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In recent years there has been renewed interest in producing energy in the form of methane gas from manure by anaerobic digestion. This paper deals with a situation where methane gas is used to fuel an engine which in turn powers a generator which produces electricity for on-farm use and for sale. Hot water produced from cooling the engine is used to maintain the anaerobic digester at a temperature near 95°F for high rate methane production. Excess hot water can be used for heating needs on the farm and in the home.

Most free-stall dairy barns in the northern United States are "cold" barns in which natural ventilation keeps the interior temperature not much warmer than outside temperature during cold weather. Manure from a cold barn must be warmed to 95°F before or soon after it enters the digester. In addition, in sub-freezing weather, manure must be thawed before it enters the digester. The thawing process requires about as much energy as does heating manure from 35° to 95°. The possible importance of this may be illustrated with the following data. During 1979-82, the average daily minimum temperature recorded at Cornell University's Caldwell Field Weather Station averaged between 14°F and 16.5°F for the four months of December through March. At locations with similar temperatures, even if the interior of the barn remains 5-15°F warmer than the outside temperature, manure will often freeze during this four month period.

While the engine produces sufficient hot water to warm the manure to 95°F, there are problems in thawing and warming the manure rapidly enough so that cold manure entering the digester does not adversely affect digester performance. Manure from a warm barn would make it much easier to operate a digester at maximum efficiency. In fact, efficient operation of a digester may require manure from a barn where manure never freezes.

Purpose

The purpose of this paper is to analyze whether benefits from a warm free stall barn, other than those associated with having non-frozen manure leave the barn on the way to the digester, are sufficient to justify the added investment and operating costs of a warm barn in comparison to a cold barn. The benefits and costs are computed disregarding the methane digester. A breakeven analysis is used to find the minimum added annual benefits required to justify the added investment in a warm barn.

Warm vs. Cold Free Stall Barns

The fact that most free stall barns in the northern United States are cold rather than warm barns suggests that dairy farmers believe that the added benefits of warm barns do not exceed the added costs. The added costs are due to

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greater initial investment for insulation and mechanical ventilation (fans) and to operating costs for the fans. There may be benefits from better feed/milk conversion ratios during cold weather in warm barns. Data from an experiment in Wisconsin will be used later in an attempt to evaluate this potential benefit. Operator comfort may be greater in the warm barns but this benefit, if any, is difficult to estimate in monetary terms.

Experience with warm barns indicates that they have some problems. One of the serious problems appears to be ventilation. In some warm barns, moisture condensing on walls and ceilings has led to serious mold and mildew situations.

Problems Associated with a Cold Free Stall Barn

We will give only limited attention to problems associated with a cold free stall barn that are unrelated to an anaerobic digester for methane production.

As manure freezes it becomes much harder to remove from a concrete floor and likely will not pass through slots in a slotted floor barn with manure storage beneath. Not only does the manure freeze over the slots in this type of barn, but the conditions in the barn become very slippery and unclean due to the manure not falling through the slots [1]. In a solid floor cold free stall barn, frozen manure limits the use of a mechanical alley scraper according to studies done at the University of Wisconsin-Madison. At the University's Marshfield Experiment Station it was found that in order for the alley scraper to work properly in the cold free stall experimental barn, electric heating cables embedded in concrete had to be used [5].

For those farms utilizing a methane digester, freezing of manure causes additional problems. Manure that has frozen on a solid floor and then been pushed into a digester as small or large chunks of frozen manure will disrupt the anaerobic fermentation process and the consequential production of methane gas. Although a heat exchanger can be used to heat the manure to approximately 95°F upon entering the digester [8], the frozen crystals will increase the amount of heat needed to warm the manure to a teperature of 95°F, at which optimum production of methane gas will occur. For digesters that work on the gravity flow concept in combination with a cold free stall barn, manure flow can become a problem as temperatures drop a few degrees below 32°F.

An example of a digester that requires no mechanical pumps or devices to move the manure out of the barn and into the digester is currently being used in the Energy Integrated Dairy Systems Project conducted by the New York State College of Agriculture and Life Sciences at Cornell University [8]. The project is being conducted at Millbrook Farm, a privately operated 180 cow farm owned by Ronald Space. Problems with cold or frozen manure entering the digester occurred at this site. To correct the problem, additional heat exchangers were placed in the hoppers into which the manure is initially scraped from the barn floor before it travels to the digester. These units are three tiered heat exchangers made of pipes through which hot water from the engine radiator flows so that heat can be transferred to the manure surrounding the pipes. This will help thaw and warm any frozen manure before it reaches the digester, thereby allowing more efficient production of methane gas. This modification did not completely solve the digester temperature problem during the 1982-83 winter.

Economic Analysis

The economic analysis compares the added investment required for a warm barn with the added benefits which are expected with a warm vs. a cold barn. The assumptions used in the investment analysis are shown in Table 1.

Table 1. Investment Analysis Assumptions

Item	Value
Planning Period	10 years
Salvage Value of Insulation and Fans at the end of 10 years	10% of initial cost
Federal and State Investment Tax Credits	16%
Marginal Tax Bracket	25%
Weighted Average Cost of Capital (Before Tax)	14%
Depreciation Option (ACRS)	5 year fast recovery with basis reduction

Investment Required

The estimated costs for construction of cold and warm free stall barns are shown in Table 2. The difference in costs between the two types of barns is estimated to be between $213 and $283 (average of $248) per cow and is due to insulation and mechanical ventilation. The costs are based on a 180 cow barn with a solid floor from which manure would be scraped daily. The analysis is more applicable to comparing new construction of a warm vs. a cold barn than to adding insulation and fans to an existing barn because the retrofit probably would cost more than adding the insulation and fans at the time the barn is built. However, the methodology presented could be used to help analyze a retrofit.

Additional Operating Costs

Additional operating costs are associated with the use of the ventilation fans necessary in a warm free stall barn. Annual repair costs are assumed to be 2 percent of the initial investment in the fans. C.R. Hogland's 1976 Dairy Systems Analysis Handbook indicates that about 27% of the combined cost of ventilation and insulation is due to the cost of the installed fans [2]. From Table 2 above, the cost of the installed fans would be $58-$76 per cow. Annual repair costs were estimated to be 2% of the midpoint of these two numbers or $1.34/cow.

The cost of additional electricity needed to run the fans was estimated as follows. The Wisconsin study discussed previously indicates that a minimum of 60

Table 2. Estimated Construction Costs on a per cow basis for Warm and Cold Free Stall Dairy Barn, based on a 180 cow barn [4]

Cold Free Stall	Per Cow a/	Warm Free Stall	Per Cow a/
Barn structure, including concrete	$597	Barn structure, including concrete	$597
Feed manger or bunk	38	Feed manger or bunk	38
Mechanical feeder	43	Mechanical feeder	43
Free stalls	65	Free stalls	65
Water plumbing, wiring	54	Water plumbing, wiring	54
Rubber cow mats [6] b/	86	Rubber cow mats [6] b/	86
		Insulation and mechanical ventilation	213-283
TOTAL	$883	TOTAL	$1,096-$1,166

a/ Derived from Dairy Cow Enterprise Budgets for 1981 by Wayne Knoblauch, Professor of Agricultural Economics at Cornell University. An economy of size savings of between 5 and 6 percent was assumed due to the larger herd size in this analysis.

b/ A 7 percent increase per year from 1974 in the cost of mats is assumed.

cfm and a maximum of 303 cfm per 1,000 pounds of liveweight represents the range in rates necessary to properly ventilate a warm free stall barn. At these ventilation rates, the fans needed to ventilate only the 20 cow warm free stall experimental barn with a solid floor used a total of 4,810 kwh of electricity each year [6]. The amount of electricity used should be directly proportional to the number of cows in the barn, assuming the cows considered in this paper weigh 1,400 pounds each, the same as the cows in the Wisconsin experiment. The R value of the insulation should also be considered identical in both cases in order for directly proportional rates of ventilation to be used. Using directly proportional rates of ventilation results in an annual increase in electricity use of 240.5 kwh per cow. At $.055 per kilowatt hour, the annual electricity cost on a per cow basis would be $13.23.

Added Returns: Milk Production versus Feed Consumption

The primary benefits likely to be gained from the investment are increased milk production and/or decreased feed intake by cows in a warm barn as compared to a cold free stall barn. It is also possible that feed consumption may actually increase in a warm barn but this should be combined with an even faster rate of increase in milk production so that the overall feed efficiency of the cows in the warm free stall barn is greater. The only detailed research on this subject found by the authors was a study conducted at the University of Wisconsin's Marshfield Experiment Station in the early 1970's. Data were collected on milk production and feed intake for three different types of free stall housing units. A 60 cow free stall barn was divided into three separate facilities, each with 20 cows. Barn A was built as a warm free stall facility with a slotted floor and manure storage beneath. Barn B was also a warm free stall facility but was equipped with a mechanical alley scraper for cleaning the solid floors. Barn C was designed as a cold free stall facility and cleaned with the same alley scraper as Barn B. The milk production and feed intake results from the Wisconsin study for Barns B and C were used in computing the net present value of the investment discussed in this paper. Table 3 was derived from a report summarizing the Wisconsin experiment [1].

Table 3. Feed Consumption and Milk Production for Three Free Stall Barns

	Barn Type		
	A - Warm Barn with slotted floor	B - Warm Barn with solid floor	C - Cold Barn with solid floor
FCM per milking day per cow	46.4 lbs	46.9 lbs	44.7 lbs
Dry matter per pound of FCM	1.07 lbs	1.01 lbs	1.05 lbs
Dry matter consumed per cow per day*	37.6 lbs	36.8 lbs	35.6 lbs
Total cow days in milk	10,126	10,063	10,284

*Includes dry days as well as milking days.

Milk production for all three groups of cows was converted to 4% fat corrected milk production in order that all comparisons would be on an equivalent basis in terms of energy requirements necessary for the production of milk constitutents. Milk production was 2.2 lbs FCM/cow/milking day higher in Barn B than in Barn C. Dry matter consumption per pound of FCM indicates a slight feed efficiency advantage in favor of the cows housed in Barn B. However, it must be kept in mind that the increase in milk production by the cows in Barn B over that of those in Barn C did not occur without a cost. Total dry matter consumption per cow per day was 1.2 pounds higher for the cows in Barn B as compared to those in Barn C. On an annual basis this amounts to $21.90 in additional feed costs per cow in Barn B when $100 per ton of dry matter is used as the cost of feed. The $100 per ton feed cost takes into consideration that a combination of hay and corn crops grown on the farm and purchased feed would be used to meet dry matter requirements. Table 4 summarizes the differences in milk production between groups B and C and determines the added returns that would occur through the use

Table 4. Differences in Dollar Value of Milk Production between Two Different Free Stall Barns

	Barn Type	
	B - Warm Barn with solid floor	C - Cold Barn with solid floor
Milking days/year	5,250	5,366
Milking days/cow/year	263	268
Average milking days/cow/year	265	265
FCM per milking day per cow	46.9 lbs	44.7 lbs
Total FCM produced/cow/year	12,429 lbs	11,846 lbs
$ Value of milk produced/cow/year @ $13.00/cwt	$1,616	$1,540
$ Value of increse in milk production/cow/year due to warm housing	$76	--

of the warm free stall barn, assuming a product value of $13.00 per cwt. of 4% FCM. 1/

It should also be pointed out that an average number of milk days per cow per year for all three barns was used to calculate total FCM per cow per year, rather than the actual number of milking days per cow per year. This was done so that total FCM production would be on a comparable basis since differences in total milk days per cow per year are likely caused by factors not related to housing differences.

Finally, the point should be made that although feed consumption and milk production appear to be quite different between the cows in the three experimental barns, Wisconsin experimenters have determined that none of the previously discussed differences were statistically significant [7]. This may mean that these results would not be repeated with any regularity under later tests run identical to the Wisconsin experiment. Therefore, the economic analysis of this paper should be looked at by readers with an eye of caution and with a sense of good judgement. On the other hand, the level of statistical testing may have been quite strenuous. If this was the case, then a less strenuous level of testing may have indicated that the results were statistically significant. Without going into a detailed statistical analysis it would be best for now to use the information provided by the research done in Wisconsin and accept the fact that milk production and feed consumption differences may not always differ between a warm and cold free stall barn to the extent they did in this Wisconsin experiment.

Herd Health and Human Comfort

Two major herd health problems occurred in the 1972-1973 Wisconsin

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1/$13.00 is the approximate price for 4% milk in the N.Y.-N.J. market in November 1983, assuming $1.00 per cwt. is deducted for the U.S. government.

experiment [1]. The two year totals for 1972 and 1973 showed that 45, 35, and 60 cases of mastitis occurred in Barns, A, B, and C respectively. Although cold Barn C did seem to produce a higher incidence of mastitis cases, the savings a warm barn would provide due to the fewer number of mastitis cases would be very difficult to quantify unless accurate data on differences in milk production, expenses for medicine, or other differences due to the higher number of mastitis cases was available. Also, since many farmers do operate cold free stall barns without significant mastitis problems the differences in mastitis cases between barns were ignored.

The second major herd health problem encountered in the cold free stall experimental barn at Wisconsin's Marshfield Station was not due to extreme cold conditions, but rather, due to extreme warm conditions in the summer months. "The natural ventilation has not provided enough air movement to keep the barn from becoming warm. Cows consistently show heat effects by crowding near outside doors and by very heavy breathing [6]." Some of these heating effects may have been due to inadequate building design. The data indicate that milk production declined as much or more in the summer months as in the winter in the cold barn. Thus the lower milk production in the cold barn may be due as much to excessive heat in the uninsulated cold barn during hot summer conditions as to the cold conditions in the winter. This may also partially explain the lower D.M. intake by the cows in the cold barn since excessively high temperatures normally reduce feed intake.

A non-monetary advantage that should at least be considered when analyzing the pros and cons of a warm free stall barn investment is operator comfort. A warm barn, assuming adequate ventilation, will provide more human comfort than a barn at 0°F to 20°F. This advantage of a warm barn may be less important to some farmers than others. No attempt was made to incorporate any operator comfort benefits in the analysis.

Reduced Operating Costs

Ad libitum water intake, a necessity for cattle in order to live and produce an adequate quantity of milk, will not occur if water pipes freeze due to low temperatures in cold free stall barns. Because of this simple fact, a warm free stall barn provides electricity savings equal to that which a cold free stall barn uses to maintain the water temperatures above freezing. The cold free stall experimental barn studied at Wisconsin's Marshfield Experiment Station used 35 kwh per cow per year to heat the water used in the barn [3]. At $.055 per kilowatt hour, a warm free stall barn would provide annual electricity savings of $1.93 per cow due to not having to heat the water in a warm barn, assuming that climatic conditions are similar to those encountered in Wisconsin.

Summary of Cash Flows

The purpose of determining the added inflows and outflows expected from an investment is to weigh the present value of the added returns against the present value of added costs and then compute a net present value of the investment. If the present value of the added returns is greater than the present value of the added costs (i.e., the net present value is positive) then the investment should be made.

An accurate net present value analysis must handle inflation correctly. The analysis can be done in two different ways. The first method expresses the value of the added inflow or outflow in each year with the effects of inflation included in the flows. These flows are known as money flows. The second type of flows that can be used in computing a net present value are those from which inflation has been removed. These flows are called real flows.

The type of flows used should make no difference in the final net present value calculated if the proper discount rate is applied to each set of flows. When money flows are used, a discount rate including the effects of inflation must be chosen. When real flows are used, a discount rate excluding the inflation factor must be applied to the flows.

The analysis presented in this paper was done using money flows. As shown in Tables 5 and 6, the added inflows and outflows were estimated by inflating 1983 values at the expected rate of increase in the cost or price of each. This was done to reflect what would actually be paid or received in each year of the planning period. Electric costs are projected to rise at 9.5% per year and all other items are projected to increase by the same rate as the general rate of inflation, which, for the purposes of this analysis is projected to be 7 percent.

Adjustment for Income Taxes

Once the flows have been converted to money flows, they are then totaled to determine the annual before tax cash flows. The next step is to convert the before tax cash flows to an after tax basis. This example has assumed the marginal tax rate (federal and state) is 25%. Therefore, the before tax cash flows were multiplied by .75 (i.e., 1 minus the tax rate).

Tax savings from depreciation and investment credit are added to the after tax cash flows described above. Depreciation tax savings are calculated by multiplying the initial investment, less the basis reduction 2/, by 15%, 22%, 21%, 21%, and 21% in years one through five respectively. These are the percentages of the investment that are depreciable (recoverable) in each year. Since depreciation is an expense, the annual depreciation deductions are multiplied by .25 to compute the depreciation tax savings. To calculate investment tax credit savings, the initial investment for the fans and insulation is multiplied by the 16% allowable credit (10% federal and 6% New York State). Since the allowable investment credit is deducted directly from the tax bill rather than being included as an expense, the investment credit tax savings computed above are in after tax terms. The tax savings for depreciation and investment credit are added to the after tax cash flows to arrive at the total after tax cash flows for each year.

2/For 1983 and later years, the basis for depreciation must be reduced by 50 percent of the Federal investment credit unless the taxpayer choses to reduce the investment credit by two percentage points.

Present Value Calculations

To reflect the time value of money concept discussed previously, the total after tax flows were discounted with the after-tax cost of capital of 10.5%. The factors for 10.5% are shown in Table 5. Finally, the present values are summed to find the net present value of the investment.

With an increase in the value of milk production of $76 per cow in 1983 terms, the net present value is $97.23 per cow. For 180 cows, the net present value would be $17,501. At the value of production increase used, the investment is quite profitable. For those who are more familiar with the concept of rates of return than with net present value, we can say that the internal rate of return on this investment is projected to be substantially above the 10.5% after tax cost of capital. Considering the current dairy surplus situation, it is doubtful that milk prices will increase much in the next few years even if we have substantial inflation in the general economy. Therefore the calculated net present value may be an overestimate.

Breakeven Analysis

The increase in milk production described in this paper is not likely to hold for every farmer investing in a warm free stall barn. We might want to ask "what level of increased production or reduced feed intake is needed to just break even, that is, make the net present value equal to zero?" The following discussion and Table 6 help explain how this "breakeven value" is calculated.

The first step is to find a net present value without any change in either milk production or feed consumption. In doing this, it was assumed that all other added inflows and outflows will remain the same as in the original analysis. The net present value with no change in milk production or feed consumption would be $-244 per cow as shown in Table 6. Therefore, in order to break even, the present value of the savings from an increase in milk production, a reduction in feed consumption, or a combination of the two must be enough to offset the $-244 net present value.

We need to estimate the annual savings over the planning period due to changes in milk production and feed consumption that will be equivalent to the net present value of $-244. This can be done meaningfully only in real terms. To calculate the annual equivalent cash flow of $-244, in real terms, a real discount rate is needed. The after-tax real discount rate is calculated with the following formula:

$$1 + r = \frac{1 + n\ (1-t)}{1+f}$$

where: r = real after-tax cost of capital or discount rate

n = nominal before-tax cost of capital

t = tax rate

f = inflation rate

Table 5. Net Present Value Analsysis - Warm vs. Cold Free Stall Housing

	Years										
	0	1	2	3	4	5	6	7	8	9	10
Added Inflows:											
Increase in milk production yr. 0 = $+76 @ 7% a/		81.32	87.01	93.10	99.62	106.59	114.06	122.04	130.58	139.72	149.50
Reduction in electricity use due to not having to heat water yr. 0 = $+1.93 @ 9.5%		2.11	2.31	2.53	2.77	3.04	3.33	3.64	3.99	4.37	4.78
Terminal value of insulation and fans (10% of initial investment) yr. 0 = $24.80 @ 7%											48.79
Added Outflows:											
Initial investment (installed fans and insulation) yr. 0 = -$248	-248										
Added repair costs for fans (based on ave. of 248) yr. 0 = $-1.34 @ 7%		-1.43	-1.53	-1.64	-1.76	-1.88	-2.01	-2.15	-2.30	-2.46	-2.64
Added electricity costs to run the fans yr. 0 = $-13.23 @ 9.5%		-14.49	-15.86	-17.37	-19.02	-20.83	-22.81	-24.97	-27.34	-29.94	-32.79
Added annual feed costs yr. 0 = $-21.90 @ 7%		-23.43	-25.07	-26.83	-28.71	-30.72	-32.87	-35.17	-37.63	-40.26	-43.08
Net Before tax cash flows		44.08	46.86	49.79	52.90	56.20	59.70	63.39	67.30	71.43	124.56
	(x)	.75									
After tax cash flows b/	-248	33.06	35.14	37.34	39.67	42.15	44.77	47.54	50.47	53.57	93.42
Plus: Depreciation tax savings on initial investment = $248 - $12.40 basis reduction (5 yr rapid ACRS, 25% tax bracket)		8.84	12.96	12.37	12.37	12.37					
Investment Credit (initial investment = $248) 16% credit		39.68									
Total after-tax cash flow	-248	81.58	48.10	49.71	52.04	54.52	44.77	47.54	50.47	53.57	93.42
10.5% discount factors		.9050	.8190	.7412	.6707	.6070	.5493	.4971	.4499	.4071	.3684
Present Values	-248	73.83	39.39	36.85	34.91	33.09	24.59	23.63	22.71	21.81	34.42

Net Present Value = $+97.23 per cow

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a/The year 0 values are projected to inflate at the rate following the year 0 value.
b/25 percent tax rate.

Table 6. Break Even Analysis

	Years										
	0	1	2	3	4	5	6	7	8	9	10
Added Inflows without Milk Production Increase:											
Reduction in electricity use due to not having to heat water yr. 0 = $+1.93 @ 9.5%		2.11	2.31	2.53	2.77	3.04	3.33	3.64	3.99	4.37	4.78
Terminal value of insulation and fans (10% of initial investment) yr. 0 = $24.80 @ 7%											48.79
Added Outflows without Additional Feed Costs											
Initial investment (installed fans and insulation) yr. 0 = -$248	-248										
Added repair costs for fans (based on ave. of 248) yr. 0 = $-1.34 @ 7%		-1.43	-1.53	-1.64	-1.76	-1.88	-2.01	-2.15	-2.30	-2.46	-2.64
Added electricity costs to run the fans yr. 0 = $-13.23 @ 9.5%		-14.49	-15.86	-17.37	-19.02	-20.83	-22.81	-24.97	-27.34	-29.94	-32.79
Before tax cash flows	-248	-13.81	-15.08	-16.48	-18.01	-19.67	-21.49	-23.48	-25.65	-28.03	18.14
	(x)	.75									
After tax cash flows	-248	-10.36	-11.31	-12.36	-13.51	-14.75	-16.12	-17.61	-19.24	-21.02	+13.61
Depreciation tax savings on initial investment = $248 - $12.40 basis reduction (5 yr rapid ACRS, 25% tax bracket)		8.84	12.96	12.37	12.37	12.37					
Investment Credit (initial investment = $248) 16% credit		39.68									
Total after-tax cash flows	-248	+38.16	+1.65	+ .01	-1.14	-2.38	-16.12	-17.61	-19.24	-21.02	+13.61
10.5% discount factors		.9050	.8190	.7412	.6707	.6070	.5493	.4971	.4499	.4071	.3684
Present Values	-248	+34.53	+1.35	+.007	- .76	-1.44	-8.85	-8.75	-8.66	-8.56	+ 5.01
Total Net Present Value without changes in milk production and feed consumption	$-244.12 per cow										

In our example with n = .14, t = .25 and f = .07, the calculations are:

$$1 + r = \frac{1 + .14(.75)}{1.07} = \frac{1.105}{1.07} = 1.0327$$

Therefore, r = .0327 or 3.27 percent.

The present value factor for the 3.27% discount rate for 10 years is 8.4139.

The NPV without changes in milk production or feed consumption is then divided by the real after tax discount factor (8.4139) to find the value of the stream of annual savings, in real dollars, that a warm barn would have to provide in order to be equal to a present value of $244.12.

$\frac{\$244.12}{8.4139}$ = $29.01 = The after tax annual savings, in real terms, required from changes in milk production and feed consumption.

If $29.01 in additional after tax income was earned from milk production increases or feed consumption decreases in the warm free stall barn, the investment would just break even. It must be remembered that this measure of savings is in real terms or in other words this level of increased benefits must occur each year after the effects of inflation have been removed.

The before tax value of savings required to break even is computed by dividing the after tax annual equivalent cash flow by 1 minus the maringal tax rate: $\frac{29.01}{.75}$ = $38.69 = real, before-tax, annual equivalent cash flow required to break even.

At $13.00 per cwt of 4% FCM, each cow in a warm barn would have to produce 298 pounds additional 4% FCM per year over that of the cows in a cold barn if feed consumption was equal for cows housed in either a cold or warm free stall barn and the entire benefit had to come from increased milk production. If milk production is equal in both types of barns but feed consumption is less for the cows in the warm barn, then each cow would have to consume approximately 774 pounds less dry matter per year when dry matter is valued at $100 per ton of complete ration. An infinite number of other combinations of changes in milk production and feed consumption could occur to equal this savings. The prices of milk and feed will also affect the change in feed consumption or milk production needed to breakeven. Table 7 outlines a range of milk and feed prices and shows the corresponding savings in feed required or milk production increases needed to breakeven at these values.

Table 7. Milk Production Increases or Feed Savings Required to Break Even at Different Prices of Milk and Feed

Price of 4% FCM per cwt	Milk (pounds/cow/year)	Price per ton of complete feed (D.M.)	Complete Feed Ration (pounds D.M./cow/year)
	Break Even Points		Break Even Points
$10.00	387	$ 60	1,289
$10.50	368	$ 65	1,190
$11.00	352	$ 70	1,105
$11.50	336	$ 75	1,031
$12.00	322	$ 80	967
$12.50	309	$ 85	910
$13.00	298	$ 90	860
$13.50	287	$ 95	814
$14.00	276	$100	774
$14.50	267	$105	737
$15.00	258	$110	703
$15.50	250	$115	673
$16.00	242	$120	645

Summary and Conclusions

An anaerobic digester for methane production will operate more efficiently if manure is at or near 95°F at the time it enters the digester. A warm rather than a cold free stall dairy barn would eliminate frozen manure and contribute to efficient digester operation. This paper has estimated that annual benefits of about $39 per cow per year would be required from changes in milk production and/or feed consumption to offset the added investment and operating costs of a warm barn.

If benefits of this magnitude cannot be expected to occur and a farmer decides that a warm barn is required to make a digester operate efficiently, then some or all of the added costs for a warm barn must be charged against the benefits of the digester.

The past and present unpopularity of warm free stall barns suggests that farmers interested in methane production will not be eager to adopt warm barns. Perhaps emphasis should be placed on barns that are not really operated as warm barns, but only operated at high enough temperatures to just eliminate frozen manure.

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ADDENDUM

Subsequent to the preparation of this publication, the authors became aware of a proposed design for an insulation and ventilation system for free stall dairy barns which would be much less expensive to install than the system discussed in this bulletin.

Anyone who is considering a warm free stall should investigate the proposed system by contacting Michael Timmons, Department of Agricultural Engineering, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca, New York, 14853.

The method used in this publication could be used to evaluate the economics of the proposed system by anyone contemplating such a system.