s) DE-EE0000753.”

MICHIGAN STATE UNIVERSITY | Extension

PURE MICHIGAN® Energy Office