

product. Tables II-9 and II-10 present characteristics of wastewater and sludge from the processing of milk and milk products.¹¹⁹

Table II-9. Dairy food processing waste characterization

Product/Operation	----- Wastewater -----	
	Weight lb/lb milk processed	BOD ₅ lb/1000 lb milk received
Bulk milk handling	6.1	1.0
Milk processing	4.9	5.2
Butter	4.85	1.46
Cheese	2.06	1.8
Condensed milk	1.85	4.5
Milk powder	2.8	3.9
Milk, ice cream, & cottage cheese	2.52	6.37
Cottage cheese	6.0	34.0
Ice cream	2.8	5.76
Milk & cottage cheese	1.84	3.47
Mixed products	1.8	2.5

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-20.

Table II-10. Dairy food waste characterization—processing wastewater

Component	Units	Industry Wide	--Whey --		Cheese waste- sludge
			Sweet Cheese	Acid cheese water	
Moisture	%	97.60	93.10	93.40	97.50
TS	% w.b.	2.40	6.90	6.60	2.50
VS	"	1.49	6.35	6.00	
FS	"	0.91	0.55	0.60	
COD	"		1.30		
BOD ₅	"	2.00			
N	"	0.077	7.48		0.18
P	"	0.050			0.12
K	"	0.067			0.05

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 4-20.

(d) Alternative milking center waste handling methods

The use of conventional septic tanks and leach beds for milking-center waste is not acceptable for three reasons:

1. Large herds generate too much milking wastewater.
2. Sanitizing chemicals used to clean milking equipment may kill septic system bacteria.
3. Manure solids washed from parlor floors will clog the leach bed.¹²⁰

A modified septic tank system using a presettling tank, a treatment tank, a dual leach bed, and proper management may work if solids are pumped out of the presettling tank on a regular basis (monthly or bimonthly) and the effluent discharge is alternated between the two leach beds on a monthly or bimonthly basis.¹²¹

Rather than using a leach bed, effluent is sometimes discharged every 2 to 5 days onto cropland, pasture, or a designated grassed infiltration area via (1) sprinkler irrigation, (2) controlled flood irrigation, or (3) discharge into gradient infiltration terraces. The size and shape of the disposal area is affected by soil types, vegetation, topography, proximity to streams, and quantity of wastewater and the vegetation on the disposal area must utilize the nutrients in the wastewater and be harvested.¹²²

Another alternative method of handling milking center wastewater is to put it into a liquid-manure system where milking-center wastewater provides the necessary dilution of liquid waste. However, some form of effluent lagoon is required and such a lagoon is usually designed with enough volume to provide one year's storage of this waste.¹²³

(6) Land Application of Dairy Manure

There are two principal objectives in applying dairy cow manure to land:

- 1) ensuring maximum utilization of the manure nutrients by crops and
- 2) minimizing water-pollution hazards.

Surface spreading and subsurface injection are the two most common land-application methods. Several guidelines must be followed to minimize environmental hazards:

- * Test soil to establish existing soil-fertility levels.
- * Test manure and wastewater to determine nutrient content.
- * Select an application rate that does not exceed crop nutrient requirements and avoids soil contamination, crop damage, and runoff and contaminated tile flow.
- * Check soil moisture before applying liquid wastes, and adjust application rates to avoid runoff.
- * To avoid runoff, do not apply manure to frozen or saturated soils.
- * Calibrate application equipment to obtain the desired application rate.
- * Incorporate raw or untreated manure to reduce odors and nitrogen losses.¹²⁴

Adequate land area must be secured to allow for manure application. One approach to determining the amount of land required is to only apply the amount of nutrients removed in the harvested crop. This will prevent nutrient buildup in the soil beyond suggested agronomic and environmental levels. Excess application may induce nutrient deficiencies in the soil and increase the potential for excess nutrients to enter waterways. Phosphorus is the nutrient of major concern on soils with high phosphorus fertility levels. Phosphorus applied to fields as manure or commercial fertilizer can move into bodies of water during erosion and runoff events, and is largely responsible for the accelerated eutrophication of many bodies of water. It also accumulates in soils if applied in quantities greater than those removed by crops.¹²⁵

(a) Factors Controlling Application Rate--rule-of-thumb estimates

Table II-11 can be used for rule-of-thumb estimates of available nutrients in different manure for the common methods of manure management. Table II-11 is limited to:¹²⁶

- i. Solid and slurry manure applied in tons
- ii. Available nutrients, first year only.
- iii. Situations where there is little carryover of nutrients from previous manure applications.
- iv. Common methods of manure management.

Manure liquids are not included because manure of this type will be diluted 4 to 10 times so that it can be flushed into storage or treatment facilities. With this method of waste management, a large loss of nitrogen can occur during storage, and tests should be made to determine the nitrogen concentration.¹²⁷

The amounts shown in the tables are in pounds of available nutrients per ton. The estimated nutrients vary considerably according to the climate and waste management system. The tables also show the estimated moisture content, which can be used as a guide. The tons are the actual weight of the manure as it is applied, which includes moisture and bedding. Use reliable local data if they are available. In most cases, manure changes weight during storage and treatment because it almost always gains or loses moisture.¹²⁸

An example of moisture gain is seen in waste management for dairy cows in the northern part of the country. Typically, the manure is placed in storage daily in either a covered tank or an open storage pond. The milking center wastewater is added, which amounts to about 5 or 6 gal/cow/day. If 5 gallons of wash water are added daily to the manure from a 1,400-pound cow, the volume is increased by about 35 percent. Similarly, if the original moisture content is 89 percent, it is increased to almost 92 percent. Consequently, it is then necessary to haul more than 13 tons of manure to the field for every 10 tons excreted if there is no drying or further dilution.¹²⁹

Table II-11. Rule-of-thumb estimates--available nutrients in manure from dairy cows

Management system	Final moisture %	Nutrients available first year		
		N	P ₂ O ₅	K ₂ O
		-----lb/ton -----		
1. Fresh manure, collected and applied daily, incorporated before drying.	89	7	3	5
2. Manure collected daily, 50% processing water added, stored in covered tank, applied seasonally, incorporated before drying.	92	3	3	5
3. Manure placed daily in open storage pond; 30% processing water added; liquids retained; spread annually in fall; incorporated before drying; cool, humid climate; evaporation = precipitation.	92	3	3	4
4. Bedded manure, unroofed stacking facility (bedding is 10% by weight); spread in spring before drying; cool, humid climate; evaporation = precipitation.	82	3	2	4
5. Manure, no bedding, stored outside; leachate lost; spread in spring before drying; cool, humid climate.	87	3	2.5	4

Source: Agricultural Waste Management Field Handbook, US Department of Agriculture, Soil Conservation Service, April, 1992, p. 11-33, 34.

The factors that most often limit the amount of manure that should be applied to cropland are existing soil-fertility levels, manure nutrient content, crop nutrient needs, site limitations, slope, runoff potential, and leaching potential. Tables II-11 and II-12 provide average nutrient values. The nutrient composition of waste is affected by housing and the waste-handling system. Bedding and additional water can dilute manure, resulting in less nutrient value per pound.¹³⁰

As a rough rule of thumb, the Illinois soil conservation service has calculated that on land producing 150 bushels of corn per acre and 40 bushels of soybeans per acre in rotation, 1.2 acres are needed to use the yearly production of phosphorus excreted by each 1000 pounds of dairy cows. 2.4 acres are needed to dispose of potash for each 1000 pounds, and 1.1 acres would be required per 1000 pounds to dispose of nitrogen, assuming a 50 percent loss of N. These acreage amounts would increase in areas where crop yields are smaller.¹³¹

A detailed accounting of nutrient flow conducted in Florida found that 23 percent of the feed N and P was accounted for in milk outputs leaving 77 percent of feed nutrients excreted. Approximately 24 percent of manure N and P were excreted in the milking area where 5 percent of manure N was lost. In the feeding area 28 percent of the manure N was excreted. The remaining manure N and P were excreted in the pasture and lanes to and from the pasture. A further 45 percent of the manure N was volatilized but all of the P was available.¹³²

Table II-12. Annual Raw-Manure Production per 1,000-Pound Animal Weight

Animal Type	Manure Production		Percent Solids	Nutrient Content			Nutrient Content		
	Tons/yr	Gal/yr		N lb/ton	P ₂ O ₅	K ₂ O	N lb/1,000 gal	P ₂ O ₅	K ₂ O
Dairy	15	3614	12.7	10.0	4.1	7.9	41.5	17.0	32.8
Beef	11	2738	11.6	11.3	8.4	9.5	45.4	33.7	38.2
Veal	11.5	2738	8.4	8.7	2.1	9.0	36.5	8.8	37.8
Swine									
Growing pig	11.9	3008	9.2	13.8	10.8	10.8	54.6	42.7	42.7
Mature hog	5.9	1425	9.2	13.9	10.8	10.8	57.5	44.7	44.7
Sow & litter	15.9	3894	9.2	14.2	10.7	11.1	58.0	43.7	45.3
Sheep	7.3	1679	25.0	22.5	7.6	19.5	97.8	33.0	83.5
Goat	7.0	1789	31.7	22.0	5.4	15.1	86.1	21.1	59.1
Poultry									
Layers	9.7	2464	25.0	27.3	23.5	13.2	107.5	92.5	52.0
Broilers	13.1	3285	25.0	33.4	16.7	12.5	133.2	66.6	49.8
Turkey	8.4	2044	25.0	23.7	20.8	16.9	97.4	85.5	69.5
Horse	8.2	2048	21.0	12.1	4.6	9.0	48.4	18.4	36.0

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, <http://oh.nrcs.usda.gov/fotg/OhioNRCStandards1.htm>, 1979-1999 various.

Improvements in N use efficiency by dairy cattle can be achieved with nutritional management or ionophores which selectively suppress bacteria in the rumen that produce ammonia. Dutch researchers suggest that the maximum N use efficiency may be about 0.43, although such high efficiency depends on temperature stress, incomplete feed digestion and variable feed quality. Recent research in Wisconsin has suggested that dairy rations could contain 0.38 percent P, rather than the currently recommended 0.48 percent P, which would decrease P excretion in manure by 25 to 30 percent without reducing milk production or reproductive efficiency.¹³³

Nutrient losses during storage and handling reduce the amount of nutrient available for land application. Phosphorus and potassium losses are usually negligible but nitrogen losses can be significant. Table II-13 provides nitrogen losses during storage and handling. Land application methods also affect the amount of nutrients available for crop uptake. Most losses occur within 24 hours of application. Manure should be incorporated into the soil as soon as possible after application. Injecting, chiseling, or knifing liquid manure into the soil minimizes odors and nutrient losses to the air or as surface runoff.¹³⁴

Table II-13. Percentage of original dairy manure nutrient content retained in various storage systems^a

Method	N	P	K
Daily spread	80	90	90
Dry + roof	70	90	90
Earthen Storage	55	60	70
Lagoon/flush	30	40	60
Open lot	60	70	65
Pits + slats	75	95	95
Scrape/storage Tank	70	90	90

^a Adapted from Moore and Gamroth (1993 - National Data base)

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, <http://www.mnplan.state.mn.us/eqb/scoping.html>, September, 1999, p. J-43.

Tables II-14, II-15 and II-16 present approximate nutrient values for land-applied solid and liquid manure, taking into account handling and storage losses. The amount of nitrogen available in the soil depends on the method of application and days to incorporation.¹³⁵

Table II-14. Typical losses between excretion and land application adjusted for dilution in the various systems—dairy manure

These values are in addition to land application losses.

System	% Nitrogen lost
Solid	
Daily scrape and haul	15-35
Manure pack	20-40
Open lot	40-60
Deep pit (poultry)	15-35
Liquid	
Anaerobic pit	15-30
Above-ground storage	10-30
Earth storage	20-40
Lagoon	70-80

Adapted from MWPS (1985)

Source: Jacobson, Larry D., et al., *Generic Environmental Impact Statement on Animal Agriculture*, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, <http://www.mnplan.state.mn.us/eqb/scoping.html>, September, 1999, p. J-43.

Table II-15. Approximate fertilizer nutrient value at time applied to land - solid handling systems^a

Type of Livestock	Bedding vs. No Bedding	Dry Matter %	Nutrient Content			
			Total N ^b	NH ₄ ^c lb/ton	P ₂ O ₅ ^d	K ₂ O ^e
Swine	Without bedding	18	10	6	9	8
	With bedding	18	8	5	7	7
Beef cattle	Without bedding ^f	52	21	7	14	23
	With bedding	50	21	8	18	26
Dairy cattle	Without bedding	18	9	4	4	10
	With bedding	21	9	5	4	10
Sheep	Without bedding	28	18	5	11	26
	With bedding	28	14	5	9	25
Poultry	Without litter	45	33	26	48	34
	With litter	75	56	36	45	34
	Deep pit (compost)	76	68	44	64	45
Turkey	Without litter	22	27	17	20	17
	With litter	29	20	13	16	13
Horses	With bedding	46	14	4	4	14

^a Manure spreader capacity: 1 bu = 40 to 60 lb.

^b Ammonium N plus organic N, which is slow-releasing.

^c Ammonium N, which is available to the plant during the growing season.

^d To convert to elemental P, multiply by 0.44.

^e To convert to elemental K, multiply by 0.83.

^f Open dirt lot.

Source: *Ohio Livestock Manure And Wastewater Management Guide*, Bulletin 604, Section 15, <http://oh.nrcs.usda.gov/fotg/OhioNRCStandards1.htm>, 1979-1999 various.

Table II-16. Approximate fertilizer nutrient value at time applied to land - liquid handling systems^a

Type of Livestock	Manure Storage	Dry Matter %	Nutrient Content			
			Total N ^b lb/1,000 gal	NH ₄ ^c	P ₂ O ₅ ^d	K ₂ O ^e
Swine	Liquid pit	4	36	26	27	22
	Lagoon ^f	1	4	3	2	4
Beef cattle	Liquid pit	11	40	24	27	34
	Lagoon ^f	1	4	2	9	5
Dairy cattle	Liquid pit	8	24	12	18	29
	Lagoon ^f	1	4	2.5	4	5
Veal calf	Liquid pit	3	24	19	25	51
Poultry	Liquid pit	3	80	64	36	96

^a Application conversion factors: 1,000 gal = about 4 tons; 27,154 gal = 1 acre-inch.

^b Ammonium N plus organic N, which is slow-releasing.

^c Ammonium N, which is available to the plant during the growing season.

^d To convert to elemental P, multiply by 0.44.

^e To convert to elemental K, multiply by 0.83.

^f Includes feedlot runoff water and is sized as follows: single-cell lagoon - 2 cu ft per 1 lb animal wt. Two-cell lagoon - cell 1, 1 to 2 cu ft per 1 lb animal wt; cell 2, 1 cu ft per 1 lb animal wt.

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, <http://oh.nrcs.usda.gov/fotg/OhioNRCStandards1.htm>, 1979-1999 various.

Tables II-17, II-18, and II-19 can be used to estimate the availability of ammonia and organic nitrogen in the soil. The phosphorus and potassium applied to the soil will be available unless removed by surface runoff and soil erosion. Nearly 100 percent of total phosphorus and potassium from manure application are considered available the first growing season. It is important to note that manure contains much more potassium than magnesium or calcium, and after many years of continued manure application, the ratio of potassium to magnesium and calcium may be too high for optimum crop growth. To adjust the ratio, additional magnesium and/or calcium may have to be added.¹³⁶

Table II-17. Average nitrogen losses by method of application and manure type.

Percent of nitrogen applied that is lost with 4 days of application.

Application method	Type of waste	% Nitrogen lost
Broadcast	Solid	15-30
	Liquid	10-25
Broadcast with immediate cultivation	Solid	1-5
	Liquid	1-5
Knifing	Liquid	0-2
Sprinkler irrigation	Liquid	15-35

^a Adapted from MWPS (1985)

Source: Jacobson, Larry D., et al., Generic Environmental Impact Statement on Animal Agriculture, University of Minnesota, College of Agriculture, Food, and Environmental Sciences, <http://www.mnplan.state.mn.us/eqb/scoping.html>, September, 1999, p. J-43.

Table II-18. Method of calculating N availability of manure^a

Available Nitrogen %		Time of Application Days Until Incorporated ^b				
NH4	Organic	Date	Days			
50	33	Nov-Feb	25	33	Nov-Feb	>3
50	33	Mar-Apr	25	33	Mar-Apr	>3
75	33	Apr-Jun	25	33	Apr-Jun	>1
75	15	Jul-Aug	25	15	Jul-Aug	>1
25	33	Sep-Oct	15	33	Sep-Oct	>1

^a The calculations are for all animal manure. It is assumed that 50% of the organic N in poultry manure is converted to NH4 rapidly and is therefore included in the NH4 column for calculating available N.

^b Incorporation is the mixing of manure and soil in the tillage layer. Disking is usually enough tillage for conserving N availability.

Only about one-third of the organic nitrogen in animal manure is available to crops during the year it is applied, and the remaining two-thirds, residual organic nitrogen, becomes part of the soil organic matter. It is mineralized or becomes available at the rate of about 5 percent a year. To determine how much nitrogen will be available to crops from manure applications, growers must take into account the mineralized nitrogen that will become available from previous manure applications (Table 9). Manure is also a good source of phosphorus and potassium. Tables 1, 4, 6, or 7 can be used to calculate the amount of phosphorus and potassium that will be available from the manure. The phosphorus and potassium in manure will be as available to the crop during the year it is applied as would the equivalent amount of fertilizer-grade phosphorus and potassium.

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, <http://oh.nrcs.usda.gov/fotg/OhioNRCStandards1.htm>, 1979-1999 various.

Table II-19. Percentage of residual organic nitrogen made available from manure applied in previous years

Years After Application	Percentage of Residual N Available
1	5.0
2	4.7
3	4.5
4	4.3
5	4.1
6	3.9
7	3.7
8	3.6
9	3.4
10	3.2

Source: Ohio Livestock Manure And Wastewater Management Guide, Bulletin 604, Section 15, <http://oh.nrcs.usda.gov/fotg/OhioNRCStandards1.htm>, 1979-1999 various.

(7) Sources of Odors From Dairy Operations

There are three primary sources of odors from dairy operations: (1) buildings, (2) manure storage or treatment units, and (3) spreading of manure and waste waters on agricultural land.¹³⁷ As a rule of thumb, about 60 percent of odors come from confinement buildings and 40 percent come from the lagoons used to store the waste.

Because confinement buildings can be a significant source of odor, management of livestock and manure in the buildings is important. Little odor is generated in the first 3 to 5 days after manure is

deposited, but if manure accumulates longer than 3 to 5 days, large amounts of offensive odors are released. Ammonia production peaks at 3 days and again at 21 days. Manure accumulated on open lots can pose greater odor nuisance during warm, wet weather than if the animals are totally under a roof. If animals become dirty with manure, their body heat will promote the rapid release of odors.¹³⁸

A building's ventilation system exhausts large amounts of odors and gases generated within the building along with the ventilation air. If the building is dirty or has high dust levels, the result will be a higher odor level. Dust levels can be reduced with proper sanitation and regular cleaning. Animal fats and oils added to the feed can also reduce feed-dust generation.¹³⁹

(a) Controlling Odors

The source of odors is the volatile compounds generated during the decomposition of manure. The two principal classes of odorous compounds are those containing sulfur, e.g., hydrogen sulfide, and those containing nitrogen in the amine form, e.g., ammonia. The generation of these compounds is affected by the type of livestock and is primarily associated with the level of protein and amount of roughage in feed rations.¹⁴⁰

The manure-handling system also affects the rate of odor generation and the characteristic smell of the odor. Manure that is collected and field-spread daily has less offensive odors than stored manure. Also, manure handled as a liquid (slurry) will have a greater potential for odor than manure handled in a solid form with bedding. Research indicates that the transport of odors is also associated with dust particles or aerosols. Therefore, controlling dust or aerosol emissions will help control odors.¹⁴¹

(b) Site Selection

Four site selection factors help to minimize odor potential:

- i. Isolation of the facility site.
- ii. Direction and distance to neighbors.
- iii. Prevailing wind direction.
- iv. Air drainage.¹⁴²

Operation size and prevailing summer wind direction affect required separation distances from neighbors. Odor potential increases when a neighboring residence is in a down-slope direction, and, in particular, when it is in a swale or small valley. During calm summer evenings, air next to the ground surface will be cooled and drift down-slope. This meteorological condition may continue for several hours each evening. When land is relatively flat, prevailing wind direction and distance to neighboring residences will affect the decision on where to locate the facility. If the site is sloping, the air-drainage factor must be considered and may outweigh prevailing wind directions.¹⁴³

(c) Building Design and Manure Collection

Accumulated manure on lot surfaces will have more odor during warm, wet weather than manure in a storage area.

Daily scraping of manure from lot surfaces will reduce odor generation.

Manure left in a building longer than 3 to 5 days will have more odor than if removed to cropland or to outside covered storage more frequently.

Flush systems reduce odors inside a building and, consequently, the amount exhausted with ventilation air, but increase the volume of wastewater to be handled and land-applied and the amount of odor outside the buildings.

Reducing dust levels within a building will lower odor problems.

Scrubbing the exhaust ventilation air with filters will reduce odors from a building.¹⁴⁴

- i. Storage Units: Manure-storage structures should be covered. For dairy and beef manure, a floating crust usually forms and acts as a "lid." However, a floating crust may not form under two conditions: excess water or low pH. Therefore, it is important to divert all clean surface runoff away from the manure-storage structure. Storage units initially loaded in the fall or winter take longer to develop a crust than those started in the spring or summer.¹⁴⁵
- ii. Lagoons: There are two principal types of livestock-waste treatment lagoons: aerobic (aerated) and anaerobic (without air). A properly designed and operated aerated lagoon will not produce odors. However, aerated lagoons are more costly to operate and most producers choose anaerobic lagoons. Anaerobic lagoons become an important source of odor because of improper design (principally overloading) and poor management.¹⁴⁶

(d) Manure Spreading

If manure must be spread when odors may be a problem, immediate soil incorporation by injection or plow-down will decrease the release of odors. Incorporation may also be necessary if limited storage capacity is available. With soil incorporation, less nitrogen will be lost by the volatilization of ammonia.¹⁴⁷

Soil incorporation is sometimes not possible due to cropping or soil conditions. Research has shown that aerating stored liquid manure for as little as four hours before spreading removes most of the odorous sulfur compounds. However, these odors are simply released in a different area when aerating the manure storage.

Many operators use irrigation equipment to spread liquid manure on cropland. This application method can increase odor problems unless special precautions are taken to reduce aerosol drift because odors are transported with the aerosol. High-pressure spray (80 to 100 psi at nozzle) will atomize the wastewater into finer aerosols that can travel farther than larger droplets from lower-pressure nozzles.¹⁴⁸

(e) Commercial Odor-Control Chemicals

There are four general types of odor-control chemicals:

- i. A masking agent is a "perfume" odor to override an offensive odor.
- ii. Counteractants are chemically designed to block the sensing of particular odors.
- iii. Odor-absorption chemicals are reactive compounds to change the odor-causing chemical.
- iv. Biological compounds such as enzymatic or bacterial products alter the decomposition pathway so that the odorous compounds are not generated. These compounds are added directly to the manure storage, and some are available to add to the feed.¹⁴⁹

The effectiveness of various odor-control chemicals is questionable and the cost of odor-control chemicals varies greatly. Odor-control chemicals are usually an expensive alternative to proper design and good management.¹⁵⁰

(8) Generating Methane From Dairy Manure Systems

Livestock manure that is handled in a slurry or liquid form and treated anaerobically in large concentrated animal production facilities (500+ dairy cows) produces biogas. Methane emissions can be reduced by recovering this gas and using it for on-farm energy needs. The biogas is captured by placing a floating, impermeable cover over the lagoon, sealed at the edges to prevent influx of air. Captured gas can be used as a cooking or lighting fuel or cleaned and used in generators, boilers, space heaters, or refrigeration equipment.¹⁵¹

The biggest problem with methane generation is that it is usually not economically feasible. For example, a case study evaluated the feasibility of a centralized digester in Tillamook County, Oregon. The study included 26,000 dairy cows with 68 percent located within a 16-km radius and 92 percent within a 40-km radius. The digester-power plant was not economically efficient and it was projected to operate at a \$514,000/yr deficit. In addition, a \$2.20/tonne surcharge was assessed to livestock producers for handling the manure.¹⁵² The following sections give the specific economic costs and benefits of methane generation and use.

(a) Performance

Gas recovery rates depend on ambient temperatures and the farm's geographic location. Average gas recovery at US dairy farms range from 187-375 m³ biogas/ 1,000 kg of volatile solids handled. Assuming 10 kg of volatile solids produced daily by an average US dairy cow and a 60 percent methane content in biogas, daily recovery rates at dairy farms handling 100 percent of the manure produced can range from 112-225 m³ methane/100 head. At dairy farms handling 55 percent of the manure produced, the methane recovery rates are proportionate.¹⁵³

(b) Capital and Installation (\$2000):

For systems with a design lifetime of 10 years, total project costs are driven by the capital and installation costs of the gas recovery system and the gas utilization equipment. Installation costs for gas recovery systems on dairy farms using 15 percent of the manure are \$87-214/cow; installation costs for dairy farms using 55 percent of the manure are \$147-281/cow. On a 1000-head dairy farm, gas-fired chillers cost \$32/head; wash water heaters cost \$8/head (using 15 percent of the manure) to \$15/head (using 55 percent of the manure); power generators cost \$32/head (using 15 percent of the manure) to \$71/head (using 55 percent of the manure).¹⁵⁴

Installation costs for the following methane production facilities for dairy waste that produced gas for an end use such as electricity production or heating were reported by the EPA in the spring of 2000 (Table II-20).

Table II-20. Methane system capital costs

Location	Year Built	Installed Cost (2000\$)	Number of Cows	Cost Per Cow	Cost Per Cow Per Year
CT	1997	\$485,000	600	\$809	\$81
MI	1981	\$294,000	720	\$407	\$41
VT	1982	\$343,000	340	\$1007	\$101
CA	1982	\$370,000	400	\$925	\$93
OR	1997	\$310,000	1000	\$310	\$31
NY	1998	\$214,000	1000	\$314	\$31
MN	1999	\$330,000	1000	\$330	\$33
PA	1979	\$612,000	2000	\$306	\$31
PA	1983	\$212,000	250	\$847	\$85
CT	1997	\$161,000	200	\$803	\$80

Source: AgSTAR Digest, United States Environmental Protection Agency, EPA-430/F-00-012, Spring, 2000, pp. 5-6, 9.

(c) Non-fuel Operation and Maintenance--Minimal maintenance costs (2000\$)

Annual O&M costs for heating and cooling on dairy farms with 500-1000 head are \$2.95/head; annual O&M for power generation costs \$3.1/head (using 15 percent of manure) to \$11.40 (using 55 percent of manure).

To make methane generation at a dairy CAFO economically viable, the costs enumerated above must be offset by the benefits from methane generation. If methane generation is used to create economic benefits from CAFO waste the cost/benefit breakdown still does not look promising. For example, the costs and benefits of a methane powered manure system with a 10 year design lifetime for dairy cows would be (in \$2000):

Installation costs for gas recovery systems on dairy farms using
 15 percent of the manure are \$87-214/cow;
 55 percent of the manure are \$147-280/cow.

At an electric price of \$0.10/kWh, annual benefit from gas recovered for on-site dairy farm power generation at dairy farms is \$23/head (using 15 percent of manure) to \$58/head (using 55 percent). Annual benefits from recovered gas for heating dairy wash water is at least \$10.70/head.¹⁵⁵

(9) Bion-based Systems For Handling Dairy Waste

In a Bion-type system, natural processes are used to handle environmental, water, air and waste problems and a large percentage of liquids are recycled. Flushing the barns releases a slurry of waste containing up to 5 percent solids. Waste effluent is routed to a small, designed wetland where much of the waste is biologically removed. The liquids are then returned to barns for re-use as flush water. Some treated liquid may be filtered--removing particulate matter to 0.5 microns--and then used for feed water. When this step is taken, it is estimated that less than five percent (5 percent) of total water needs will be drawn from wells. There is no lagoon and no irrigation system. Ozone injection may be used at various points in the system.¹⁵⁶

Proponents of Bion-type systems claim that
 Separated solids stack and are essentially odor-free.

Solids may be used immediately on crops. All crop nutrients are available.

Ozonation breaks ammonia into its components of nitrate and water, nitrogen levels are somewhat enhanced. Phosphorus levels are slightly decreased.

Odor levels are reduced:

Separated liquids and solids are, essentially, odor-free.

Barn odors have decreased.

Pathogens are removed

Costs are reduced:

Easily transported dried or composted solids are trucked to the spread site.

Substantial savings in labor and time.

Mortalities are composted, under low odor conditions, using a mixture of sawdust and solids.

Barn floors are cleaner.

Barn odors decrease noticeably.

Calculated costs for a bion-type system are quite low. An anaerobic digestion system, coupled with an engineered wetland system is typically claimed to require just over one-half acre of bare land. Such a system can process 15,000 gallons of effluent daily or about 5 million gallons per year. Each plant has a construction cost of approximately \$250,000, yielding a cost of about three cents per gallon or about 40 cents per cow per day.¹⁵⁷

Unfortunately, bion-type systems have some major drawbacks. They are highly susceptible to imbalance in the biological components of the systems (the wetlands) and when bion-type systems are not working well, they are not working at all. Further, bion-type systems only function when temperatures are above freezing--and warmer temperatures work better than cooler temperatures. These drawbacks may make bion-type systems subject to high odor emissions, and bion-type systems are poor choices for areas that experience any prolonged periods of cool, winter weather.

(a) Conclusion--costs vs. benefits

The costs of treating dairy CAFO waste in a responsible manner are substantial. And since the costs of the systems involved are additions to the current large dairy CAFO flush and dump in lagoons systems, these costs represent one measure of the costs the dairy is shifting to the local region and thus, avoiding. The \$.40 per cow per day cost of the bion-type system adds \$146 per year to the cost of each cow. This alone is enough to nullify the slight cost advantage of larger dairy CAFOs over smaller, more conventional dairy farms. Since these methods of waste handling are not required in smaller, more conventional dairies where sufficient land is available to spread the manure, it is clear that most, if not all of the cost advantage of larger dairy CAFOs is presently coming from shifting the costs of dairy waste to the surrounding region.

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