

Anaerobic Digestion Economics

Dairy Anaerobic Digestion Workshop
Sunnyside, WA
25 February 2005

Philip D. Lusk
Resource Development Associates
Pierre, SD



On Economics...

- Economics is the only field where 2 people can get a Nobel Prize for saying exactly the opposite thing
- An economist is someone who knows the price of everything and the value of nothing
- An economist is someone who didn't have enough personality to become an accountant
- An economist is someone who sees something working in practice and asks whether it would work in principle
- Economists have forecasted 9 of the last 5 recessions

Is This a Good or a Bad Project?

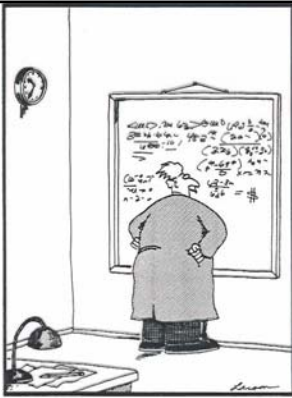
- 5.3 Simple Payback Period (years)
- (1.8) 5-Year Internal Rate of Return (%)
- (142,482) 5-Year Net Present Value (\$)
- 103,006 5-Year Average Income (\$)
- 95,368 5-Year Average Cash Flow (\$)
- (27,162) 5-Year Cumulative Cash Flow (\$)
- 1.0 1st Year Acid-Test ratio (\$)
- 1.60 Net Generation Benefit (¢/kWh)

Economics Working Definition

- "Economics" of capital budgeting
 - Key assumptions
 - Competitive market
 - Rational behavior in market
 - Consistency in measurement
- Goal is profit maximization
 - Generally not enough money; must allocate assets between competing ends
- Economics
 - Provides decision tools, not ultimate solutions

Introduction to Economic Analysis

- Economics of liquidity
 - Cash-Flow
 - Schedule of annual net profits (loss)
 - Simple Payback Period (SPP)
 - $SPP = \text{net investment} / \text{net annual cash flow}$
 - Return on Investment (ROI)
 - $ROI = 1 / SPP$
 - Problems with the economics of liquidity
 - Does not account for project life
 - Does not account for time value of money



Einstein discovers that time is actually money.

Introduction to Economic Analysis

- Economics of profitability
 - Time-value of money concept explains that a current dollar is more valuable than a future dollar
 - A beer today is better than a beer tomorrow...
 - Present value is determined by discount rate (DR)
 - Is a beer today better than three beers tomorrow?
- "Life-Cycle Costing"

Introduction to Economic Analysis

- Economics of profitability
 - Net Present Value (NPV)
 - NPV describes present worth of investments
 - If NPV > 0, accept investment
 - If NPV < 0, reject investment
 - Internal Rate of Return (IRR)
 - IRR is the DR where NPV is zero
 - If IRR > DR, accept investment
 - If IRR < DR, reject investment

Introduction to Economic Analysis

- Life-Cycle costing problems
 - NPV has a bias in favor of "large" projects
 - IRR assumes all positive cash flows reinvested at calculated IRR rate
 - Multiple IRR's can exist under certain conditions
 - When comparing two different projects, one could have a higher IRR but lower NPV
- NPV usually superior to IRR
 - DR used as reinvestment rate in NPV
 - IRR is the implied reinvestment rate in IRR

Introduction to Economic Analysis

- Discount rate importance
 - Choice is **critical** to the outcome
 - What level of risk is involved?
 - Worthy at low DR may be unjustifiable at a higher DR
 - Nominal v. Real DR
 - Inflation adjusted?
 - Ask for a DR if possible
 - Guess a DR if needed
 - DR = prime interest rate + risk adjustment factor

How to Lie with Numbers

- Are you buying or selling?
- Project life fudging
 - Using lives that are too short or too long
 - Who benefits using a 30 year project life?
- Fuel escalation rate fudging
 - Using rates that are too high or too low
 - Who benefits using a 10% increase in electricity prices?
- Discount rate fudging
 - Using a DR that is too high or too low
 - Who benefits using a 3% discount rate?
- Cross-subsidizing

Introduction to Financial Analysis

- Sources and Uses of Funds Statement
 - Sources of Funds
 - Local, state & federal sources
 - Equity
 - Senior & junior debt
 - Uses of Funds Construction Budget
 - Land acquisition
 - Project development & permitting
 - Site grading & utilities
 - "Turn-Key" AD unit & prime mover
 - Operating equipment & tools
 - Uses of Funds Owner's Budget
 - Working capital
 - Operations salaries & expenses
 - Financing costs
 - Construction interest
 - Contingency

Introduction to Financial Analysis

- Income statement
 - \$ over time (i.e., income & cash flow)
- Owner's equity statement
 - Difference in starting and ending equity
 - + grants & income before taxes, - distributions to owners
- Balance sheet
 - Assets = Liabilities + Owner's Equity
 - Current Ratio = Current Assets / Current Liabilities (>2.0?)
 - Acid-Test Ratio = (Cash + Equivs) / Current Liabilities (>1.0)
- Cash-flow statement
 - Operating, investing, and financing cash flows

Animal Species & Minimum Capacity

- Depends on a number of factors
 - Power when
 - Electricity rate is > 4.50 ¢/kWh
 - Herd size when
 - Dairy > 400 head
 - Hog > 4000 head
 - Caged Layers > 40,000 head

Methane Generation & VS Destruction

- Depends on feed, temp, SRT & other factors
- What is the refractory concentration of TVS?
- Dairy Manure – 8.3 ft³ methane/pound VSd?*

 - Plug-Flow – 30%-35% VSd
 - CSTR – 35%-40% VSd?
 - Fixed Film – 35%-40% VSd?

* Martin (2003) reported 12.3 ft³ methane/pound VSd and 29.7% VSd @ AA Dairy

AD System Costs

- Dairy plug flow digesters w/ electric
 - Cost range of \$147/AU to \$630/AU
 - Weighted average cost of \$292/AU
 - Likely average cost of \$400/AU to \$500/AU
- Sample size
 - 14 systems
 - 28,525 AU
 - \$8.335 million installed cost
 - 2,325 kW installed capacity
 - 12 AU/kW average

AD System Costs

- Dairy plug flow digesters w/ boilers
 - Cost range of \$147/AU to \$840/AU
 - Weighted average cost is \$313/AU
- Sample size
 - 4 systems
 - 2870 AU
 - \$0.899 million installed cost

AD System Costs

- Dairy CSTR digesters w/ electric
 - Cost range of \$336/AU to \$605/AU
 - Weighted average cost of \$455/AU
 - Likely average cost of \$450/AU to \$550/AU
- Sample size
 - 4 systems
 - 3738 AU
 - \$1.700 million installed cost
 - 240 kW installed capacity
 - 16 AU/kW average

AD System Costs

- Dairy 2-Stage CSTR digesters w/ electric
 - Cost range of \$357/AU to \$655/AU
 - Weighted average cost of \$420/AU
- Sample size
 - 3 systems
 - 5810 AU
 - \$2.438 million installed cost
 - 720 kW installed capacity
 - 8 AU/kW average

AD System Costs

- Dairy fixed-film digester w/ electric
 - Cost range of \$250/AU to \$350/AU
 - Weighted average cost of \$300/AU
- Sample size
 - Projected
 - 8 AU/kW average

Prime Mover Conversion Efficiency

- Boilers
 - 85% efficient
- Generators
 - Engines
 - 25%-37% thermal efficiency
 - 9,225-13,650 Btu/kWh heat rate (3413 Btu / % efficiency)
 - Microturbines
 - 30%-32% thermal efficiency
 - 10,665-11,400 Btu/kWh heat rate
 - Thermal energy recovery
 - = $(1/(\text{thermal efficiency}/100)) * 3413 * 0.75$ - 3413
 - @ 32% thermal efficiency, 4586 Btu/kWh recovered

Co-Product Sales Key to Economic Merit

- Fiber sales - Highly dependent on location
 - Dairy – \$5.00/ton to \$10/ton
 - A 1000 head dairy generates around 3400 tons/year of fiber. Assuming evaporation is 25% and fiber is \$7.50/ton, around \$19,000/year in revenues could be generated.

Co-Product Sales Key to Economic Merit

- Filtrate
 - Do nutrients really have salable value today?
- Methane greenhouse gas (GHG) credits
 - Methane GHG credits @ \$1.25/ton CO₂ (\$5.04/tonne C equivalent)
 - A 1000 head dairy generates around 1580 tonnes/year of C equivalent methane emissions. Assuming \$5.04/tonne means close to \$8000/year in revenues

System Operations & Maintenance

- Digester
 - 1.75% to 2.25% of capital cost
 - For a \$200,000 digester, digester O&M is predicted around \$4000/year at 2.0% of capital cost
- Engines
 - 1.25¢/kWh -1.50¢/kWh, **likely discounts farm labor costs**
 - For a 1000 head dairy, engine O&M is predicted around \$15,000/year at 1.25¢/kWh
- Microturbines
 - 1.50 ¢/kWh for 250-kW and larger projects; 2.50¢/kWh for 70-kW projects. Reported 8,000-hour maintenance cycle, 80,000-hour life-cycle, maintenance contracts

Parasitic Heating and Electricity

- Parasitic Electricity
 - 2.0 – 6.0 kWh/ton feedstock processed
 - A 1000 head dairy that scrapes produces around 18,805 tons/year of manure. Assuming 5.0 kWh/ton means that around 94,000 kWh/year in parasitic electric is required, around 7.5% of total kWh generated
- Parasitic Heating
 - 1 Btu = 1 pound water by 1 F°
 - A 1000 head dairy that scrapes produces around 38 million pounds/year of manure. Assuming a 30°F dt means that around 1,128 MBtu/year in parasitic thermal is required, around 20% of the engine's recoverable thermal energy

Labor Requirements

- Usually minimal
 - Farmers report labor is 15-30 minutes/day
 - Feed digester
 - Check engine oil
 - Around 0.25 FTE over long-haul
 - Engine O&M
 - Change oil
 - Change heads
 - Could be less w/ a microturbine

Project Life

- Covered lagoons – Depends on cover
 - Could be 3-4 years
 - Could be as long as 10-15 years
- Everything else should last 15-20 years
 - If well designed
 - If built of decent materials
 - If properly maintained

"McGuire, what's with you? Everybody else here seems to have a perfectly clear idea of what 'cost-effectiveness' means."



Case Study Development

- Characterize available wastes
- Determine "best" AD technology type
- On-site interviews conducted with five county livestock producers
 - Information combined with data commonly used to characterize manures
 - Including the specific Comprehensive Nutrient Management Plan (CNMP) developed for each farm

Client HC04-01-DA

- Family owned and operated dairy farm, with a total of ~2300 animals on-site
 - ~1950 animals are milked daily and ~300 animals are housed in the dry cow barn
- Contract with a second party to produce feed, remove manure and apply it at agronomic rates
 - Manure management portion is estimated to be \$16,000/year, ~\$7.10/head/year
- Goals are to add to farm profitability and odor control
 - If odors can be effectively controlled, then the herd size at this site could possibly be expanded

Client HC04-02-DA

- Family owned corporation, with a total of ~1047 animals on-site
 - ~850 animals are milked daily and ~35 animals are housed in the dry cow barn
- Contract with a second party to remove manure and apply it at agronomic rates
 - Manure management portion is estimated to be \$25,000/year, ~\$28.00/head/year
- Goals are to supply power and odor control

Client HC04-03-CL

- Incorporated poultry egg laying operation and egg processing plant
 - ~600,000 laying hens on-site
- Contracts with second parties to apply the manure at agronomic rates
 - Manure management portion is estimated to be \$75,000/year, ~\$22.70/AU/year
- Goals are to produce energy and odor control
 - If odors can be effectively controlled, then the flock size at this site could possibly be expanded
 - Desired hurdle rate is a 15%-20% Return on Equity

Client HC04-04-DA

- Family owned and operated dairy farm, with a total of ~1310 animals on-site
 - ~1225 animals are milked daily and ~85 animals are housed in the dry cow barn
- Contract with a second party to produce feed, remove manure and apply it at agronomic rates
 - Manure management portion is estimated to be \$100,000/year, ~\$82/head/year
- Goals are to reduce energy costs, better manage manure residuals, and odor control
 - If odors can be effectively controlled, then the herd size at this site could possibly be expanded
 - Economic hurdle is a <10 year Simple Payback Period

Client HC04-05-DA

- Family owned and operated dairy farm, with a total of ~1630 animals on-site
 - ~1330 animals are milked daily and ~210 animals are housed in the dry cow barn for ~ 210 days/year
- Contract with a second party to produce feed, remove manure and apply it at agronomic rates
 - Manure management portion is estimated to be \$100,000/year, ~\$67.85/head/year
- Goal is odor control
 - If odors can be effectively controlled, then the herd size at this site could possibly be expanded
 - Economic hurdle is a <5 year Simple Payback Period

Estimated Manure Production

| Client | Manure tons/day | % |
|---------------|-----------------|------------|
| 01-DA | 138 | 31 |
| 05-DA | 106 | 24 |
| 4-DA | 76 | 17 |
| 03-CL | 64 | 14 |
| 02-DA | <u>61</u> | <u>14</u> |
| TOTALS | 445 | 100 |

Estimated Methane Production Potential

| | Digester Type | VSd % | Total VS #/day | CH ₄ ft ³ /# VSd | CH ₄ ft ³ /day | % |
|---------------|-----------------|-------|----------------|--|--------------------------------------|----------|
| 03-CL | Attached Growth | 50% | 22,937 | 9.0 | 109,058 | 30 |
| 01-DA | Attached Growth | 40% | 31,223 | 8.3 | 103,222 | 28 |
| 05-DA | CSTR | 35% | 23,370 | 8.3 | 67,613 | 18 |
| 04-DA | Attached Growth | 40% | 16,612 | 8.3 | 56,594 | 15 |
| 02-DA | Plug Flow | 30% | <u>13,007</u> | 8.3 | <u>32,495</u> | <u>9</u> |
| TOTALS | | | 107,149 | | 368,982 | 100 |

AD System Cost Comparison

| | 01-DA | 02-DA | 03-CL | 04-DA | 05-DA |
|---|---------------|--------------|----------------|---------------|---------------|
| General Conditions | 25,250 | 30,500 | 24,625 | 25,250 | 23,375 |
| Flow Equalization | 43,125 | 12,500 | 68,750 | 83,125 | 62,500 |
| Anaerobic Digester | 273,000 | 121,000 | 273,000 | 243,625 | 578,750 |
| Engine/Generator | 314,900 | 99,095 | 332,750 | 172,700 | 206,275 |
| Flare | 16,500 | 5,000 | 15,000 | 16,500 | 15,000 |
| Solids Handling | 57,750 | 0 | 0 | 0 | 45,875 |
| Site Piping & Electrical | 37,125 | 33,200 | 28,125 | 21,875 | 37,500 |
| Freight & Installation | 61,875 | NA | 21,875 | 61,875 | 5,625 |
| Design Services/Construction Management | 73,270 | 29,500 | 72,250 | 55,280 | 80,440 |
| Contingency/Rounding | <u>47,205</u> | <u>1,705</u> | <u>113,625</u> | <u>29,770</u> | <u>44,660</u> |
| TOTAL | 950,000 | 332,500 | 950,000 | 710,000 | 1,100,000 |
| AU | 3038 | 1178 | 3300 | 1715 | 1990 |
| \$/AU | 313 | 282 | 288 | 414 | 553 |

Key Cost Assumptions

| | |
|----------------|--------------|
| Project Life | 20 years |
| Discount Rate | 10.00 % |
| FTE Operator | 0.50 |
| Operator Wages | 10.00 \$/hr |
| Benefits | 26% |
| Engine O&M | 1.5¢/kWh |
| Plant O&M | 1.0% of cost |

Key Revenue Assumptions

| | |
|---------------------------|----------------------------|
| Retail Electric Energy | 9.5¢/kWh |
| Wholesale Electric Energy | 5.0¢/kWh |
| Propane | \$1.00/gallon |
| Fiber Product | \$6.00/ton |
| Carbon Credit | \$1.25/ton CO ₂ |
| Odor Control | \$0/year |
| Storage Pit Clean-Out | \$0/year |

Economic Performance Comparison

| | 01-DA | 02-DA | 03-CL | 04-DA | 05-DA |
|-------------------------------------|---------|----------|---------|----------|-----------|
| Simple Payback Period (years) | 4.8 | 6.7 | 5.1 | 8.7 | 9.4 |
| 10-Year Internal Rate of Return (%) | 16.0 | 7.9 | 14.4 | 2.6 | 1.1 |
| 10-Year Return on Equity (%) | 22.5 | 18.8 | 21.6 | 13.9 | 13.1 |
| 10-Year Net Present Value (\$) | 116,132 | (12,993) | 84,549 | (93,836) | (172,214) |
| 10-Year Average Income (\$) | 102,724 | 30,235 | 98,409 | 47,376 | 69,032 |
| 10-Year Cumulative Cash Flow (\$) | 457,236 | 72,737 | 405,836 | 47,757 | 30,319 |
| AD Treatment Benefit (\$/head/year) | 20.32 | 8.20 | 0.07 | 3.90 | 2.06 |
| AD Treatment Benefit (\$/AU/year) | 15.05 | 6.18 | 12.30 | 2.78 | 1.52 |



LIMITATIONS

UNTIL YOU SPREAD YOUR WINGS,
YOU'LL HAVE NO IDEA HOW FAR YOU CAN WALK.