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CHP Case Studies / Business Case

Methane Recovery from Hog Waste Integrated with Combined Heat and Power Technologies

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From Biogas to Btu

- 1000 Finish, or
- 5000 Sow Farrow to Wean
  - Both types of farms produce around 45,000 cubic feet of biogas per day
  - With a Methane content of between 55% and 80%
  - Farm produces between 25 and 36 MMBtu per day or between 9,000 and 13,000 MMBtu per year

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From Btu to kW

- Assume a Heat Rate of 14,000 Btu/kWh (24% efficient prime mover) such as a microturbine or recip. engine
- 25 MMBtu/day to 36 MMBtu/day can fuel prime movers of between 74 and 107 kW installed capacity
- A 74 to 107 kW generator produces:
  - between 1,700 and 2,500 kWh per day
  - between 53,000 and 77,000 kWh per month
  - Between 650,000 and 940,000 kWh per year

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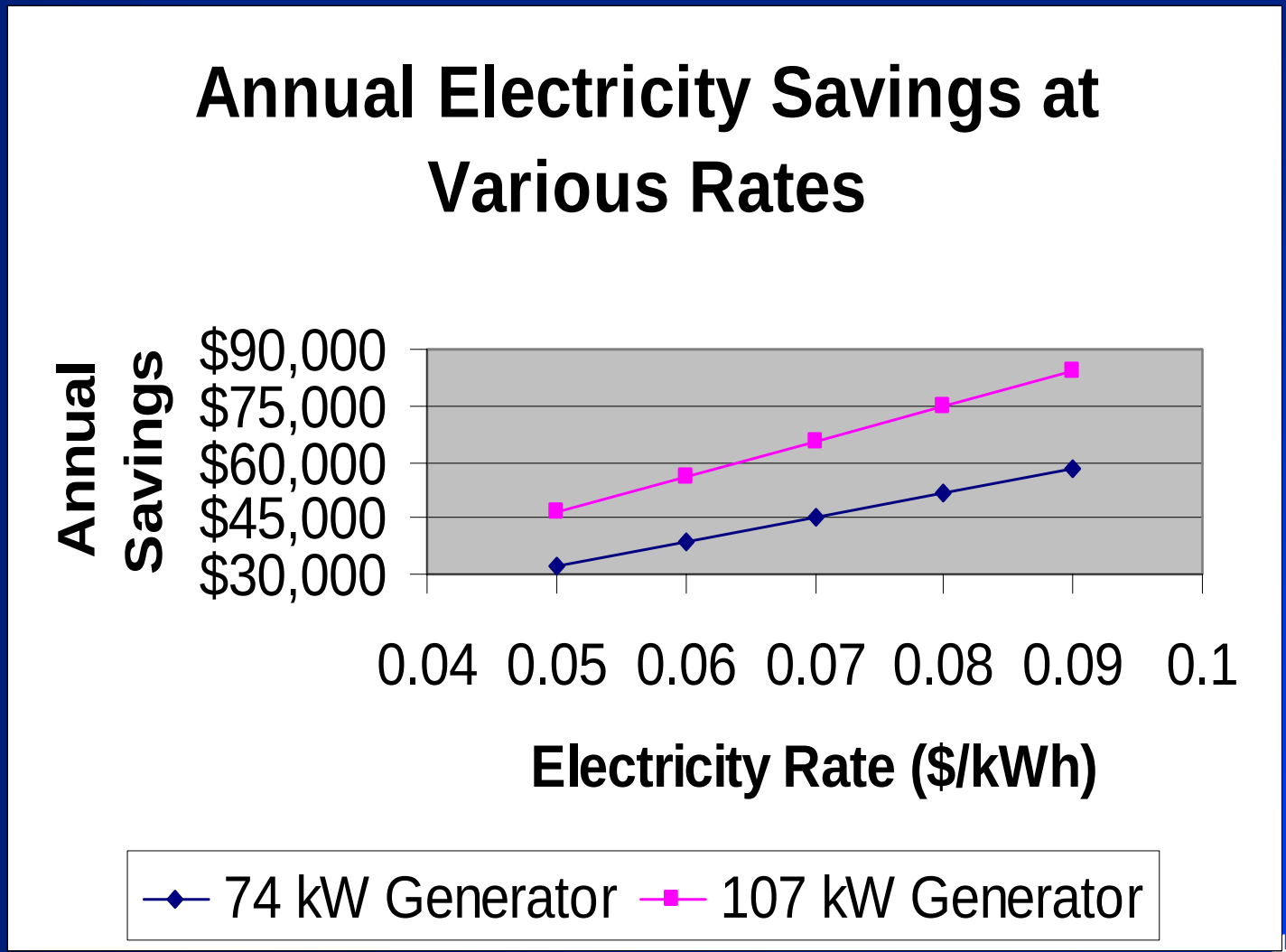
Electricity Savings



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Heat Recovery

Installed Capacity	Approximate Heat Recovery per Year	Required Fuel Equivalent (at 80% Boiler Efficiency) per Year	Savings from Heat Recovery @ $5/MMBtu Gas Cost per Year	Savings from Heat Recovery @ $7/MMBtu Gas Cost per Year
74 kW	2,700 MMBtu	3,400 MMBtu	$17,000	$23,700
107 kW	3,900 MMBtu	4,900 MMBtu	$24,500	$34,300

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Total Savings Potential

- Approximate Savings Assuming
- Low Case:
  5 cent/kWh avoided electricity charges and $5/MMBtu natural gas prices
- High Case:
  9 cents/kWh avoided electricity charges and $7/MMBtu natural gas prices

Installed Capacity	Low Savings Case $/Year	High Savings Case $/Year
74 kW	49,400	82,000
107 kW	71,400	118,700

Installed Cost - Rules of Thumb

Reciprocating Engines <500kW

- **Recoverable Useful Heat:** **4,000 to 5,000 Btu/h per kW**
- **O&M Costs:** **$0.012 to $0.015 per kWh**
- **Installed Costs: (with heat recovery)** **$1,400 to $1,800 per kW**

Microturbines 30 to 400 kW

- **Recoverable Useful Heat:** **6,000 – 7,000 *Btu/h per kW***
- **O&M Cost *(per kWh)*** **$0.01 to $0.015**
- **Installed Cost: *(with heat recovery)*** **$1,000 to $2,000**

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System Paybacks – On Incremental CHP Facility Only

Capacity	Installed Cost	Yearly O&M Cost	Low Savings Case Years	High Savings Case Years
74 kW	$120,000	$8,500	2.9	1.6
107 kW	$160,000	$12,000	2.7	1.5

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Case Study 1: Colorado Pork LLC

- 6,300 Sow Farrow to Wean
- Biogas Produced: 61,000 cf/day
- Anaerobic Digester with Biogas Recovery; Caterpillar 3306 engine
- Generating Capacity: 85 kW (operates at 60 kW)
- Thermal Heat Recovered: 2,200 MMBtu/Year (est.) hot water
- Heated Anaerobic Digester with CHP system installed in response to Amendment 14 regulations

Project Financials

Costs

Anaerobic Digester/Secondary Basin:	$149,000
Pumps, Valves, Meters:	$ 62,000
Engineering	$31,000
Total Heated Anaerobic Digester:	$242,000
85 kW Engine plus Generator:	$115,000
CHP Plant Engineering:	$31,000
Total Generating Facility Installed:	$146,000
Total Digester + Generating Facility:	$388,000
Alternative: Aerobic Digester:	$100,000

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Project Financials (cont'd)

Savings

From Lagoon Cleanout:	$10,000
From Electricity:	$39,000
Total Savings:	$49,000

Payback

Heated Anaerobic Digester Only:	14.2 Years
Heated Anaerobic Digester+ Generating Facility:	7.9 Years
Incremental Generating Facility Only:	3.7 Years

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Project Outcome

- The project shows a relatively attractive payback on capital investment
- Anaerobic digester with CHP facility assured compliance with Amendment 14 Regulations

Case Study 2: Afxantiou Farm in Cyprus

- 1,700 Sow Farrow to Finish Operation
- Anaerobic digester with biogas recovery and Caterpillar Model MCG310 engine with heat recovery
- Generating Capacity: 205 kW
- Biogas Produced: 85,000 cf/day
- Recoverable Heat: 7,665 MMBtu/Year
- Used Heat: 2,935 MMBtu/Year to meet digester heating requirements

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Project Financials

Digester & Generating Equipment Cost:

Total Cost:	$1,380,000
Government Grant:	$ 500,000
Net Cost:	$ 880,000

Annual Savings:

Avoided Electricity:	$210,000
Avoided Gas:	$ 18,000
Total Savings:	$228,000

Estimated Simple Payback on Total Project:

Without Grant:	6.1 Years
With Grant:	3.9 Years

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Project Outcome

- The incumbent utility company's electricity rates are relatively high at 15 ¢/kWh, which makes it more attractive to self-generate the farm's electricity needs. Excess electricity can be sold back to the utility company at 8.3 ¢/kWh
- Afxantiou Farm took advantage of available grant money. The government of Cyprus is providing a $500,000 grant for the project
- Under Cyprus' recently imposed strict environmental regulations the Farm needed to install at least a lined basin for the animal waste, an unrecoverable capital expense. By opting for an anaerobic digester with a CHP system the Farm was able to able to:
  - comply with the regulations
  - while generating revenues

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Case Study 3: Barham Farms

- 4,000 sow farrow-to-wean facility
- Biogas Produced: 19,200 cf/day
- Energy Plant Equipment: Inground unheated anaerobic digester
- Caterpillar Model 3406NA engine
- Generating Capacity: 120 kW (often operated at 90 kW)
- Thermal Heat Recovered: 3,150 MMBtu/Year

Project Outcome and Financials

- The 120kW engine / generator was significantly oversized for available biogas from the digester. As a result:
  - The standby tariff imposed on the CHP system was based on the rated capacity of 120kW, while the CHP unit was never operated at more than 60%
  - The low engine utilization factor (operating at well below the rated capacity) resulted in reduced system efficiencies
  - Result: Negative cash-flow
  - CHP system shut-down in 2004

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Project Outcome and Financials (cont'd)

- In response to the problems incurred by Barham Farms, an analysis of the anaerobic digester / CHP system design was conducted by the CHP Application Program at North Carolina State University
- The study revealed that a properly designed 50kW CHP system would have provided a much better match between the digester and engine configuration
- This sized system would result in approximately $38,000 per year savings on the farm's electric utility costs, providing a 6 year simple payback on the total investment

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Case Study 4: Smithfield Foods/ Vestal Farms

- 10,000 Head Finishing Operation
- 100,000 gallons/day manure
- 30 kW Capstone Microturbine
- Biogas Produced: 45,000 cf/day
- Recovered Heat: 5,800 MMBtu/Year (estimated)

Financials

- Microturbine heat recovery equipment engineering: $120,000
- Annual Projected Savings from recovered thermal energy: $ 46,250
- Estimated Incremental Payback on Microturbine Installation: 2.6 Years

Project Outcome

- The CHP system at Vestal Farm is very well matched to the thermal needs of the anaerobic digester
- The microturbine's thermal recovery is sufficient to maintain the heat at 95ºF in the anaerobic digester for about 7 months of the year and at about 85ºF during the winter months; minimal supplemental heat is provided by an additional burner during the winter months
- Facility is installed and tested. Operator is currently negotiating stand-by power contract with incumbent utility

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In Summary

- Combined Anaerobic Digesters/CHP Systems installed have been shown to work across:
  - Different anaerobic digester technologies
  - Different climates
  - Different utility territories (with different buy-back rates and stand-by tariffs)
  - Different regulatory structures and manure management requirements
- If the AD/CHP System is
  - Properly designed
  - Installed
  - Maintained

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