Plant Power:
Biomass-to-Energy for Minnesota Communities

May 14, 2004

<u>Report Prepared for:</u>

Minnesota Department of Commerce
www.commerce.state.mn.us

Minnesota Office of Environmental Assistance
www.moea.state.mn.us

<u>Report Prepared by:</u>

Minnesotans for an Energy-Efficient Economy
www.me3.org

Principal Researcher – Shalini Gupta

Report Contents

Project Overview

The aim of this project is to provide an assessment of Minnesota's current status in developing biomass heat and power projects, to learn from existing biomass energy project applications, and help identify potential communities and locations where near-term biomass technologies can be developed.

Section I lists potential locations where plant-residue fueled district heating systems and centralized biogas plants could be developed in Minnesota. Criteria for prioritization include: being a top county in estimated biomass availability, having assigned Job Opportunity Building Zone (JOBZ) acreage, and the presence of large natural gas users in the area. Rising natural gas prices are making biomass fuels more competitive, and locations with significant natural gas users may provide a competitive market for heat from combusted plant residue and biogas from anaerobically digested organic matter. Locations listed are preliminary, based on existing and available data; meant only to be a guide to potential locations where future feasibility studies could be implemented.

Section II contains a preliminary inventory of existing and planned biomass heat and power projects in Minnesota. The inventory does not include facilities utilizing landfill gas, refuse derived fuels (RDF), or facilities co-firing biomass with other fossil fuels. The inventory was assembled through conversations with government officials, private developers, university researchers, environmental engineers, Clean Energy Resource Team (CERTS) coordinators, and various other professionals working in the renewable energy field. Newspaper clippings and state legislation were also sources of information. The list of existing projects may not be complete as private industry-based combined heat and power (CHP) projects were difficult to confirm.

Based on the inventories developed in Section I, three broad biomass-to-energy technology concepts were chosen to be investigated further. The following three concepts were chosen because there are currently projects being planned relating to them, there was broad interest shown by multiple stakeholders in learning more about those technology concepts, and there were established on-the-ground applications outside of the state. The three are:

(1) <u>Plant Residue-fueled District Heating Systems</u>
Combustion of urban wood waste, forest residues, sawmill residues, and/or agricultural residues for community heating purposes. The term district (or community) heating, refers to facilities that produce heat without generating electricity, and distribute that heat to a set of residential, commercial, and/or industrial thermal load users via a system of distribution pipes.

(2) <u>On-farm Anaerobic Co-digestion of Multiple Waste Streams</u>
A single, farmer owned, anaerobic digester which is co-digesting the farm's animal manure as well as local agro-industrial wastes, for the production of heat and/or power.

(3) <u>Centralized Biogas Plants</u>
A centrally located anaerobic digester utilizing manure from multiple farms as well as organic waste streams from regional industries, for the production of heat and/or power.

Section III outlines existing applications of the three technology concepts, including U.S. and international applications.

Sources for the case studies included project websites, existing publications, newspaper articles, and conversations with project developers, financiers, and organizers. Each case study generally covers the following areas: reason for developing, fuel source, system components, output energy and products, emissions and environmental concerns, ownership structure, partnerships employed, financing, policy initiatives, and challenges faced.

Section I: Potential Locations for Project Development

More Minnesota communities relied on district energy systems at the turn of the century than do today. District energy is a simple idea, and its time has come again, especially since natural gas costs are volatile and rising. A district energy system relies on a common energy source, like a boiler, combined with a system of pipes connecting the buildings. The pipes can be used to distribute hot water in the winter for heating or chilled water in the summer for cooling. In hundreds of European towns, where cheap natural gas is unavailable or the gas distribution infrastructure is weak, district energy is very common. Often, all the homes, commercial businesses, and industries in a town are connected to a network of highly insulated underground pipes, and a single boiler is used to heat the town. Increasingly, absorption chillers are being added to such systems to provide summer cooling as well.[1]

The primary attraction of district energy is its potential for high efficiency. Efficiency gains can be achieved not only in the buildings themselves by insulating and improving air tightness, but also by increasing the efficiency of combustion. Exceptionally efficient systems use the energy from waste heat of highly efficient electric power plants. By substituting bio-based energy sources for fossil fuels, district energy can offer both high efficiency and the many economic and environmental benefits of renewable energy.

Another technology gaining increasing attention in northern Europe is the production of energy (either thermal or electrical) through centralized management of animal wastes in manure digesters. The scale can be of modest size, combining manure from several farms by trucking or piping it to a common location. Turnkey, computer-controlled manure digesters are installed by specialized companies, such as Dansk Biogas. Environmental benefits and challenges posed by these technologies are outside the scope of this paper however.

The following section identifies potential locations in Minnesota where plant-residue fueled municipal heating systems and/or centralized biogas plants could be further investigated. The sites listed were the outcome of comparing multiple data sets with strict criteria guidelines. Data sets used to determine the sites included information on: biomass availability, competitive alternative fuel usage, and state policy advantages such as the allotment of JOBZ. The analysis is restricted by the type of data available and the baseline criteria outlined, and should only be taken as a preliminary guide to further study.

Criteria for Plant-residue Fueled Municipal Heating Systems

The potential sites for plant-residue fueled district heating system sites were selected according to criteria based on lessons learned from case studies in Section III and relevant literature.[2] All listed potential locations were required to meet the following criteria:

1. Must be in a county that is ranked as being in the top ten of all counties in Minnesota for at least one of the following biomass residues: forest residues, mill residues, urban wood waste, and agricultural residues. There are 87 counties in Minnesota. If the county ranks in the top 15 of a second biomass residue, that is also listed.[3]
   - It is critical that an adequate amount of plant-residue fuel is available within close proximity to the district heating plant to minimize transportation costs.

---

[1] Minnesota Project, 1980, "District Heating in Minnesota: A Strategy for Small Communities"

[2] Minnesotans for an Energy-Efficient Economy, March 2004, "Biomass-community energy systems: a viable near-term option for Minnesota communities"; available online at www.me3.org/issues/biomass/community.pdf.

[3] Data Sources: Oak Ridge National Laboratory (ORNL) preliminary October 2003 county level estimates for forest residues, urban wood waste, and agricultural residues; and Minnesota Department of Natural Resources (DNR) 2001 estimates of unused, available county level mill residue estimates. ORNL counties were ranked based on quantities available at lowest available price classes. As these rankings are based on national and state studies, local actual biomass amounts available may vary.

2. Must have a localized total natural gas consumption greater than 100,000 MMBtu per year.[4]
   - Locations with large natural gas fuel users are expected to be more affected by fluctuating natural gas prices, creating a market opening for biomass fuels. Major industrial fuel users are also likelier to have the high thermal loads needed to support a community energy system.

3. Must have Job Opportunity Building Zone acreage assigned to the location.[5]
   - Projects can decrease investment costs by taking advantage of state incentives for economic development.

4. Must have greater than 30% of the city's commercial boilers older than 30 years[6].
   - Renovating/Constructing a district energy system is expected to garner more support if a significant number of commercial boilers in the location are already in need of replacement.

5. Must not have had a District Energy System that was abandoned after 1980.[7]
   - Cities that have recently abandoned their district heating systems will most likely have newer individual building boilers installed that would not be cost-effective to replace.

---

[4] Data Source: Minnesota Pollution Control Agency boiler permit database; most recent complete data year is 2001.
[5] Data Source: Minnesota Department of Employment & Economic Development JOBZ list: www.dted.state.mn.us/searchframe.asp?url=jobz.asp
[6] Data Source: Minnesota Department of Labor & Industry boiler and pressure vessel database: http://workplace.doli.state.mn.us/codesearch
[7] Minnesota Project, 1980, "District Heating in Minnesota: A Strategy for Small Communities"; Local Government Websites; University of Rochester District Energy Library, accessible at www.energy.rochester.edu; Personal Communication with Utilities.

Potential Sites for Plant-residue District Heating Systems

Sites listed are preliminary and are only to be a guide to potential locations where future feasibility studies could be implemented. Potential locations were chosen based solely on the strict criteria outlined in (1-5) above. Locations are listed in alphabetical order.

Cities	Cities	Cities
Albert Lea	Melrose	Sherburn
Duluth	New Ulm	St. Cloud
Fairmont	Park Rapids	Virginia
Grand Rapids	Preston	Windom
Mankato	Rochester	Winnebago

ALBERT LEA

Freeborn County Biomass Rank: Agricultural Residue – 8
Job Zone Acres – 393
District Energy System – None
% Boilers built before 1974 – 43%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Agra Resources Coop dba EXOL	78242 150th St	745,290	-	-	-	-
Streater Inc	411 1st Ave S	49,807	-	-	-	-
ISD 241 - SW Jr High & Sibley Elementary	1006 S Highway 69	9,951	-	-	-	-
Alliance Pipeline - Albert Lea 25-A	85485 200th St	7,669	-	-	-	-

DULUTH

St. Louis County Biomass Rank: Forest residue – 1; Mill residue – 2; Urban Wood waste - 6
Job Zone Acres - 351
District Heating System – Existing, Cooperative Owned
% Boilers built before 1974 – 37%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
College of St Scholastica	1200 Kenwood Ave	61,289	14,544	-	-	-
Duluth Air National Guard Base	4680 Viper St	40,349	698	132	-	-
Duluth Entertainment & Convention Center	350 Harbor Dr	29,812	721	-	-	-
Duluth International Airport (DAA)	4701 Grinden Dr	93	530	-	-	-
Duluth Steam Cooperative Association	1 Lake Place Dr	7,916	1,906	-	-	1,198,459
Georgia-Pacific - Duluth Hardboard	1220 W Railroad St	60,189	256,509	-	240,986	-
Maney International of Duluth Inc	3204 Carlton St	21	-	-	-	-
ME Global Inc	200 E Carterett St	84,707	-	-	-	-
Minnesota Power Inc - ML Hibbard	4913 Main St	68,598	-	-	3,204,621	1,094,281
Northwest Airlines - Airbus Maintenance	4600 Stebner Rd	25,350	-	-	-	-
St Mary's Medical Center	407 E 3rd St	13,487	2,771	-	-	-
University of Minnesota - Duluth	223 College St	252,580	6,945	-	-	-
Western Lake Superior Sanitary District	2626 Courtland St	2,827	2,288	-	-	262,763

FAIRMONT

Martin County Biomass Rank: Agricultural Residue – 7
Job Zone Acres – 241
District Energy System – Existing, Municipally Owned
% Boilers built before 1974 – 59%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
3M - Fairmont	710 N State St	18,710	-	219	-	-
Fairmont Foods of Minnesota	905 E 4th St	2,426	1,803	-	-	-
Fairmont Power Plant	301 W 7th St	138,564	1,971	-	-	-
Weigh-Tronix Inc	1000 Armstrong Dr	89,385	-	-	-	-

GRAND RAPIDS

Itasca County Biomass Rank: Forest residue – 3; Mill Residue - 9
Job Zone Acres - 334
District Heating System - None
% Boilers built before 1974 – 32%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Blandin Paper/Rapids Energy Center	115 SW 1st St	1,170,563	-	-	4,299,046	900,532
ISD 318 - Grand Rapids High School	800 Conifer Dr NW	14,916	13,869	-	-	-
Itasca Community College	1851 E Highway 169	7,916	-	-	911	-
Potlatch - Grand Rapids	502 County Road 63	394,752	-	-	725,952	-

MANKATO

Blue Earth County Biomass Rank: Agricultural Residue – 6; Urban Wood Waste – 15
Job Zone Acres – 87
District Energy System - None
% Boilers built before 1974 – 40%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
ADM - Mankato	2019 3rd Ave	293,720	23,624	-	-	1,427,031
Associated Finishing Inc	320 Mallard Ln	22,842	-	-	-	-
CHS Oilseed Processing - Mankato	2020 S Riverfront Dr	815,584	397,660	-	-	-
Crown Cork & Seal Co Inc - Mankato	174 Chestnut St	29,678	-	-	-	-
Dotson Co Inc	200 W Rock St	3,290	-	-	-	-
Minnesota Elevator Inc	RR 3 Box 26	21	-	-	-	-
NSP dba Xcel Energy - Key City/ Wilmarth	1040 Summit Ave	41,737	-	-	-	-

MELROSE

Stearns County Biomass Rank: Urban Wood Waste – 7; Mill Residue – 14
Job Zone Acres – 208
District Energy System – None
% Boilers built before 1974 – 41%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
Melrose Dairy Proteins LLC	1000 Kraft Dr E	385,397	144,720	-	-	-

NEW ULM

Brown County Biomass Rank: Agricultural Residue – 9
Job Zone Acres – 216
District Energy System – Existing, Municipally Owned
% Boilers built before 1974 – 53%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
New Ulm Public Utilities-Municipal Power	310 1st St N	492,073	-	-	-	-
Kraft Foods - New Ulm	2525 S Bridge St	122,682	2,125	-	-	-
MCG Inc	1500 N Front St	1,007	-	-	-	-

PARK RAPIDS

Hubbard County Biomass Rank: Forest Residue – 8
Job Zone Acres – 132
District Energy System - None
% Boilers built before 1974 – 31%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Lamb Weston/RDO Frozen	3704 Park Ave S	904,033	102,654	-	-	-

PRESTON

Fillmore County Biomass Rank: Mill Residue - 7
Job Zone Acres - 7
District Heating System - None
% Boilers built before 1974 – 50%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Pro-Corn LLC	701 Industrial Dr N	769,365	-	137	-	-

ROCHESTER

Olmsted County Biomass Rank: Urban Wood Waste - 8
Job Zone Acres – 38
District Energy System – Existing, Municipally Owned
% Boilers built before 1974 – 34%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Mayo Medical Center - Rochester	233 3rd St NW	1,947,875	203,229	-	-	-
IBM - Rochester	3605 Highway 52 N	323,316	19,160	-	-	-
Rochester Public Utilities - Silver Lake	425 W Silver Lake Dr NE	273,962	-	-	-	2,289,091
Quest International	2402 7th St NW	147,210	-	-	-	-
Seneca Foods Corp - Rochester	1217 3rd Ave SE	133,198	-	-	-	-
Crenlo Inc - Plant 2	2501 County Road 4 NW	127,359	-	13,532	-	-
Associated Milk Producers Inc -Rochester	700 1st Ave SE	119,762	108,061	-	-	-
Pace Dairy Foods Co	2700 Valleyhigh Dr NW	30,778	-	-	-	-
Olmsted Waste-to-Energy Facility	301 (Silver Creek Rd NE)	10,989	1,498	-	-	-
Halcon Corp	1811 2nd Ave NE	15,482	-	-	-	-

SHERBURN

Martin County Biomass Rank: Agricultural Residue – 7
Job Zone Acres – 28
District Energy System – None
% Boilers built before 1974 – 54%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Interstate Power & Light - Fox Lake	844 125th St	670,667	310,494	-	-	-

ST. CLOUD

Stearns County Biomass Rank: Urban Wood Waste – 7; Mill Residue – 14
Job Zone Acres – 145
District Energy System – None
% Boilers built before 1974 – 35%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
G & K Services - St Cloud	1250 Kuhn Dr	28,167	-	-	-	-
Grede - St Cloud Inc	5200 Foundry Cir	1,439	-	-	-	-
ISD 742 - St Cloud Apollo High School	1000 44th Ave N	53,456	5,118	-	-	-
ISD 742 - St Cloud Technical High School	233 12th Ave S	54,093	5,197	-	-	-
Nahan Printing Inc	7000 Saukview Dr	23,223	-	-	-	-
New Flyer USA Inc - St Cloud	6200 Glenn Carlson Dr	56,334	-	-	-	-
Park Industries	6600 Saukview Dr	5,541	239	-	-	-
Quebecor World St Cloud	660 Mayhew Lake Rd NE	92,140	-	-	-	-
St Cloud Hospital	1406 6th Ave N	144,496	2,238	-	-	-
St Cloud State University	720 4th Ave S	79,917	122,575	-	-	-
St Cloud Technical College	1540 Northway Dr	17,754	-	-	-	-
St Cloud WWTP	524 240th St	31	4,532	-	-	-

VIRGINIA

St. Louis County Biomass Rank: Forest Residue – 1; Mill Residue – 2; Urban Wood Waste – 6
Job Zone Acres – 233
District Energy System – Existing. Municipally Owned
% Boilers built before 1974 – 29%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
City of Virginia Dept Public Utilities	620 S 2nd St	160,810	-	-	-	1,580,185
Virginia Regional Medical Center	901 9th St N	42,148	-	-	-	-

WINDOM

Cottonwood County Biomass Rank: Agricultural Residue - 5
Job Zone Acres – 89
District Energy System – Abandoned earlier than 1980
% Boilers built before 1974 – 53%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address		Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
PM Windom - Beef Processing	2850 Highway 60 E	56101	104,630	-	-	-	-

WINNEBAGO
Faribault County Biomass Rank: Agricultural Residue – 3
Job Zone Acres – 194
District Energy System - None
% Boilers built before 1974 – 67%

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LPG/Propane	Wood Waste	Coal
Corn Plus	711 6th Ave SE	879,968	-	-	-	-

Below is a table listing all existing district heating systems in Minnesota, along with their associated biomass county ranking (out of 87 counties). Forest residue (F), urban wood waste (U), and agricultural residue (A) rankings are based on preliminary, October 2003, estimates conducted by Oak Ridge National Laboratory. Mill residue (M) rankings are based on 2001 MN Department of Natural Resources data estimates of available (unused) sawmill residue. A table listing a few of the state university-owned campus heating systems is also listed. The ones that have met the criteria listed above and are listed locations for conversion to plant-residue fuel are italicized.

Existing Municipal-Based District Heating Systems*

County	County Biomass Ranking				Existing Municipal District Heating Systems
	Forest residue	Mill residue	Urban wood waste	Agricultural residue	
Brown	63	-	37	9	*New Ulm*
Hennepin	45	38	1	48	Minneapolis
Kandiyohi	46	-	22	12	Willmar
Martin	49	-	42	7	*Fairmont*
Olmsted	37	-	8	17	*Rochester*
Ramsey	-	-	2	-	St. Paul
St. Louis	1	2	6	-	*Duluth*
St. Louis	1	2	6	-	Hibbing
St. Louis	1	2	6	-	*Virginia*

* *Italics* indicate city met potential site criterion outlined earlier.

Existing State-Owned University/College Campus Systems*

County	County Biomass Ranking				Existing Campus Systems
	Forest residue	Mill residue	Urban wood waste	Agricultural residue	
Blue Earth	52	29	15	6	*Mankato State*
Clay	53	-	17	57	MN State Moorhead
Polk	28	40	32	60	UofM Crookston
St. Louis	1	2	6	-	*UofM Duluth*
Stevens	72	-	72	13	UofM Morris
Winona	22	-	18	29	Winona State

* *Italics* indicate city met potential site criterion outlined earlier. This preliminary list may not include all state-owned college campus systems.

Certain existing municipal and college systems fell outside of this project's parameters for the following reasons:

- Minneapolis and St. Paul do not have assigned JOBZ acreage and St. Paul already has an existing wood-fired district heating system.

- The Willmar Municipal system did not make the criteria cut of being in the top ten counties for biomass residue potential. However, Kandiyohi county ranks 12th in estimated agricultural residue availability.
- The city of Hibbing does not utilize a significant amount of natural gas, with the Hibbing Public Utility using predominantly coal to fuel its district heating system. Conversion to biomass fuels could still be favored due to the high availability of wood waste in St. Louis County and the environmental benefits associated with the use of biomass over coal.
- Existing campus systems that were not selected did not make the criteria for being in the top ten counties for biomass residue potential. However, Stevens county (UofM Morris) ranks 13th in estimated agricultural residue potential, Clay county (Minnesota State, Moorhead) and Winona County (Winona State) rank 17th and 18th, respectively, in estimated urban wood waste availability.

Criteria for Centralized Biogas Plants

The potential sites for centralized biogas plant sites were selected according to criteria based on lessons learned from case studies in Section III and relevant literature.[8,9] All listed potential locations were required to meet the following criteria:

1. Must be in a county ranked by the Minnesota Department of Commerce as being in the top three of all counties in Minnesota for cow manure and swine manure for electricity production potential.[10] The top three counties for cow manure are: (1) Stearns, (2) Otter Tail, and (3) Winona; the top three for swine manure potential are: (1) Martin, (2) Blue Earth, and (3) Nicollet.
    - It is critical that an adequate amount of manure is available in close proximity to the plant in order to minimize transportation costs.

2. Must have at least one agricultural processing industry based in the location.[11]
    - It is important that an adequate amount of other organic digestible matter be available within close proximity to co-digesting facilities to minimize transportation costs and increase biogas production potential.
    - Agro-industries will have less pretreatment needs than other types of organic waste.

3. Must have a municipal total of natural gas consumption of greater than 100,000 MMBTUs per year.[12]
    - Locations with large natural gas fuel users are expected to be more affected by fluctuating natural gas prices, creating a market opening for biogas and the thermal heat generated. Sale of excess biogas to current industries utilizing natural gas to meet their thermal needs could provide a valuable revenue stream for the centralized biogas plant.

4. Must have Job Opportunity Building Zone acreage assigned to the location.[13]
    - Projects can decrease investment costs by taking advantage of state incentives for economic development.

If areas have existing district heating systems or existing waste water treatment plants (WWTP) using anaerobic digestion, that is also noted. The district heating system could be an adequate purchaser of the biogas for its heating needs, while the WWTP could be a potential partner in co-digestion. Locations listed are preliminary and are only to be a guide to potential locations where future feasibility studies could be implemented. Potential locations were chosen based strictly on the criteria outlined above.

---

[8] Agricultural Utilization Research Institute, August 2003, "Self-Screening Assessment – the Appropriateness of a Community Manure Food Waste Digestion System," available online at: http://www.auri.org/research/manuredigester/pdfs/Community%20Manure%20Digester.pdf.

[9] Braun, R., 2002, "Potential for Co-digestion: Limits and Merits," available online at: http://www.novaenergie.ch/iea-bioenergy-task37/Dokumente/final.PDF.

[10] Data Source: Minnesota Department of Commerce, April 2003, "Minnesota's Potential for Electricity Production Using Manure Biogas Resources," Final Report. Available online at:
http://www.state.mn.us/mn/externalDocs/MN_Biogas_Potential_Report_041003013143_biogasfinal2.pdf
There is also a searchable database for Dairy farms in the State, developed by the Minnesota Department of Agriculture:http://www2.mda.state.mn.us/webapp/dairyinsp/default.jsp

[11] Data Source: Minnesota Pollution Control Agency data and Directory of Minnesota Manufacturers data, compiled by Melody Sakazaki at the Minnesota Project. Facilities with less than 20 employees were excluded.

[12] Data Source: Minnesota Pollution Control Agency boiler permit database; most recent complete data year is 2001.

[13] Data Source: Minnesota Department of Employment & Economic Development JOBZ list, available online at: www.dted.state.mn.us/searchframe.asp?url=jobz.asp

Potential Sites for Centralized Biogas Plants

Sites listed are preliminary and are only to be a guide to potential locations where future feasibility studies could be implemented. Potential locations were chosen based solely on the strict criteria outlined in (1-4) above. Locations are listed in alphabetical order.

Cities
Fairmont
Mankato
Melrose
Perham
St. Cloud

FAIRMONT

Manure Rank - Martin County #1 in Swine Manure
Job Zone Acres - 241
Agro-industries - Olson Locker Inc.; Fairmont Foods of Minnesota
Waste Water Treatment Plant Anaerobic Digester - None
District Heating System - Yes, Municipal System

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
3M - Fairmont	710 N State St	18,710	-	219	-	-
Fairmont Foods of Minnesota	905 E 4th St	2,426	1,803	-	-	-
Fairmont Power Plant	301 W 7th St	138,564	1,971	-	-	-
Weigh-Tronix Inc	1000 Armstrong Dr	89,385	-	-	-	-

MANKATO

Manure Rank - Blue Earth County #2 Swine Manure
Job Zone Acres - 87
Agro-industries - Pioneer Snacks Inc; Pioneer Snacks Inc Warehouse; Mankato Rendering Company; All American Foods Inc; Rollies Dairy Fresh; Central Bi-Products Rendering Service; Hilltop Meat Market
Waste Water Treatment Plant Anaerobic Digester - Yes
District Heating System – Yes, Mankato State Campus System

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
ADM - Mankato	2019 3rd Ave	293,720	23,624	-	-	1,427,031
Associated Finishing Inc	320 Mallard Ln	22,842	-	-	-	-
CHS Oilseed Processing - Mankato	2020 S Riverfront Dr	815,584	397,660	-	-	-
Crown Cork & Seal Co Inc - Mankato	174 Chestnut St	29,678	-	-	-	-
Dotson Co Inc	200 W Rock St	3,290	-	-	-	-
Minnesota Elevator Inc	RR 3 Box 26	21	-	-	-	-
NSP dba Xcel Energy - Key City/ Wilmarth	1040 Summit Ave	41,737	-	-	-	-

MELROSE

Manure Rank – Stearns County #1 in Dairy Cow Manure
Job Zone Acres - 208
Agro-industries - Jennie-O-Turkey Store; Poepping James Pep's Pork; Nathe Dairy Products Distributor, Melrose Dairy Proteins
Waste Water Treatment Plant Anaerobic Digester - Yes
District Heating System - No

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
Melrose Dairy Proteins LLC	1000 Kraft Dr E	385,397	144,720	-	-	-

PERHAM

Manure Rank – Otter Tail County #2 in Dairy Cow Manure
Job Zone Acres - 390
Agro-industries - Perham Meat Market & Locker; Barrel O'Fun Snack Food Co
Waste Water Treatment Plant Anaerobic Digester - None
District Heating System - None

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
Barrel O'Fun Snack Food Co	800 4th St NW	114,766	-	-	-	-

ST. CLOUD

Manure Rank – Stearns County #1 in Dairy Cow Manure
Job Zone Acres – 145
Agro-industries - Purity Dairy Inc; D & K'S Quality Meats
Waste Water Treatment Plant Anaerobic Digester - Yes
District Heating System – None

Major Natural Gas Fuel Users in 2001 (MMBtu)

Company	Address	Natural Gas	Fuel Oil	LGP/Propane	Wood Waste	Coal
G & K Services - St Cloud	1250 Kuhn Dr	28,167	-	-	-	-
Grede - St Cloud Inc	5200 Foundry Cir	1,439	-	-	-	-
ISD 742 - St Cloud Apollo High School	1000 44th Ave N	53,456	5,118	-	-	-
ISD 742 - St Cloud Technical High School	233 12th Ave S	54,093	5,197	-	-	-
Nahan Printing Inc	7000 Saukview Dr	23,223	-	-	-	-
New Flyer USA Inc - St Cloud	6200 Glenn Carlson Dr	56,334	-	-	-	-
Park Industries	6600 Saukview Dr	5,541	239	-	-	-
Quebecor World St Cloud	660 Mayhew Lake Rd NE	92,140	-	-	-	-
St Cloud Hospital	1406 6th Ave N	144,496	2,238	-	-	-
St Cloud State University	720 4th Ave S	79,917	122,575	-	-	-
St Cloud Technical College	1540 Northway Dr	17,754	-	-	-	-
St Cloud WWTP	524 240th St	31	4,532	-	-	-

Section II: Inventory of Biomass Heat & Power Projects in Minnesota

When evaluating bio-energy opportunities in Minnesota, it is useful to examine the range of existing biomass energy applications. Based upon publicly available data, the following inventory represents an extensive sample of projects. By design, the list does not include landfill gas projects, refuse-derived fuel, or co-firing of biomass materials in fossil fuel facilities, such as coal plants. Information on projects missing from these lists may be e-mailed to mike.taylor@state.mn.us.

Existing Biomass Heat and/or Power Projects in Minnesota

Fuel	Process/Technology	Developer	Energy Output	Location	Scale (MWe)	Utility Purchaser	Source
Beet Tailings, Pulp	Anaerobic Digestion	American Crystal Sugar	Biogas	E Grand Forks/Moorhead	Unknown	Internal Use	Melissa Pawlisch, UofM
Cow Manure	Anaerobic Digestion	Horizon Dairy, Mitch Davis	Biogas (Heat & Power)	Le Sueur	.260	Great River Energy?	Amanda Bilek, Minn. Project
Cow Manure	Anaerobic Digestion	Haubenschild Farms	Biogas (Heat & Power)	Princeton	0.135	Great River Energy	CERTs Manual, Minn. Project
Mill & Logging Residue	Combustion	Potlatch Corp	Heat & Power	Cloquet	61.4	Internal Use	NREL
Mill & Logging Residue	Combustion	Blandin Paper	Heat & Power	Grand Rapids	31.5	Internal Use	NREL
Mill & Logging Residue	Combustion	Boise Cascade	Heat & Power	International Falls	29.3	Internal Use	NREL
Mill & Logging Residue	Combustion	Hibbard Steam St.	Heat & Power	St. Louis City	53	Minnesota Power	2000 Utility Databook, DOC
Mill & Logging Residue	Combustion	Champion Paper	Heat & Power	Sartell	24	Internal Use	NREL
Urban Wood Waste	Combustion	District Energy St. Paul	Heat & Power	St. Paul	25	Xcel Energy	St. Paul District Energy Website
Waste Water Reclamation	Anaerobic Digestion	Albert Lea WWTP	Biogas (Heat)	Albert Lea	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Austin WWTF	Biogas (Heat)	Austin	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Bemidji WWTF	Biogas (Heat)	Bemidji	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Blue Earth WWTP	Biogas (Heat)	Blue Earth	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Brainerd Public Utilities	Biogas (Heat)	Brainerd	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Cambridge WWTP	Biogas (Flaring)	Cambridge	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Western Lake Superior Sanitary District	Biogas (Heat & Power)	Duluth	0.140	Internal Use	Kathy Hamel, Duluth WLSSD
Waste Water Reclamation	Anaerobic Digestion	City of Elk River WWTP	Biogas (Heat)	Elk River	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Fairbault WWTP	Biogas (Heat)	Fairbault	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Fergus Falls WWTP	Biogas (Flaring)	Fergus Falls	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Harmony	Biogas (Heat)	Harmony	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Hokah	Biogas (Heat)	Hokah	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	International Falls WWTP	Biogas (Heat)	International Falls	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Luverne WWTP	Biogas (Heat)	Luverne	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	City of Mankato WWTP	Biogas (Heat)	Mankato	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Marshall WWTP	Biogas (Heat)	Marshall	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Melrose WWTP	Biogas (Heat)	Melrose	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Monticello WWTP	Biogas (Heat)	Monticello	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Moorhead WWTP	Biogas (Heat)	Moorhead	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	New Richland	Biogas (Heat)	New Richland	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Owatonna WWTP	Biogas (Heat & Power)	Owatonna	10-20 kWh/day	Internal Use	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Pine Island	Biogas (Heat)	Pine Island	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Redwing Municipal WWTP	Biogas (Heat)	Redwing	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Rochester Water Reclamation Plant	Biogas (Heat & Power)	Rochester	1	Internal Use	CERTs Meeting Notes, Manual
Waste Water Reclamation	Anaerobic Digestion	St. Cloud WWTP	Biogas (Heat)	St. Cloud	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	St. James WWTF	Biogas (Heat)	St. James	0	None	MPCA, Minnesota Project
Waste Water Reclamation	Anaerobic Digestion	Wadena WWTP	Biogas (Heat)	Wadena	0	None	MPCA, Minnesota Project

Planned & Under Construction Biomass Heat and/or Power Projects in Minnesota

(As the projects listed below are not certain to be developed, this draft inventory is in progress.)

Fuel	Process/Technology	Developer	Energy Output	Location	Scale (MWe)	Status	Source
Agricultural Processing Waste	Anaerobic Co-digestion	Minn. Dehydrated Vegetables	Biogas (Heat/Power)	Fosston	TBD	Near Completion	MMUA October 2003 "The Resource"
Animal Manure	Anaerobic Digestion	8,000 Cow Dairy Farm	Biogas (Natural Gas Pipes)	Morris	TBD	Discussing	CERTs Notes; Lola Schoenrich, MN Proj.
Animal Manure and Human Waste	Centralized Anaer. Co-digestion	Brian Klutcher	Biogas (Heat & Power)	Redwood Area	TBD	Discussing	Lola Schoenrich, MN Project
Animal Manure and Human Waste	Anaerobic Digestion	Willmar	Biogas	Willmar	TBD	Studying	Willmar City Council Meeting 4/13/03
Chicken Fat & Hog waste	Gasification to Acetylene	Afuels, LLC	Power	Madelia	TBD	Discussing	BDC meeting 4-2-04
Corn and Pea Processing Waste	Anaerobic Co-digestion	Seneca Foods	Biogas (Heat & Power)	Montgomery	1.5	Stalled	CERTs Manual
Corn Stalk & Soybean Residue	Gasification to Acetylene	Afuels, LLC	Power	Tracy	TBD	Discussing	Canby News 2.18.04
Dairy Cow Manure	Anaerobic Digestion	Ripley Dairy	Biogas (Heat & Power)	Dodge County	TBD	Suspended	MP CIP filing, Dean Talbott; MN Project
Energy Crop Wood (Poplars)	Unknown	WesMin RC&D, ORNL	Unknown	Alexandria	TBD	Discussing	CERTs Manual
Energy Crops, Wood/Ag Residues	Combustion	Hibbing Public Utility (3)	District Heating & Power	Hibbing	20	Planning	The Daily Tribune, 4.6.04
Energy Crops, Wood/Ag Residues	Combustion	Virginia Public Utility (3)	District Heating & Power	Virginia	15	Planning	The Daily Tribune, 4.6.04
Hog Manure	Centralized Anaer. Digestion	Unknown	Biogas	Fairmont	TBD	Planning	Mark Wuollet, Internex, Ltd
Hybrid Hazelnut Energy Crop	Biorefining	Unknown	Multiple outputs	Bell Plaine	TBD	Discussing	CERTs Notes; IREE Bioenergy Cluster
Malting Waste & Agric Residues	Combustion	Rahr Malting	Heat & Power	Shakopee	32 ?	Testing Fuels	IREE Bioenergy Cluster
Manure & Food Processing Waste	Centralized Anaer. Co-digestion	Little Pine Dairy	Biogas (Heat & Power)	Perham	TBD	Planning/Financing	Amanda Bilek, Minnesota Project
Manure & Other Organic Wastes	Anaerobic Co-digestion	Daley Farm, Dairyland Power	Biogas (Heat & Power)	Rochester Area	0.75	Planning	Kenric Scheevel, Dairyland Power Coop
Waste water treatment	Anaerobic Digestion (expansion)	City of Mankato	Add Power	Mankato	TBD	Checking Viability	MPCA; Minnesota Project
Waste water treatment plant	Anaerobic Digestion (expansion)	Austin Municipal	Add Power	Austin	0.060	Planning	IPL CIP filing
Wood chips, corn stover, C&D waste	Combustion	Rock Tenn, StPaul Port Auth.	Heat & Power	St. Paul	12	Pre-planning	Pete Grills; Tim Nolan, OEA
Wood Waste	Gasification	Central MN Ethanol Coop	Heat & Power	Little Falls	1	Construction	Cecil Massie, Sebesta Blomberg
Wood Waste	Combustion?	Itasca Power Company (4)	Heat & Power	Northome	10-20 ?	Negotiating Xcel PPA	Northome Record, Weekly, March 16, 2004
Wood Waste and Crop Residues	Combustion	Green Institute	District Heating & Power	Minneapolis	23	Planning	Carl Nelson, Green Institute
Wood Waste and Crop Residues	Combustion	UofM Morris	Campus Heating	Morris	0	Planning/Financing	UofM Morris
Turkey Litter	Combustion	FibroMinn (1)	Power	Benson	55	Planning/Financing	State Legislation
Unknown	Combustion	Duluth Steam Coop	Add Power to District Heat	Duluth	TBD	Discussing	Jerry Pelofski, Duluth Steam; CERTs
Unknown	Combustion	St. Paul District Energy (2)	Heat & Power	St. Paul	8	Discussing	Keith Jacobson, DNR; State Legislation

(1) Fibrominn has an authorized PPA with Xcel through the Biomass mandate for up to 55MW.
(2) St. Paul District Energy has an authorized PPA with Xcel through the Biomass mandate for up to 33 MW. 25 MW of that facility came online in 2003.
(3) Hibbing and Virginia are purchasing NGPP's authorized PPA with Xcel (through the Biomass mandate) for 35 MW.
(4) Itasca Power has an authorized PPA with Xcel through the Biomass mandate for up to 20 MW. Legislation requires that the purchase cost to utilities from the Itasca Project be less than 5.5 cents per kWh.

Section III: Case Studies of On-the-Ground Applications

What works? To understand the potential for application of bio-energy technologies in Minnesota, it is useful to examine case studies. By reviewing the market conditions, policy climate, and investment decisions that resulted in real projects on the ground, entrepreneurs and planners can identify locations and applications in Minnesota that might offer comparable opportunities. This section begins with an inventory of known existing applications in the U.S. of (1) Plant residue-fueled district heating systems; (2) On-farm Anaerobic Co-digesters; and (3) Centralized Biogas Plants. For each of these three technology applications, one or two case studies are conducted.

(1) Plant Residue-fueled District Heating Systems

Barre, Vermont
55,000 sq. ft. apartment complex heating system
Fuel: Sawmill chips
Online: 1991

Chadron State College, Nebraska
1.2 million sq. ft. campus heating system
Fuel: Forest residues
Online: 1990

Montpelier, Vermont
500,000 sq. ft. capitol complex heating system
Fuel: Forest residues
Online: 1950s

St. Paul, Minnesota
~17.25 million sq. ft. heating and 25 MW electricity
Downtown combined heat and power system
Fuel: Urban wood waste
Online: 2003

*Since a synopsis of wood-fired district energy systems in the United States was conducted in March 2004 by Minnesotans for an Energy-Efficient Economy,[14] and there are no known agricultural-residue district heating systems currently in operation in the country, *the case study focuses on an overview of the Danish experience with agricultural-residue fueled district energy systems.* Denmark has 58 straw-fired district heating systems in operation, some that have been in operation for over 20 years.

(2) On-farm Anaerobic Co-digesters

Gypsy Hill Farm – Lancaster, PA
Generates Heat (used internally) and Power (sold to electric utility)
Fuel: Manure from 4000 pigs and cheese whey
Online: Major renovation completed in 2000

[14] Minnesotans for an Energy-Efficient Economy, March 2004, "Biomass-community energy systems: a viable near-term option for Minnesota communities"; available online at www.me3.org/issues/biomass/community.pdf.

**Matlink Dairy Farm - Clymer, NY*
Generates combined heat (used internally) and power (sold to electric utility)
Fuel: Manure from 675 dairy cows and various food industry waste
Online: 2001

(3) Centralized Biogas Plants

**Chino Basin, California*
Generates heat and power (370 kWe electricity)
Fuel: manure from 6 farms (6,250 cows) and small amounts of industrial food waste
Online: 2002

Tillamook, Oregon
Generates heat (internal use) and power (sold to electric utility)
Fuel: manure from approximately 10 farms (4,000 cows)
Online: 2003

*As the Chino Basin Project has only been online since 2002, *an overview case study of the Danish experience with centralized biogas plants was also conducted*. Denmark has 20 centralized biogas plants in operation, a majority of which were built between 1984 and 1998.

Plant-residue Fueled District Heating Systems

Case Study: Straw-fired District Heating Systems in Denmark

There are 58 straw-fired district heating systems in Denmark, with average plant sizes ranging from 0.6 megawatts (MW) thermal to 9 MW thermal. Since 1980, Denmark has been converting older district heating systems to straw fuel, as well as building new straw-fired district heating systems. The following case study is a summary of the handling, production and utilization of straw in these district heating systems. The information presented has been predominantly compiled from various sections in the 1998 Danish Bioenergy Centre technical document titled "Straw for Energy Production." All metric and Danish currency units have been converted to U.S. measurements and dollar amounts.

Intent for Developing. The oil crisis in the 1970s and a tax imposed by the Danish government on fossil fuels motivated the initial straw fuel conversion of existing district heating systems. Straw was a domestic surplus agricultural product that had the added benefits of being carbon dioxide-neutral. The utilization of straw for energy production was also part of a long-term policy of the Danish government to increase renewable energy production by 1 percent per year.

Fuel Source. The straw fuel used in district heating systems is the by-product of commercially grown cereal crops, primarily wheat and barley. In 1996 there were 6.6 million tons of straw harvested, of which approximately 15 percent was used for energy production—7 percent in farm-scale boilers, 5 percent in district heating, 3 percent in combined heat and power plants, and one percent in conventional power plants. Approximately 40 percent of the straw is either not gathered or chaffed and plowed back into the soil for soil amelioration.

Straw Collection & Delivery. Straw management for energy use has developed into an independent industry in Danish agriculture, with larger farms and machine pools investing in the necessary equipment. The straw is collected through combined harvesting and the swaths of straw are baled almost immediately to allow for soil treatment to begin in preparation for the following year's crop. All district heating systems are designed to accept bales having the dimensions of approximately 3.9 x 4.3 x 7.9 feet and with up to 20 percent moisture content. The straw is weighed and the moisture content is measured at the straw delivery site by the district heating plant.

The straw market for energy production is primarily determined by long term contracts between an individual straw producer or an association of straw producers and the district energy plant purchaser. Straw is also traded on the spot market. The Danish Energy Agency reported the price of straw in 1994 to be $34.84 per ton, with approximately one-fourth of the cost associated with transport and three-fourths for actual production costs.

System Components. All straw-fired district heating plants primarily consist of the following components:

- Straw storage with weighing scales
- Straw crane and/or conveyor
- Chaff cutter, shredder, or slicer
- Firing system and boiler
- Combustion air fans
- Flue gas cleaning and ash/slag conveyor
- Chimney and flue gas fan
- Control and regulation equipment

In addition to the straw-fired boiler, all plants are equipped with an oil-fired boiler for backup generation in case of maintenance or repair shutdown. Hot water storage tanks have also been installed at 23 of the straw-fired district heating facilities to smooth out peak winter heat demand. The plants are staffed during normal business hours with electronic monitoring at other times.

Product Output. The energy generated is used for space heating and hot water needs during winter. In areas where industrial thermal loads are not present, only hot water is produced in the summer months. Some straw-fired heating plants are later converted into combined heat and power generating facilities. Straw also contains about 3 to 5 percent ash, which is collected and applied as fertilizer.

Emissions & Environmental Concerns. The primary environmental concerns cited by Danish straw-fired district heating plants include: particulate matter, carbon monoxide, nitrogen oxides (NOx), sulfur dioxide (SO2) and the ash resulting from combusted straw. Other emissions of concern are polyaromatic hydrocarbons (PAH), dioxins, and hydrogen chloride (HCl). Carbon dioxide is also emitted, but the use of straw as the fuel source is considered to be carbon dioxide neutral.

Based on emission measurements made on 13 of the district heating plants from 1987 to 1993, dust and carbon monoxide emissions were beyond the Danish Environmental Protection Agency's allowed limits. Larger plants generally have equipment to remove NOx and sulfur dioxide particles. This equipment is generally not cost-effective for smaller district heating plants and many balance operations between complete combustion (to decrease carbon monoxide and presumably PAH and dioxin), and low flame temperatures (to decrease NOx formation). Hydrogen chloride, which contributes to acid rain and is corrosive to the boiler, is thought to be originating from the fertilizer and pesticides used on the crops.

Ownership. The majority of the straw-fired districts heating plants in Denmark are privately owned cooperatives with limited liability. (The owners, which could be a group of farmers or an association of straw suppliers, are usually only liable for their contribution, with each consumer having a vote.) There are also publicly owned municipal district heating systems as well as private companies owning plants.

Financing. Up to 50 percent of the capital costs associated with building a district heating plant was subsidized by the Danish government between 1980 and 1997. The remainder of the funding was provided through long-term index-linked loans. For payback of the loan, a district heating plant's primary source of revenue is the sale of heat, avoiding the cost of burning more expensive fuel oil. Most projects were built with the intention of breaking even, paid for by 10-year loans.

Policy Initiatives. The Danish government gave significant support to the development of the country's bioenergy resources:

- Money was allotted for bioenergy research and development.
- Environmentally-oriented directives were passed requiring that the country's carbon dioxide emissions be halved by 2030, compared with their 1998 levels. Renewable energy sources now account for 35 percent of Denmark's gross energy consumption.

District heating specific incentives included:

- Grants covering 50 percent of the construction costs of district heating and CHP plants utilizing biomass fuels.
- Exemption of biomass district heating plants from the energy and carbon dioxide taxes that fossil fuel energy sources were required to pay.

Challenges Faced. The low straw-ash combustion temperature, ash disposal, and local shortages of straw have been the primary challenges facing Danish straw-fueled district energy systems. Straw is a more difficult fuel to work with than other biomass fuels due to its low calorific value, with the chlorine and alkalis from the straw reacting corrosively with high steam pressures and temperatures. Even though straw is a more difficult fuel to work with, many district heating companies prefer to use straw because of its local availability and favorable prices. Local shortages of straw have resulted in 11 plants upgrading their storage, feeder system and boiler to co-fire with wood wastes.

Main Data

The data is an example estimate for the development of a straw-fired district heating plant at a location where no facility or distribution system had existed previously. The example was provided by The Danish Bioenergy Centre technical document "Straw for Energy Production" and based on Denmark's historical experience with developing new district energy systems.

Typical Costs for a New Straw-fired District Heating Plant in Denmark (1995 USD prices)

260 small customers	4,550 MWh (thermal)
10 large customers	3,300 MWh (thermal)
Distribution system losses	30%
Heat production	11,200 MWh
Heat production, straw	93%
Heat production, oil	7%
Peak output requirement	3 MW
Straw-based boiler output	2 MW
Fuel transport mechanism	Big bales by tractor or truck
Annual straw needs	3,166 tons/yr
Annual straw fuel cost	$222,300
Annual Amount of oil	22,968 gallons
Annual Oil cost	$53,100
Total investment capital costs [15]	$5,040,000
Government subsidy possible	$864,000
Facility O&M costs[16]	$518,040
Ownership structure of most plants	Cooperatives, LLC
Straw-fired systems in place since	1980

[15] Includes capital cost of heating plant, distribution system, consumer service pipes, consumer house installations, unforeseen expenses.
[16] Includes maintenance of plant, maintenance of distribution system, electrical power needed and chemicals, other costs (insurance, etc), personnel and administration, 20 year depreciation, loan payments, and interest.

Publication References

Centre for Biomass Technology, 2000, "Danish Bioenergy Solutions – reliable & efficiency," available online at: www.videncenter.dk/uk/index.htm under <publications>.

Centre for Biomass Technology, 1998, "Straw for Energy Production - Technology - Environment - Economy," second edition available online at: www.videncenter.dk/uk/index.htm under <publications>.

Centre for Biomass Technology, 2002, "Wood for Energy Production: Technology - Environment – Economy," second revised edition available online at: www.videncenter.dk/uk/index.htm under <publications>.

European Commission, April 2000, "BIO-COST: Impact of different national biomass policies on investment costs of biomass district heating plants," available online at: www.eva.ac.at/projekte/biocost.htm

Gupta, S., March 2004, "Biomass-community energy systems: a viable near-term option for Minnesota communities," available online at: www.me3.org/issues/biomass/community.pdf.

Unit Conversions

tonne = 1.102311 ton
inch = 2.54 cm
liter = 0.2641721 gallon
Bank of Canada, Historical Currency Converter, Dec 30, 1994: 1 DKK = .16 USD
Bank of Canada Historical Currency Converter, Dec. 29, 1995: 1 DKK = .18 USD

On-farm Anaerobic Co-digesters

Case Study: Matlink Dairy Farms, Clymer, New York

Matlink Farms, a 675-cow dairy farm, began co-digesting food waste in their on-farm anaerobic digester in 2001. It is a complete mix digester producing approximately 250,000 cubic feet of methane gas per day.

Intent for Developing. The primary motivation for the installation of the digester by the farm was for waste and odor management. By minimizing the odor of the manure, it can be stored and utilized at intervals and more freely land applied in the summer, in line with a nutrient management plan. Offsetting natural gas and electricity purchases through heat and power generation were secondarily considered as a means of generating revenue.

Fuel Source. The input into the anaerobic digester includes the manure from the 675 dairy cows on the farm as well as whey from a local ice-cream maker, fish stick oil, and grape juice production residue. The food waste percentage varies up to 30 percent of the total material digested, averaging about 12,000 gallons daily input. The inclusion of food waste, which is truck transported from approximately 10 to 40 miles away, has more than tripled the amount of biogas that was being produced by manure alone. The system was designed to incorporate manure from up to 1,500 cows in order to allow for future opportunities to partner with other dairies in the area for a centralized manure management system.

System Components. The bag-covered digester has a 600,000-gallon capacity. Manure is gravity-fed into an in-ground, 20,000 gallon concrete holding area. The food waste is trucked in and stored in a separate adjacent tank to the manure. The manure and food waste material are then heated and mixed before being fed into the 80’ x 70’ x 16’ deep digester for about 20 days of retention. The generated biogas is piped uphill from the digesters to the generator buildings, compressed, and then metered into a 145 kW Waukesha electrical generator. After leftover material (digestate) is pumped out of the digester, it is separated with a screw press and dried - using heat from the generator - and stockpiled in an adjacent building.

Product Output. The generator, originally designed to burn natural gas, produces about 884,000 kWh of electricity per year, almost twice the farm’s needs. Excess power is sold to the regional electric grid, operated by Niagara Mohawk Power Corporation. Cogenerated hot water is used to meet the thermal needs of the digester process and to supply heat to the calf barn. While extra biogas is currently flared, an onsite food waste drier is in the process of implementation that would use the excess gas to dry oats, rice hulls and cheese whey to be used as animal feed. The digestate is separated into its liquid and solid components, having a significantly reduced odor than raw manure, and the liquid component is field-applied in the summer as fertilizer. The separated solids are made into bedding and used for sales as a soil compost amendment.

Emissions & Environmental Concerns. According to RCM Digesters, the designers of the project, Matlink Dairy Farms have not exceeded the required limits of ammonia and hydrogen sulfide. Heavy metals and toxic chemicals are not expected to be an issue since the input into the digester is manure and food waste. Food waste is under strict regulation that precludes it from having many negative pollutants that would affect the digester operation or the final digestate product. If there are any persistent chemicals in the manure, it would be from residual pesticides in the cow feed, and the pollutants would be part of the digestate as well as the raw manure. Tests for fecal chloroform in the digestate have shown only trace amounts present.

Financing. The total capital costs of the digester system were $623,000, with the financing package taking five years to assemble. The New York State Energy Research and Development Authority (NYSERDA) assisted the initial planning and design of the facility through a $200,000 grant. The Seneca Trail Resource Conservation & Development District assisted Ted Mathews, the owner of the farm, in applying for the NYSERDA grant. The remainder of the financing came from the farm owner.

Economic Viability. Annual operating and maintenance costs are approximately $115,910, with spreading costs of the digestate equaling 81 percent of the total annual operating costs. Annual benefits are expected to reach $392,785 with tipping fees from the food waste accounting for 53 percent of the annual revenue, and gas sales to the upcoming drying operation accounting for 25 percent of the annual revenue. Electricity sales to the utility were only three percent of the annual revenue. Due to the inclusion of the added tipping revenue and increased gas production from the handling of food waste, the project is able to have a net annual income of $215,643, which is a two-year simple payback with the government grant and three years without.

Policy Initiatives. Net metering rules and the availability of both energy and agriculture agency government grants for pilot projects were critical to the projects development. Federal combined animal feed operations (CAFO) legislation and nutrient management rules governing medium CAFOs, 200 to 699 animal units, also played an important role in motivating the farmer to look for alternative nutrient management options.

Challenges Faced. One primary challenge the Matlink Farms co-digester faced, involved developing the power purchase agreement with the local electric utility. Technical challenges have included dealing with foam generation and the potential risk of contamination from the food waste.

<u>**Main Data**</u>

Animal Manure	675 dairy cows
Alternative Biomass	Food wastes
Average Transport Distance	20-60 miles
Transport Vehicle	Trucks
Biogas Production	250,000 cubic feet per day
Digester Capacity	600,000 gallons
Process Temperature	100 degrees F
Utilization of biogas	CHP-plant
Other products	soil amendment, bedding, fertilizer
Total Capital Costs[17]	$622,520
Annual Capital Costs	$61,232
Annual Operating Costs[18]	$115,910
Annual Benefits[19]	$392,785
Net Annual Income from Manure	$215,643
Government Grant	$200,000
Design and Consultancy	RCM Digesters, Inc.
Farm Owner	Ted Mathews
Operation Start-up	2001

[17] Capital costs includes: digester costs (construction and materials; mixer and pumps); engine-generator set (engine generator, switching equipment, engine building); solids and liquid separation (separator, separator building); and liquid storage. Detailed Economic Analysis can be found at: http://www.manuremanagement.cornell.edu/Docs/Posters/Digestion/Matlink-Eco%20Analy.pdf
[18] Maintenance and operating costs includes maintenance, insurance, repairs, reporting food waste to regulators, water treatment for heat exchange system, and spreading costs by tractor tank wagon and irrigation.
[19] Benefits calculated include: electricity sales to utility, tipping fee for handling food wastes, bedding material replacement, compost sales, hot water (heat for calf barn), odor control avoided cost of additives and management time), and gas sales to drying operation.

Contacts

Tom Fiesinger
New York State Energy Research & Development Authority
(518) 862-1090, ext 3218
twf@nyserda.org

Jo Ann Kurtis
Seneca Trail Resource Conservation & Development District
(716) 699-8923

Ted Mathews
Owner
Matlink Dairy
Tedmathews@madbbs.com

Mark Moser
RCM Digester, Inc.
(510) 658-4466

Peter Wright
Senior Extension Associate
Cornell University
(607) 255-2803
pew2@cornell.edu

Publication References

Cornell University Manure Management Program; Fact sheet posters on Matlink project description, economic analysis, and results and lessons learned, available online at: www.manuremanagement.cornell.edu/HTMLs/Posters.htm

Cornell University Manure Management Program www.manuremanagement.cornell.edu

"Polypropylene covers for biogas generators – a New York dairy farm converts waste to electricity" by Sara R. Black, October/November 2003, *GFR Magazine*, a publication of the Geosynthetics Materials Association.

Presentation by Ted Mathews, Matlink Farms Owner, in Spring 2004 at an AgStar conference, available online at: www.epa.gov/agstar/conference04/mathews.pdf

Richard Mattocks of Environomics and Mark Moser of RCM Digesters, "Anaerobic Digesters at Dairies in Cold Climates," available online at: www.rcmdigesters.com/images/PDF/RCMColdClimateDigesters062503.pdf

Centralized Biogas Plants

Case Study: Chino Basin, California

The Chino Basin project is the first centralized anaerobic digester to be developed in the United States. The project came online in 2002 and incorporates cow manure from six regional farms as well as a small percentage of other organic waste from local food industries. The 6 dairy-cow farms have an average farm size of 700 cows and the centralized biogas plant utilizes a mesophilic plug flow digester to process the various waste streams.

Intent for Developing. The environmental benefits associated with the development of a centralized anaerobic digester were the primary motivating force for the Chino Basin project. The Chino Basin has the largest concentration of cows in the world, with 350,000 cows that produce over 1 million tons of manure annually. This results in a significant nutrient and salt impact on the water quality in the area. Improving water quality through organics management, and reducing demand for imported water supplies from the Colorado River and San Francisco Bay Delta were also important goals. Farm groups favored a centralized system as a means to involve multiple small and moderate sized farms in watershed protection efforts and avoid the costs associated with individual farm nutrient management plans. The generation of renewable energy and increased energy self-sufficiency became an additional motivating force following the California energy crisis. Improving air quality, reducing global warming methane emissions, and being able to follow an established European model and track record for developing centralized biogas facilities, were also driving factors for the project.

Fuel Source. The project is designed to handle waste from 6,250 dairy cows, equivalent to approximately 225 tons of manure per day. The food waste usage is being expanded, with the plant currently accepting a small percentage of organic waste from the cheese and salad dressing industry. The manure is trucked to the central facility from a 0.25 to 6.0 mile radius, with the collection trucks being owned and operated by the biogas plant operators (in this case the local water utility) with the participating farmers paying the biogas plant a tipping fee.

Product Output. The biogas resulting from the anaerobic digestion process is used to generate heat and run an off-site 370 kW electricity generator. The electricity is used by the water utility for internal use to run a groundwater desalinization plant as well as the utility's other wastewater treatment facilities to offset peak electricity use. An additional product the system produces includes 135 tons per day of organic fertilizer.

Emissions & Environmental Concerns. Due to the Chino Basin's air quality and watershed concerns, a significant investment was made to ensure that the facility has high environmental performance. They have installed bio-filters and other state of the art emissions control equipment to reduce odor and emissions. The only emissions of note are those originating from the electrical engine generator, which is also designed to meet strict air quality regulations.

Ownership. The project is owned and developed by the Inland Empire Utilities Agency (IEUA), a municipal water district located in west San Bernardino County. The water utility also partnered with federal and state agriculture and energy agencies, the private sector, and farm groups. The multi-stakeholder planning effort and coordination to develop the watershed management strategy took two years. The partners were:

- Inland Empire Utilities Agency (area water utility and watershed manager)
- U.S. Department of Agriculture's Natural Resources Conservation Service
- U.S. Department of Energy and the California Energy Commission

- Synagro Technologies (a residuals management company)
- Milk Producer Council (a local dairy industry group)

Financing. The total capital cost of the Chino Basin centralized biogas plant was $8.5 million. It received a $5 million grant from the U.S. Department of Agriculture's Natural Resources Conservation Service for watershed protection. The remainder of the financing came from the California Energy Commission for the renewable energy component of the plant, with the Inland Empire Utilities Agency investing $1.5 million of its own funds in the facility. The capital cost of the project was entirely government funded by government grants. The participating dairy farms paid for some on-farm equipment, such as the tractors and labor involved.

Economic Viability. The regional urban-based ratepayers and users of IEUA's urban sewer system are currently paying 50 percent of the operation and maintenance costs incurred by the project. The other 50 percent of the revenues for maintaining the facility come from peak electricity purchase savings and from the tipping fees charged to the farmers. The current food industry waste is too minimal to account as a significant contribution to revenues in tipping fees. In order to reduce the burden on the urban ratepayer and make the facility more financially stable and attractive to farmers, the IEUA is expanding the project to incorporate a higher percentage of food and other agro-industrial processing waste products. The California Energy Commission will provide a grant to convert the plant to a higher temperature, modified complete-mix digester. This increased co-digestion is expected to increase food waste tipping revenue as well as significantly increase the plant's biogas production. The IEUA also hopes to begin selling carbon credits in the national carbon market, and are looking for means to capture revenues from the other environmental benefits of the project, such as from the reduction in ammonia emissions and improved watershed health.

Policy Initiatives. There were a number of energy related policies that were instrumental in promoting the development of the Chino Basin project. These included:

- California's 1 MW-limit net metering law
- The California legislature's 2002 goal of achieving 20 percent renewable energy by 2010.
- The ability of entities generating renewable energy to sell to Direct Access firms that are required to meet a certain renewable energy percentages in order to qualify for a state subsidy that makes "green power" competitive with conventional power rates.
- Green Tags allow firms throughout the country to invest in California's renewable energy projects and receive credits that count toward their own state's renewable energy targets.
- Self-generation legislation in 2002 which authorized municipal water districts to self-generate power for the district's own purposes, even if not located on district property.

In addition to these energy related policy initiatives, the impaired nature of the watershed and airshed have resulted in policies outlining strict nutrient management regulations for farms.

Challenges Faced. Facility-siting, negotiating with the local electric utility and initial high operating costs were the primary issues the Chino Basin project faced.

- <u>Facility siting</u> - rural residents were weary of siting a large manure handling facility in their area. In order to mitigate community concerns, the IEUA involved the community from the onset.
- <u>Electric utility issues</u> – In order to use the electricity generated from the biogas at a desalinization facility located one mile away, the electric utility imposed a wheeling charge for using transmission lines. In order to avoid this excess cost, the IEUA used their authority as a water utility to build underground pipe infrastructure, piped the biogas the one-mile distance and generated the electricity directly at the desalinization facility.
- <u>High initial operational costs</u> – The biogas plant's initial operational costs were higher than expected, reaching $.20/kWh. The project has also had issues with oversight of the project as well

as some technical problems in its first year of operation. As the project moves into its second year, many of the management and technical issues are being ironed out.

Main Data

Manure Amount	225 tons/day dairy manure
Alternative Biomass	Small amounts of food waste
Fuel Transport Mechanism	Trucks
Average Transport Distance	0.4 to 6.0 miles
System Capacity	370 kWe
Biogas Generation	210,000 cu ft/day
Utilization	Heat & Power
Digester Volume	1.2 million gallons
Investment Capital Costs	$8.5 million
Government Grant[20]	$8.5 million
Ownership	Inland Empire Utility Agency (water utility)
Operation Start-up	2002

Contacts

Rich Atwater
Chief Executive Officer and General Manager
Inland Empire Utilities Agency
(909) 357-0241
atwater@ieua.org

Martha Davis
Manager of Strategic Policy Development
Inland Empire Utilities Agency
(909) 993-1742
mdavis@ieua.org

John Gundlach
Manager of Organics Management
Inland Empire Utilities Agency
(909) 993-1640
jgundlach@ieua.org

Zhiqin Zhang
California Energy Commission
Technical Lead, Biogas Projects
(916) 654.4063
zzhang@energy.state.ca.us

Publication References

Atwater, Rich, Inland Empire Utilities Agency General Manager, memo received on April 20, 2004 outlining policy initiatives.

California Energy Commission, Public Interest Energy Research (PIER) Program: Anaerobic Digestion, online at: http://www.energy.ca.gov/pier/renew/biomass/bioch_en/anaerob_dgstn.html

Inland Empire Utilities Agency website: www.ieua.org/Organics/plug_flow.htm

National Renewable Energy Laboratory, 1998, "Methane Recovery from Animal Manures – the Current Opportunities Casebook," available online at: http://www.nrel.gov/docs/fy99osti/25145.pdf

[20] Includes federal, state, and municipal grants.

Case Study: Centralized Biogas Plants in Denmark

There are currently 20 centralized biogas plants operating in Denmark, which were built between 1984 and 1998. The number of farms participating and contributing manure to a given centralized plant varies from a few farms to 80 different livestock herds. In addition to manure, the plants also receive a variety of other organic wastes. A majority of the centralized biogas plants are found in western Denmark where livestock and manure production are concentrated. Their conversion capacity ranges from 28 to 550 tons of biomass per day, with the amount of produced biogas ranging between 35,300 to more than 529,500 cubic feet per day.

Following is a general overview of Denmark's experience with centralized biogas plants. For a more in-depth discussion, analysis and data on particular Danish plants, please refer to the reference section at the end of this case study. The information presented in this case study is predominantly taken from the 1999 Danish Institute of Agricultural and Fisheries Economics publication, "Centralised Biogas Plants – Integrated Energy Production, Waste Treatment and Nutrient Redistribution Facilities". All metric and Danish currency units have been converted to U.S. measurements and dollar amounts.

Intent for Developing. Various governmental organizations and individuals pursued centralized biogas plants as an integrated solution to existing agricultural, energy and environmental problems. None of the centralized biogas plants were built solely for profit. The primary motivations included:

(1) Environmental Concerns: Centralized biogas plants were seen to be well-suited for recycling various types of organic wastes and reducing nutrient losses from the soil due to manure application. Odor reduction and international commitments to reduce greenhouse gas emissions, were also driving forces.
(2) Benefits to the Farmer: Centralized biogas plants were an economically beneficial way for farmers to comply with legislative demands concerning manure application and nitrogen utilization.
(3) Energy Interests: The utilization of the biogas to generate heat and power was seen as a means of reducing Denmark's dependence on imported fossil fuel energy sources and promoting renewable energy production.

Fuel Source. Approximately 75 percent of the biomass treated at a given centralized facility is manure, with the other 25 percent being organic waste. The manure is transported from participating farms to the biogas plant by trucks owned and operated by the biogas plant. Fifty-one percent of the Danish centralized biogas plants accept pig manure, 44 percent accept cow manure, 4 percent accept mixed cow and pig manure, and one percent accepts mink or poultry and crop residuals. The types of organic waste accepted varies and includes gastrointestinal substances from slaughterhouses, waste from the fishing industry, flotation sludge from various parts of the food industry, as well as waste from tanneries, breweries, dairies, oil mills, and the drug industry. Facilities are also using an increasing amount of municipal sewage sludge and source separated household waste. The amount of organic waste needed generally depends on the biogas production output needs, the type of nutrient mix needed by crop land in the end fertilizer, and the tipping fee paid by the organic waste industries to the biogas plant. There is special consideration given to the type of organic waste accepted and the type of sanitation used, as much of the digestate is used as fertilizer after digestion and must not contain toxic substances.

System Components. Twelve of the centralized biogas plants use thermophilic bacteria (operating at 120-130 degrees F); the remainder use mesophilic bacteria (operating at 85 to 105 degrees F). Manure and organic waste are mixed and digested for 12 – 25 days, with sanitation taking place during this period so weeds and pathogens are killed to an acceptable level. The primary components of most of the centralized biogas plants include:

- Pre-storage/receiving equipment for manure and other organic waste
- Digester
- Post-storage tanks for digestate
- Pipe systems with pumps and valves (for moving digestate, biogas, process heat)
- Biogas storage
- Biogas utilization (i.e. gas engine for power and heat production)

Emissions & Environmental Concerns. Hydrogen sulfide, ammonia and particulate matter tend to be the primary emissions of concern at centralized biogas plants. An efficient and low-cost method used by Danish plants to reduce the hydrogen sulfide emissions, as well as ammonia emissions, is through the cleaning of the gas by mixing it with atmospheric air. Ammonia volatilization is further minimized through the employment of best practices during storage and spreading of the digestate. Covered storage tanks and good application practices have been found to solve the problem of excessive ammonia volatilization. Heavy metals and persistent organic compounds have been controlled through quality-control selection of the organic material that is put into the digester.

Ownership. A majority of the centralized plants are owned through cooperatives, with the members being the participating manure suppliers. Farmers started a number of the centralized biogas plants in Denmark, particularly the larger ones.

- 9 plants are owned by farmers as cooperative companies
- 5 plants are cooperatives that include the heat (or gas) consumers and farmers
- 3 plants are owned and operated by municipalities
- 2 plants are owned by private foundations
- 1 plant is a private company

Partnerships Employed. The projects are partnerships of agriculture, energy, and farm interests in the public and private sector working in collaboration with one another. Government agriculture and energy agencies are closely involved in the financing and technical assistance/scientific monitoring of the projects. Food processing industries consider centralized biogas plants an appropriate waste disposal and recycling possibility that is safe, convenient and economically advantageous.

Product Output. The generated biogas is used to generate both electricity and heat, with the electricity sold to the grid and the heat used for digester process needs as well as piping to meet the thermal needs of local district heating systems. Most plants have gradually increased the amount of biogas they produce, primarily through greater incorporation of organic industrial waste – particularly fatty waste with a high percentage of biologically decomposable organic matter. Excess amounts of digested manure (digestate) are sold by nutrient value as fertilizer among participating farmers. Six plants use special separator equipment for separating the digested manure to produce a solid with a fiber fraction that can be used to produce a soil amendment.

Financing. Government grants have financed 20 to 40 percent of the capital investment costs associated with the development of a centralized biogas plant. This number has been declining as plants show improved economic results and the perceptions of risk have decreased. The remainder of the investment costs is predominantly financed through long-term (20 year) indexed mortgage loans guaranteed by associated municipalities. To reduce individual farmer cost, a few of the cooperatively owned facilities have set up common manure tanks, lowering the price for individual farm storage capacity, with farmers able to rent the capacity needed.

Economic Viability. The economic viability of centralized biogas plants has improved over the years, primarily due to increasing the overall biomass and organic waste processed by the plants. The Danish

Energy Agency estimates that nearly 45 percent of the biogas generated at centralized biogas plants originates from the food/organic waste streams, making organic waste supplies an essential component for the economic success for plants where the primary income is biogas production and energy sales. Collection of gate fees for the receipt of waste has also provided significant revenue. Of the 17 centralized biogas plants that the Danish Institute for Agricultural and Fisheries Economics has data available for (as of 1999), five were generating sufficient income significantly above the plant's breakeven level, five were breaking even, three were under pressure and earning less than their break even level, and four were generating income significantly less than their break-even level.

Policy Initiatives. Danish centralized biogas plants were developed within a framework of legislative initiatives. These support measures are considered critical to the economic survival of biogas plants. Relevant policies instated during the 1980s and 1990s included:

Land application policies

- Restriction on manure land application and levels of nitrogen utilized.
- A requirement for farms to have six- to nine-month slurry storage capacity.

Waste use policies

- No organic matter was allowed to be land filled.
- A tax was applied on waste that was incinerated, but not if it was recycled.
- Danish Environmental Protection Agency set target to recycle 50% of country's organic waste by 2005.

Project funding

- Government allotted grants covering 20-40% of the investment costs for a centralized biogas plant.
- It was made possible for such projects to take out long-term (20 year) loans at low interest rates.
- The Danish Energy Research Program gave grants for project research and development and has funded reviews and pilot/demonstration projects. Follow up programs recording experience gained is collected, analyzed and communicated to farmers, plant operators, advisors, plant constructors and authorities.

Energy policies

- Heat from biogas is exempted from an energy tax imposed on fossil fuel sources.
- Power companies were required to purchase electricity produced by biogas at prices stated by legislation.
- A production grant was established of approximately 4.3 cents per kWh of electricity produced.
- A national target was set to reduce the county's 1988 carbon dioxide emissions level by 20% by 2005.
- The Danish Energy Agency set a target for the 1995 biogas production level to be quadrupled by 2005.

Other issues that facilitated integration of centralized biogas plants into Denmark's landscape included the widespread existence of district heating systems, which became purchasers of the heat generated from biogas six to eight months of the year.

Challenges Faced. The reason why some of the plants did not do well was primarily due to inappropriate design and construction. This led to increased operational costs and lower energy sales than expected. Transport costs are also generally high for centralized biogas plants since costs are incurred during both manure collection and digestate redistribution. However, it is considered to be a significant advantage to farmers that the transportation networks contribute to the redistribution of nutrients from the livestock farmers and food waste industries to crop producers. While the anaerobic digestion takes place in closed tanks, centralized biogas plants have a reputation in Denmark for emitting odor, though at a much lower levels relative to raw manure. Some technologies (such as burning extracted air and using bark and charcoal filters) have proven to be successful at eliminating the odor resulting from the centralized anaerobic digestion process.

Main Data (Hashoj, Denmark) (1994 USD prices)

The following data is from the centralized biogas plant in Hashoj, Denmark. In an economic assessment of centralized biogas plants by the Danish Institute of Agricultural and Fisheries Economics (1999), Hashoj was considered to be obtaining sufficient income from plant operations, significantly above breakeven levels. The data for the Hashoj plant and the other 19 centralized biogas plants in Denmark is available in, "Danish Centralised Biogas Plants – Plant Descriptions" and the above listed 1999 Danish Institute of Agricultural and Fisheries Economics paper.

Animal Manure	100 tons/day
Alternative organic biomass	38 tons/day
Biogas production	312,660 cubic feet per day
Digester capacity	105,944 cubic feet
Process temperature	98.6 degrees F
Gas Storage capacity	77,692 cubic feet
Utilization of biogas	CHP-plant/gas boiler
Average transport distance	2.5 miles
Capital cost[21]	$3,500,000
Government Grant	$816,000 (23% of total capital cost)
Ownership	Cooperatively owned
Operation Start-up	1994

Publication References

Centre for Biomass Technology, 2000, "Danish Bioenergy Solutions – reliable & efficiency," available online at: www.videncenter.dk/uk/index.htm. Click on <English> then on <Publications>.

Gregerson, Kurt, Danish Institute of Agricultural and Fisheries Economics, 1999, "Centralised Biogas Plants – Integrated Energy Production, Waste Treatment and Nutrient Redistribution Facilities," available online at: http://wesrv5.sdu.dk/bio/pdf/centra.pdf.

University of Southern Denmark Bioenergy Department, 2000, "Danish Centralised Biogas Plants – Plant Descriptions," available online at: http://websrv5.sdu.dk/bio/pdf/rap2.pdf.

University of Southern Denmark Bioenergy Department, 2000, "Practical guidelines for the planning of a manure based biogas plant" web page: http://websrv5.sdu.dk/bio/planning.htm.

University of Southern Denmark Bioenergy Department, 2000,"Handling of digestate" web page: http://websrv5.sdu.dk/bio/handling.htm.

Al Seadi, Teodorita, University of Southern Denmark, 2001, "Good Practice in Quality Management of AD residues from biogas production," for International Energy Agency Task 24 Energy from Biological Conversion of Organic Waste, available online at: http://websrv5.sdu.dk/bio/pdf/manage.pdf.

International Energy Agency, July 2001, "Biogas and More! Systems and Markets Overview of Anaerobic digestion," Task 24 paper available online at: http://websrv5.sdu.dk/bio/pdf/biogas.pdf.

Joensson, O., Polman, E., Jensen, J.K., Eklund, R., Schyl, H. and S. Ivarsson, "Sustainable Gas Enters the European Gas Distribution System," available online at: www.dgc.dk/publikationer/konference/jkj_sustain_gas.pdf.

[21] Includes biogas plant, vehicles, and storage tanks

Unit Conversions

tonne = 1.102311 ton
cubic Nm = 38.04 cubic feet
km = 0.62 mile
Celsius = (5/9)*(Farenheit-32)
Bank of Canada, Historical Currency Converter, Dec 30, 1994: 1 DKK = .16 USD
Bank of Canada Historical Currency Converter, Dec. 29, 1995: 1 DKK = .18 USD