

Making Dairy Power Profitable

Strategies for biogas energy generation from dairy manure anaerobic digestion

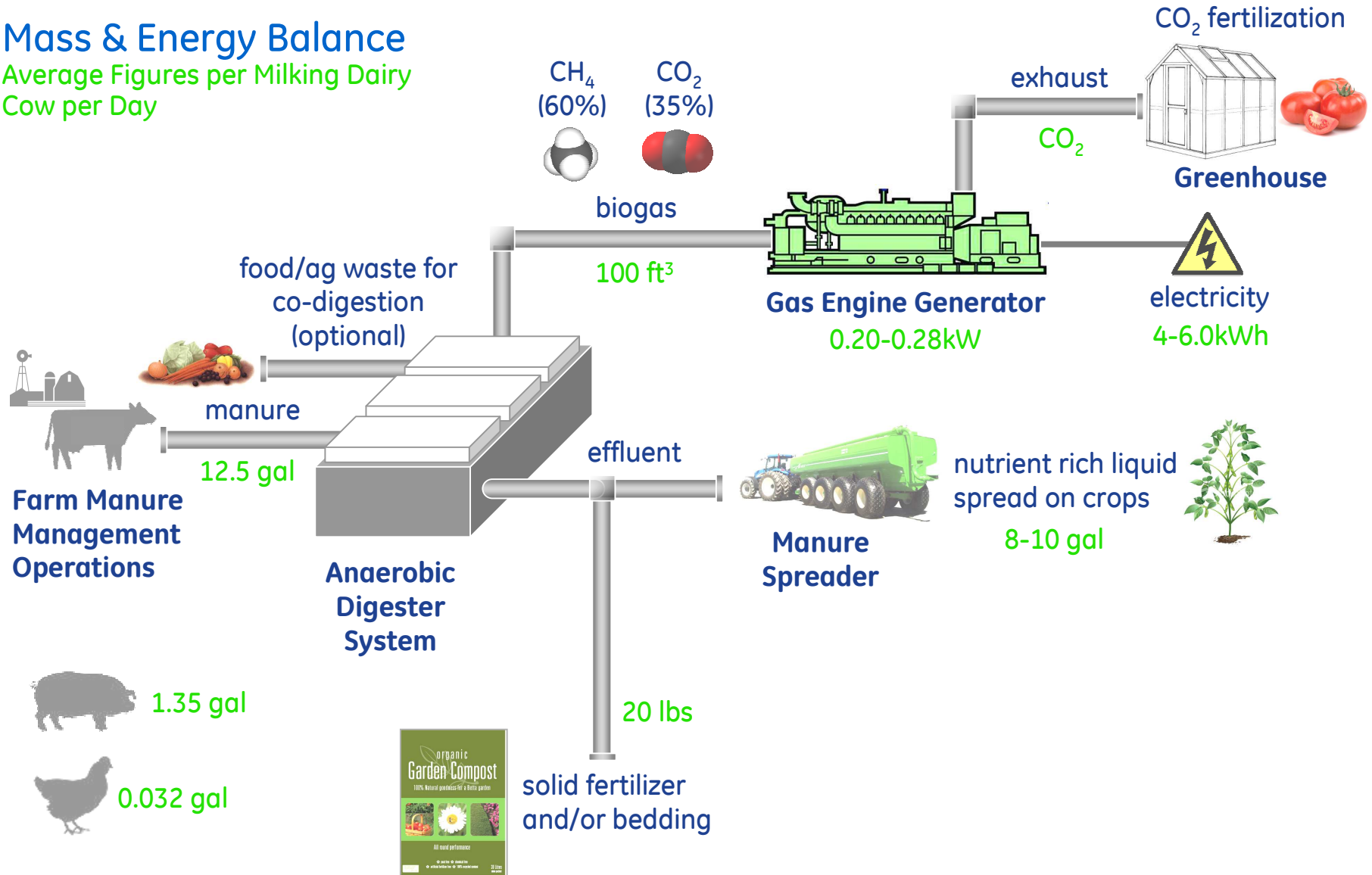
Shonodeep Modak
Growth & Innovation, GE Energy



The manure anaerobic digestion biogas-to-energy system

Mass & Energy Balance

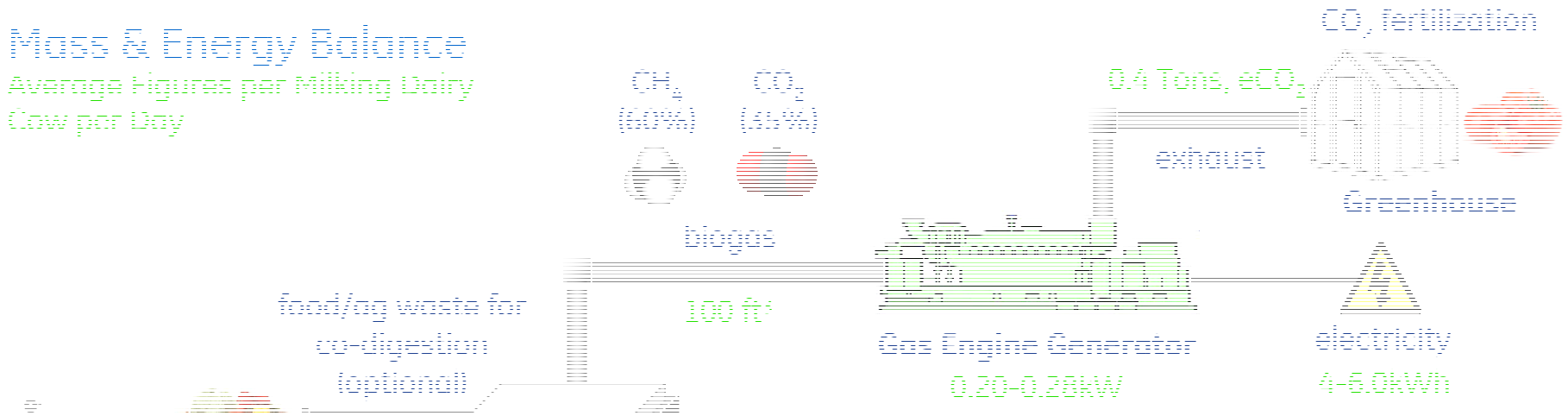
Average Figures per Milking Dairy Cow per Day



The manure anaerobic digestion biogas-to-energy system

Mass & Energy Balance

Average Figures per Milking Dairy Cow per Day



So, why is GE here?

GE Energy's family of Jenbacher biogas engines.
1,450 engines (985MW) installed in biogas applications worldwide.



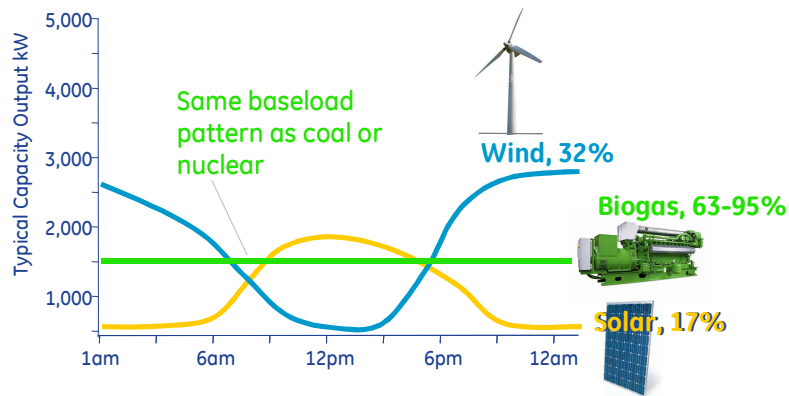
Type 2	Type 3	Type 4	Type 4
250-335 kW	500-1,100 kW	800-1,500 kW	1,700-3,100 kW
η : 36-47%	η : 36-47%	η : 36-47%	η : 36-47%

Greenhouse Gas Services *a GE AES venture*

GE-AES Greenhouse Gas Services
Project investment and carbon management services.

A renewable energy solution with numerous benefits

Benefit 1. Biogas-derived power is constant and reliable baseload renewable energy with capacity factors approaching 95%³



Benefit 2. Energy from agricultural waste offsets eCO₂ than just fossil power.

1MWh of biogas is worth:

0.8 Tons CO₂  ¹ + 4.3 Tons eCO₂  ² = 5.1 Tons eCO₂

Avoided Fossil Fuel Use (Coal) Dairy Manure Methane Avoidance Equivalent Emissions

Benefit 3. Organic food waste can be added to reduce landfill volume and increase energy output



Benefit 4. Renewable energy revenues can reduce farm operating costs and supplement farmer incomes

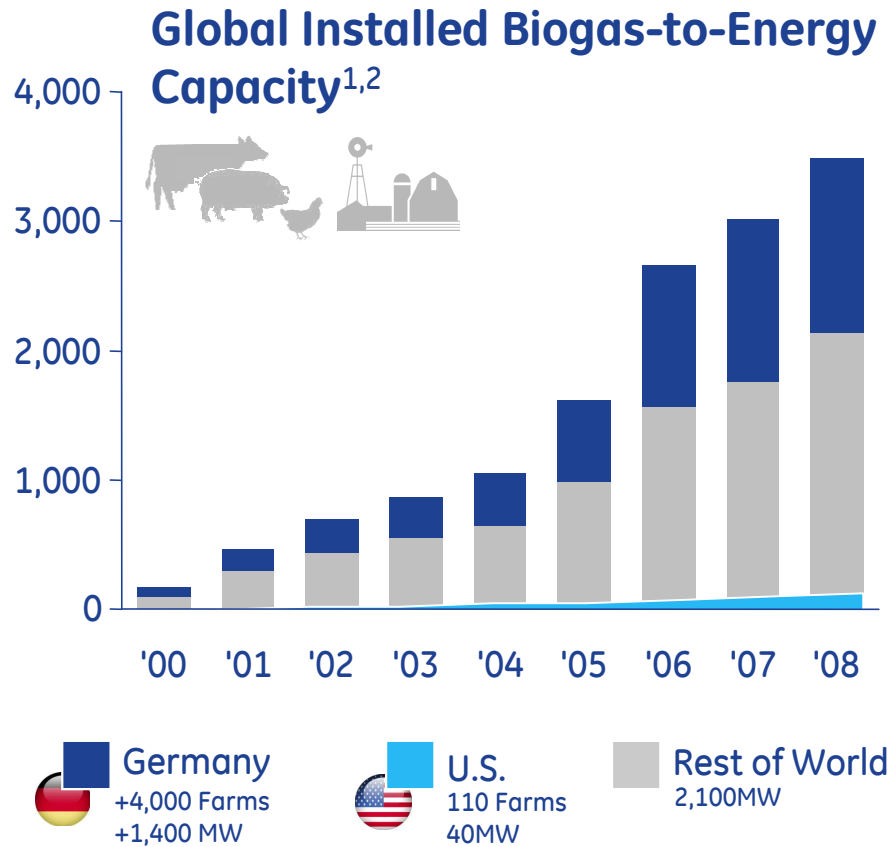


Benefit 5. Job creation. 12.4 FTE's/project⁴

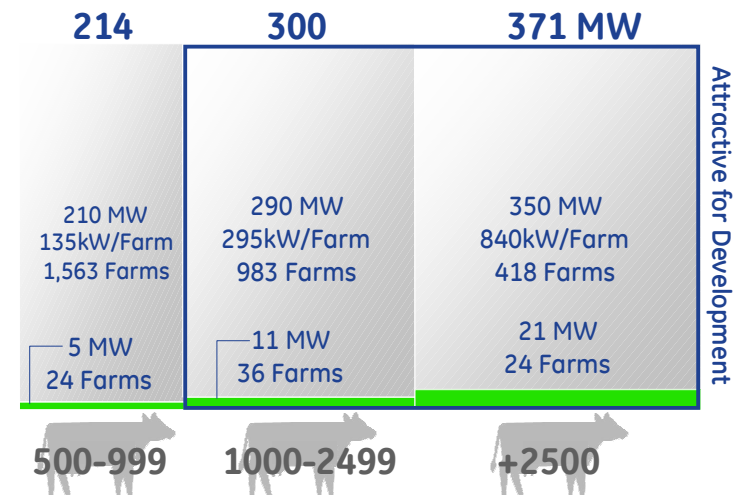


1. 0.813 Tons-CO₂/MWh for coal power displacement (US EIA, 1994)
 2. To generate approximately 1 MWh from a Jenbacher 320 requires 310 cfm of biogas at 58% methane (BTU content of 500 BTU/cf). This equals 310 cfm x 60 minutes x 58% CH₄ / 35.31 m³/cf * 0.67 kg/m³ / 1000 kg/ton * 21 = 4.3 Tons eCO₂ of methane avoidance (Reference Greenhouse Gas Services). Assumes open lagoon.
 3. OECD/IEA, 2008 Power Generation Cost Assumptions. Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible, i.e. running full time at rated power.
 4. Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety. Renewable Energy Employment Effects: Impact of the Expansion of Renewable Energy on the German Labor Market. Page 6. Estimated 12.4 new jobs/biogas-to-energy project.

Yet the in the US, progress has been slow to start



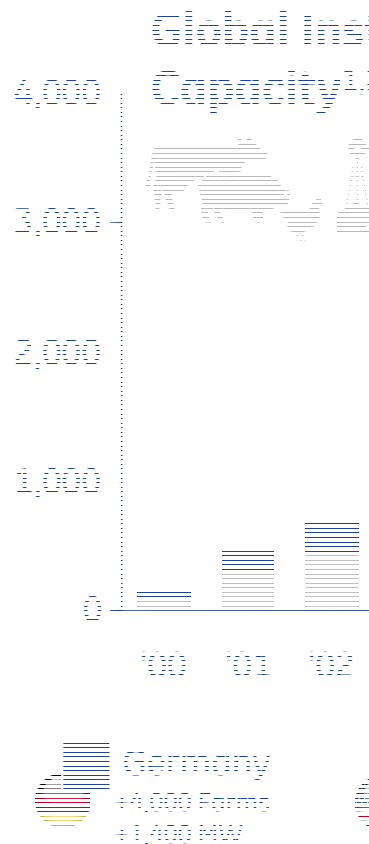
US dairy farm development^{3,4}



Less than 2% of the qualified potential is developed!

1. BAROMETRE BIOGAZ. EurObserver N° 186, page 45-59. July 2008 http://www.euroobserver.org/pdf/baro186_a.pdf?bcsi_scan_8029A76587052C3C=0&bcsi_scan_filename=baro186_a.pdf
 2. EurObserver
 3. Anaerobic digesters, sorted by operational status and by state.xls, http://www.epa.gov/agstar/pdf/digesters_all.xls
 4. USDA NASS, Table 17. Milk Cow Herd Size by Inventory and Sales: 2007 http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/index.asp and Table 21. Hogs and Pigs Herd Size by Inventory and Sales: 2002 http://www.nass.usda.gov/Census/Create_Census_US.jsp

Yet the in the US, progress has been slow to start



1,300 dairy farms...



Energy from enabled candidate dairy farms^{1,2}



670 MW

x 522,000⁶



Annual CO₂ avoidance from the offset of coal-based power and methane emissions from manure³

9 Mtons



Generation of construction and maintenance jobs (FTE)⁴

17,800 Jobs



Improved ground water safety from a near 100% kill of pathogens under anaerobic conditions



Increased energy security from reduced reliance on imported fossil fuels

development^{5,4}

371 MW

350 MW
840kW/Farm
410 Farms

21 MW
24 Farms

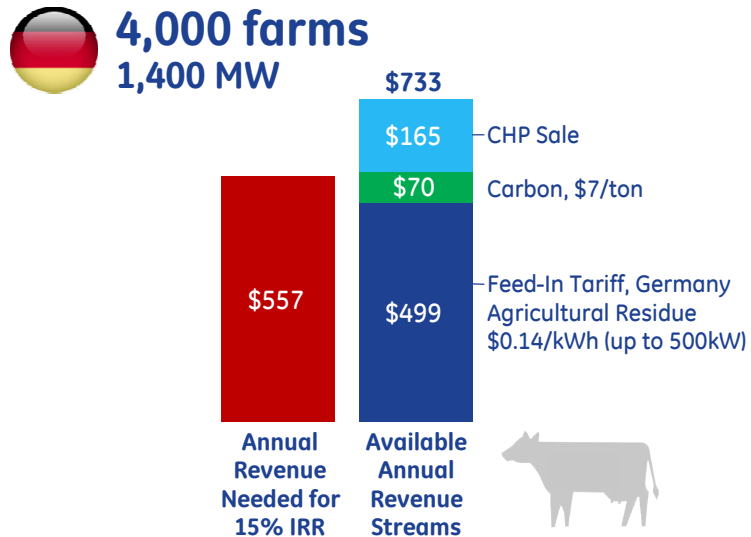
Additional for Development



the qualified developed

1. GE Energy Legislative Strategy Model – FINAL.xls, using average herd sizes >1000 head and typical operating conditions stated in Inputs tab
 2. Based on 15% IRR hurdle rate for dairy farm of herd size >1000 head. Hog farms not included, but expected to be of equivalent opportunity size.
 3. 0.813 Tons-CO₂/MW for coal power displacement (US EIA, 1994) + 0.916 Tons-CO₂/MW from manure management methane destruction (IPCC, 2006)
 4. Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety. Renewable Energy Employment Effects: Impact of the Expansion of Renewable Energy on the German Labor Market. Page 6. Estimated 12.4 new jobs/biogas-to-energy project. <http://www.erneuerbare-energien.de/inhalt/42722/>
 5. With California excluded due to NO_x emissions regulations
 6. The average residential household consumption in the United States in 2007 was 11,232kWh/year. <http://www.eia.doe.gov/cneaf/electricity/esr/table5.html>

Why? Poor incentives and financing challenges

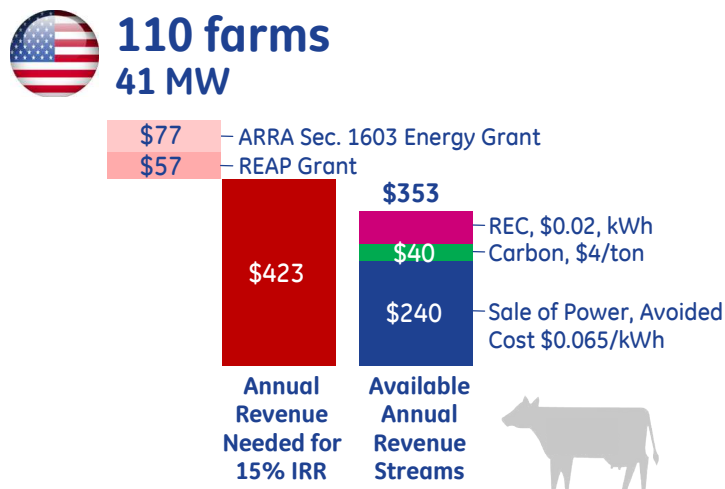


Typical Digester Technologies



Complete Mix Digesters

Advanced technologies increase biogas output and revenue



Plug Flow and Covered Lagoon Digesters

Less than 40% of completed digesters are operating in the US

2,500 head dairy farm, 20% equity, debt at 6% interest for 10 years. 470kW generator set @ 90% availability, 40% efficiency, 40scfm methane/cow/day. \$4/Ton CO₂, \$0.02/kWh REC, \$0.10/kWh PPA, Treasury Grant (ARRA Sec. 1603). 15 year project life. No added organic waste.

So, how do we overcome this? The basics.

Investment Metrics

➔ Internal Rate of Return (IRR)

Capital Cost/Annualized EBITDA

Profitability Drivers

Farm Size

Technology Selection

Power Price

Carbon Price

Finance Structure



The annualized effective compounded return rate that can be earned on the invested capital.

Rule of Thumb:
IRR > 15%

So, how do we overcome this? The basics.

Investment Metrics

Internal Rate of Return (IRR)

 **Capital Cost/Annualized EBITDA**

Profitability Drivers

Farm Size

Technology Selection

Power Price

Carbon Price

Finance Structure

Earnings before interest, taxes, depreciation and amortization.

An approximate measure of a company's operating cash flow based on data from the company's income statement.

Rule of Thumb:

Capital Cost/Annualized EBITDA > 7

So, how do we overcome this? Project profitability.

Investment Metrics

Internal Rate of Return (IRR)

Capital Cost/Annualized EBITDA

Profitability Drivers

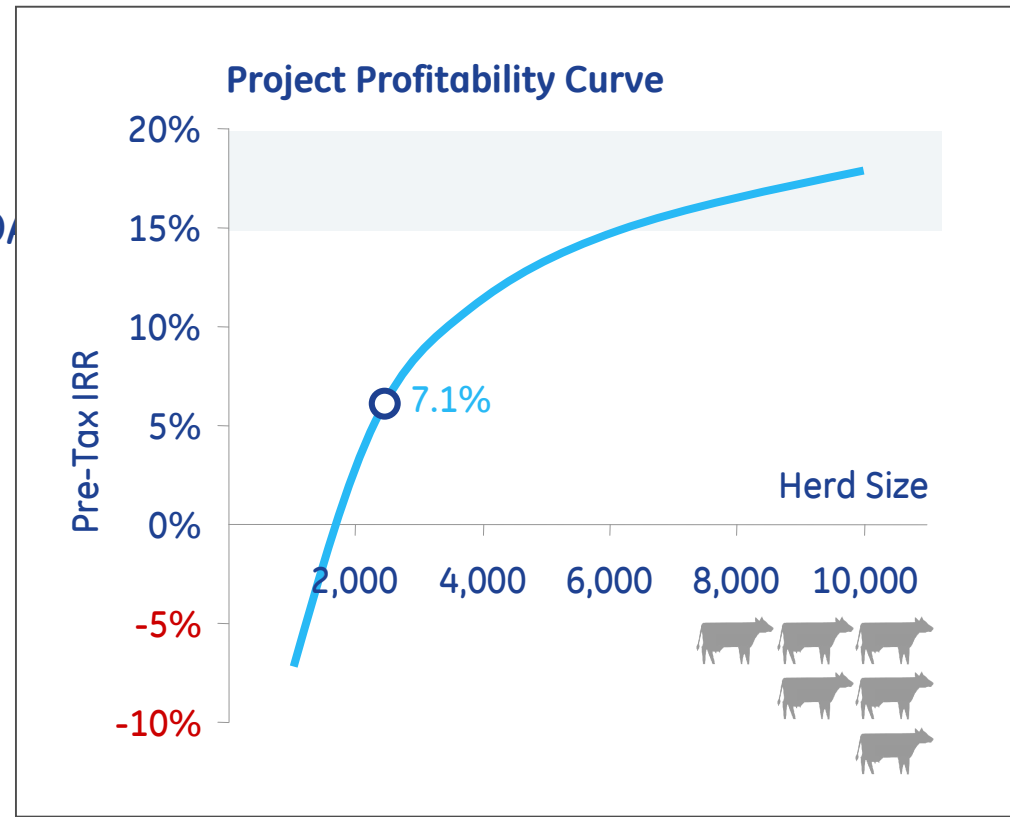
➔ **Farm Size**

Technology Selection

Power Price

Carbon Price

Finance Structure



○ **Producer Bill.** 2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. 470 kW generator set @ 90% availability, 40% efficiency, 40 ft³/cow/day. \$4/Ton CO₂, \$0.02/kWh REC, \$0.10/kWh PPA, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. CapEx, \$2.2M.

So, how do we overcome this? Project profitability.

Investment Metrics

Internal Rate of Return (IRR)

Capital Cost/Annualized

Profitability Drivers

Farm Size

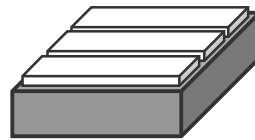
 **Technology Selection**

Power Price

Carbon Price

Finance Structure

Digester Technology



Methane Production Rate	Pre-Tax IRR
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25 ft ³ /cow/day	-3%
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35 ft ³ /cow/day	4%
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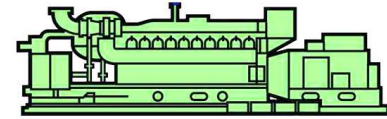
<input checked="" type="radio"/> 40 ft ³ /cow/day	7%
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55 ft ³ /cow/day	14%
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60 ft ³ /cow/day	16%
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Every 5 ft³/cow/day is worth 2-3% in IRR

Biogas Engine Technology



Engine Efficiency	Pre-Tax IRR
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33%	2%
-----	----

36%	4%
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<input checked="" type="radio"/> 39%	6%
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42%	7%
-----	----

45%	9%
-----	----

48%	10%
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Every 3% in efficiency is worth 1-2% in IRR

So, how do we overcome this? Project profitability.

Investment Metrics

Internal Rate of Return (IRR)

Capital Cost/Annualized EE

Profitability Drivers

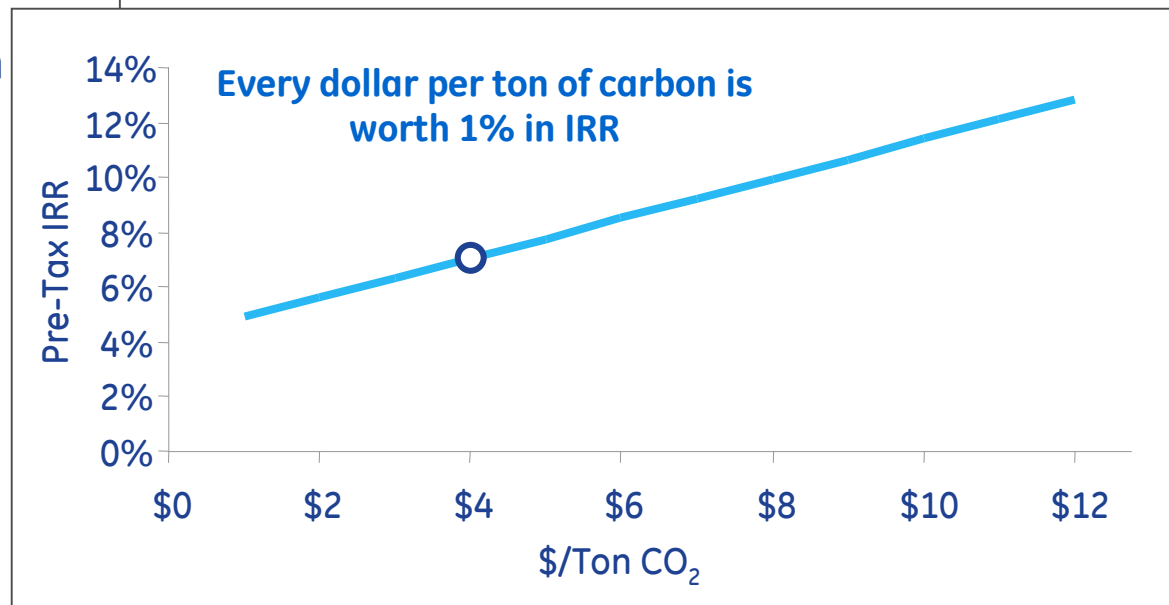
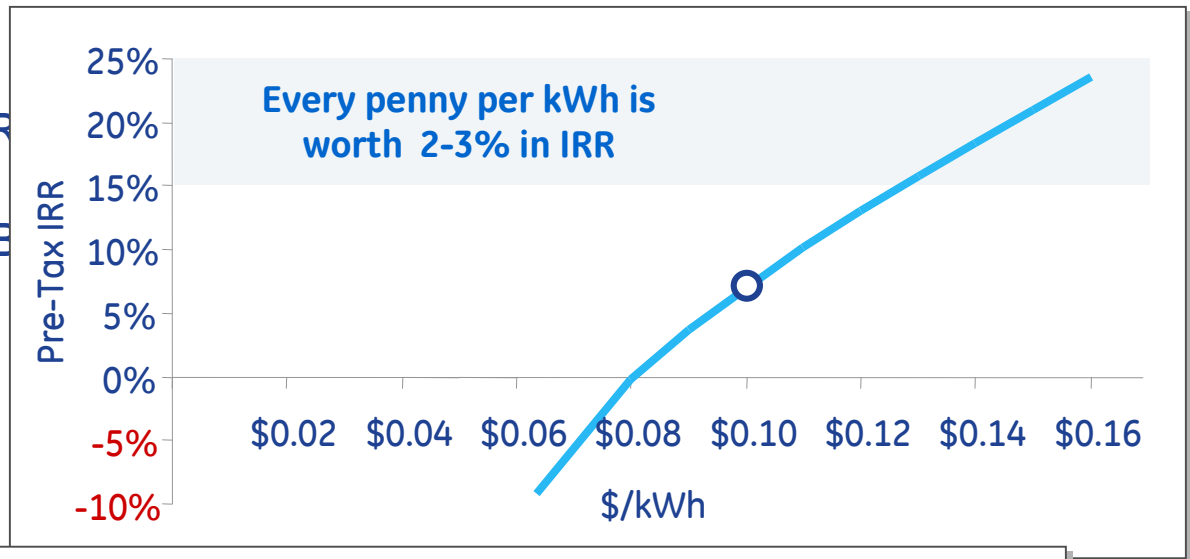
Farm Size

Technology Selection

➔ Power Price

➔ Carbon Price

Finance Structure



So, how do we overcome this? Project profitability.

Investment Metrics

Internal Rate of Return (IRR)

Capital Cost/Annualized

Profitability Drivers

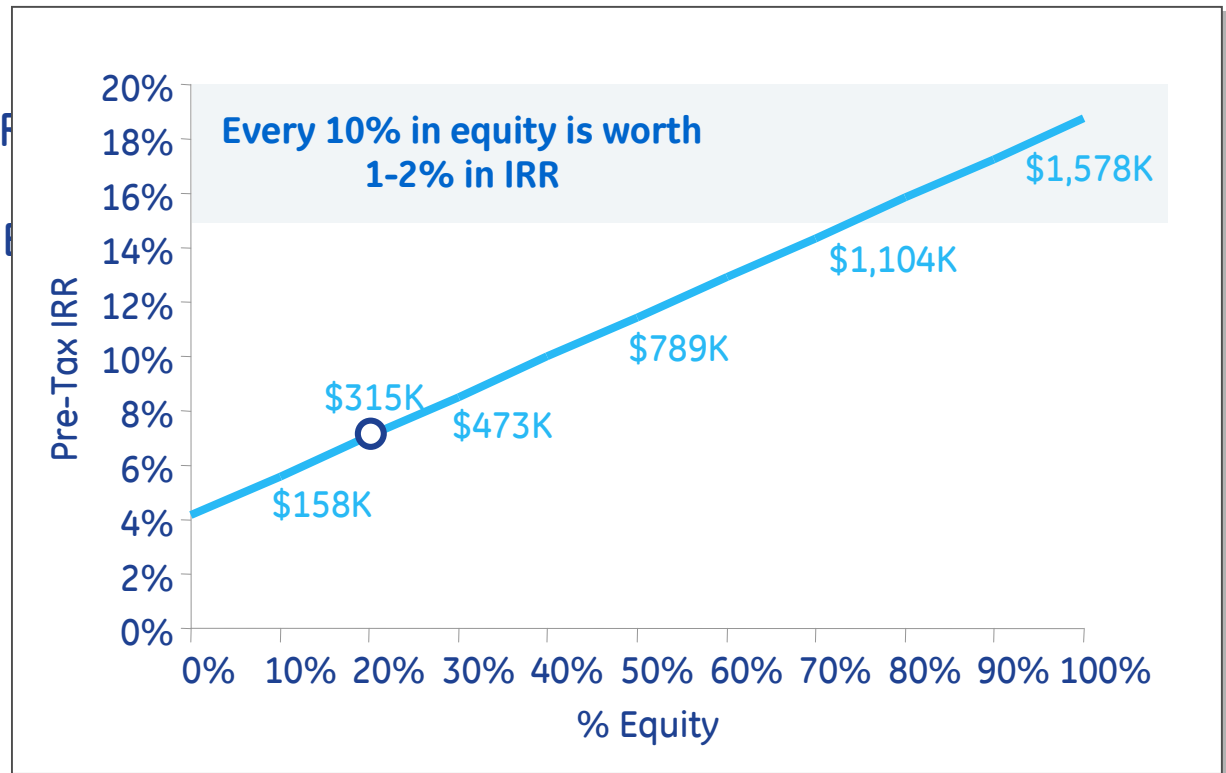
Farm Size

Technology Selection

Power Price

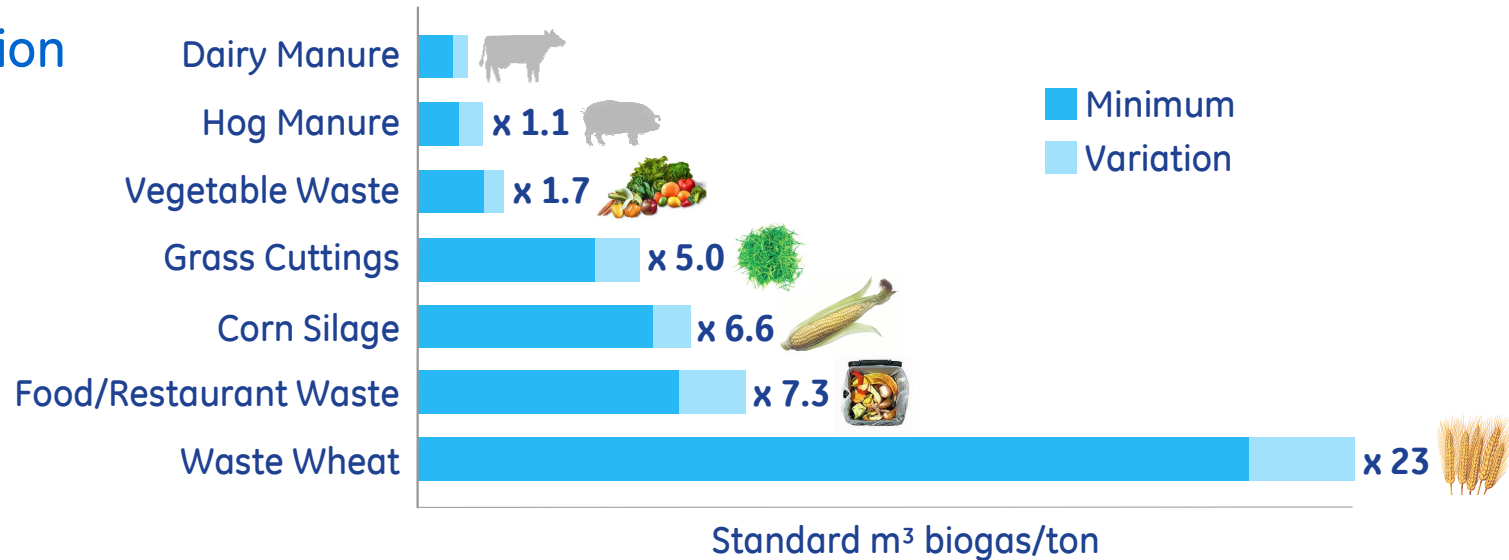
Carbon Price

➔ Finance Structure

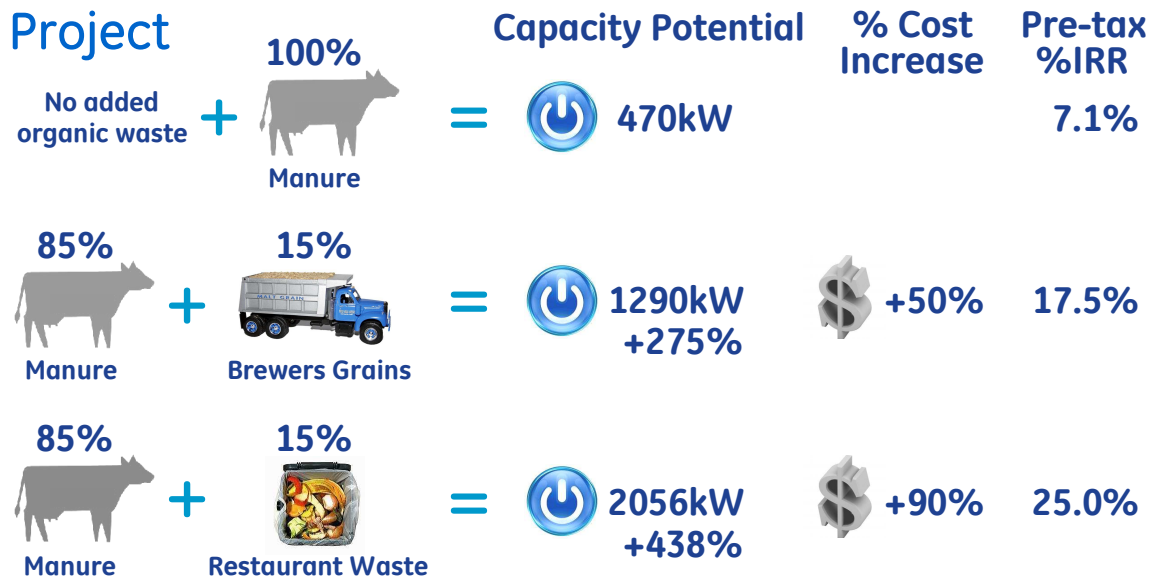


Game changing solutions for achieving profitability

Codigestion



Codigestion and Project Profitability



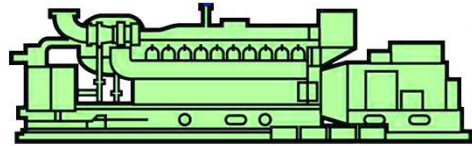
Biogas potential based on the Ontario Ministry of Ag, Food and Rural Affairs Info Sheet "Calculations and Information for Sizing Anaerobic Digestion Systems (uses example of 1000 milking cows and assumes constant digester tank size, base case qualified range is 800,000-1,000,000kWh)

Game changing solutions for achieving profitability

Engine/Generator Leasing



=



IRR, No Lease
7.1%

IRR, With Lease
10.5%

Digester Back-End



10-15 Tons/Week

Bedding



\$20/Ton

Compost



\$19/ton

University of Maine
<http://www.extension.umaine.edu/maine/quine/pellet/results3.htm>

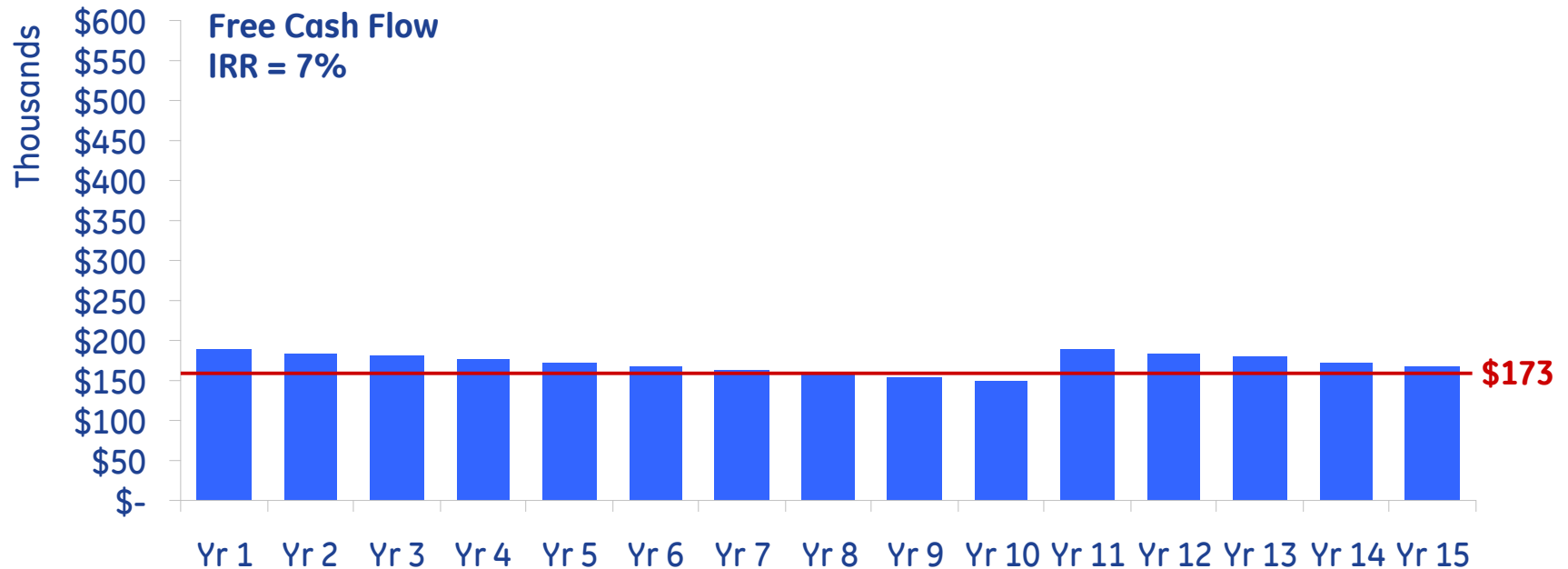
\$28/Yard, *Compost News* January 2009
Finished compost is 1,350 pounds/yard

How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. 470 kW generator set @ 90% availability, 40% efficiency, 40 ft³/cow/day. \$4/Ton CO₂, \$0.02/kWh REC, \$0.10/kWh PPA, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. CapEx, \$2.2M.

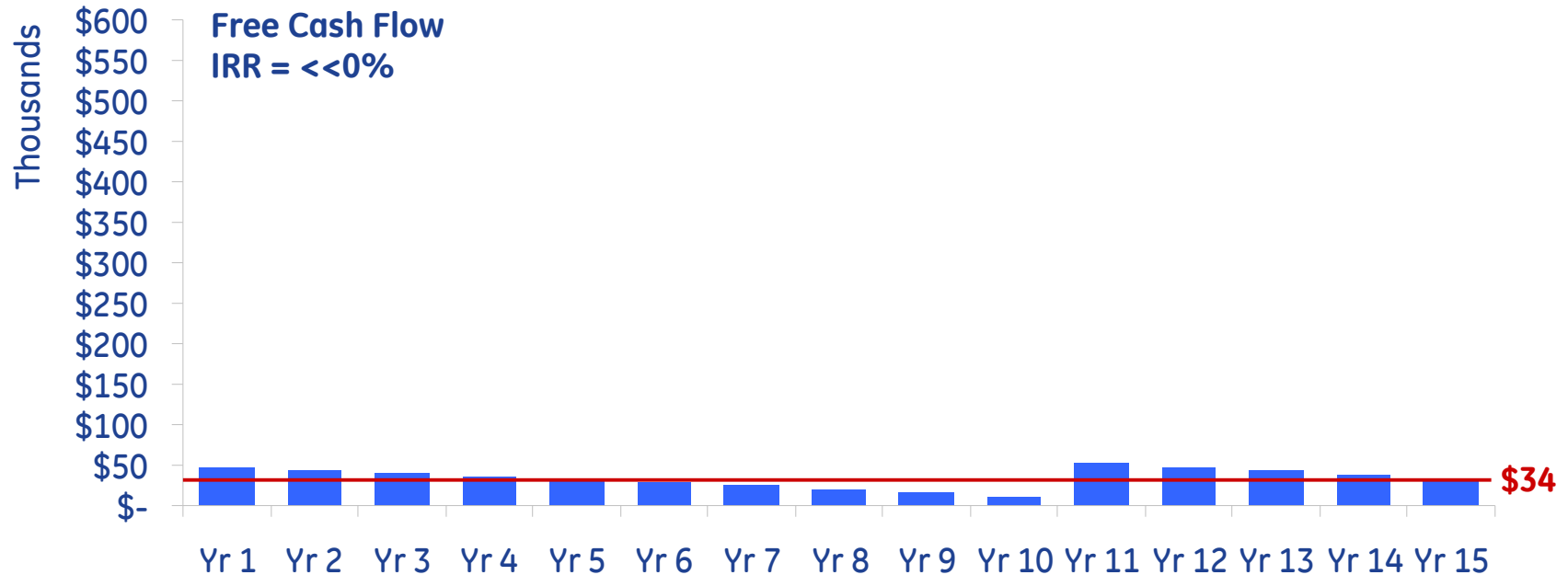


How much money?

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2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. 470 kW generator set @ 90% availability, 40% efficiency, 40 ft³/cow/day. \$4/Ton CO₂, \$0.02/kWh REC, **\$0.06/kWh PPA**, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. CapEx, \$2.2M.

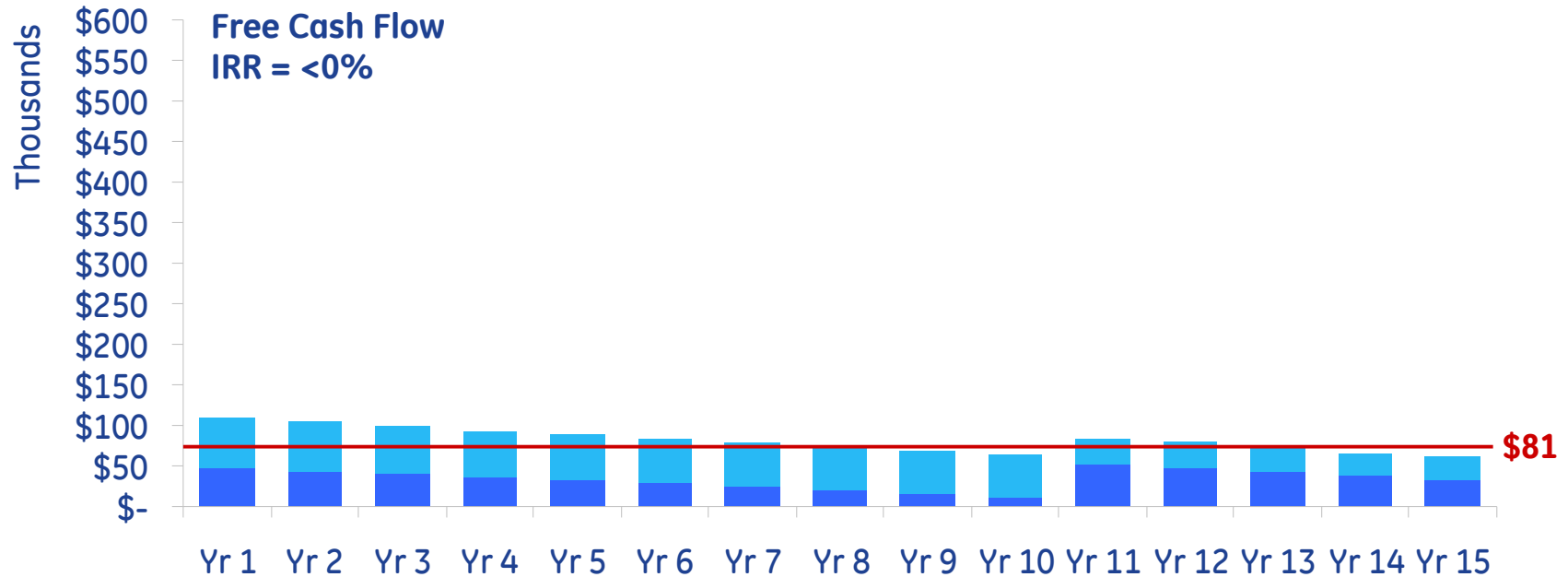


How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **680 kW** generator set @ 90% availability, 40% efficiency, **55 ft³/cow/day**. \$4/Ton CO₂, \$0.02/kWh REC, **\$0.06/kWh PPA**, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. **CapEx, \$2.4M.**

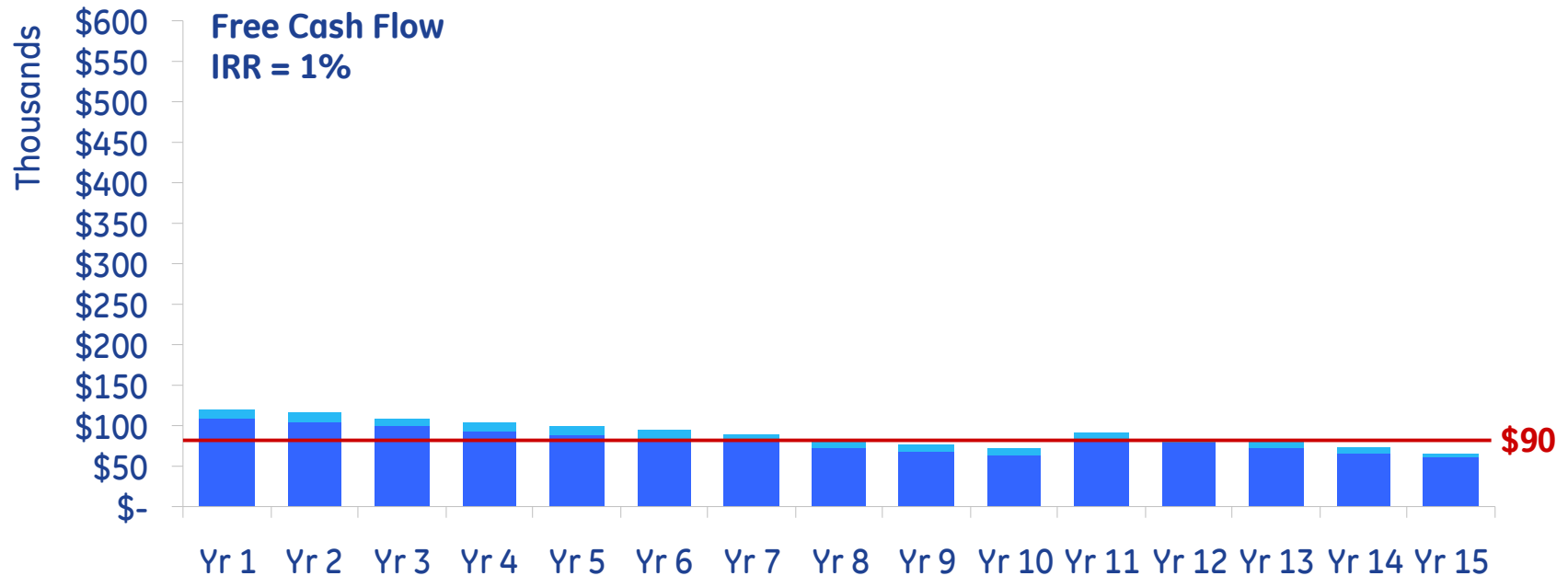


How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **712 kW** generator set @ 90% availability, **42% efficiency, 55 ft³/cow/day**. \$4/Ton CO₂, \$0.02/kWh REC, **\$0.06/kWh PPA**, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. **CapEx, \$2.4M**.

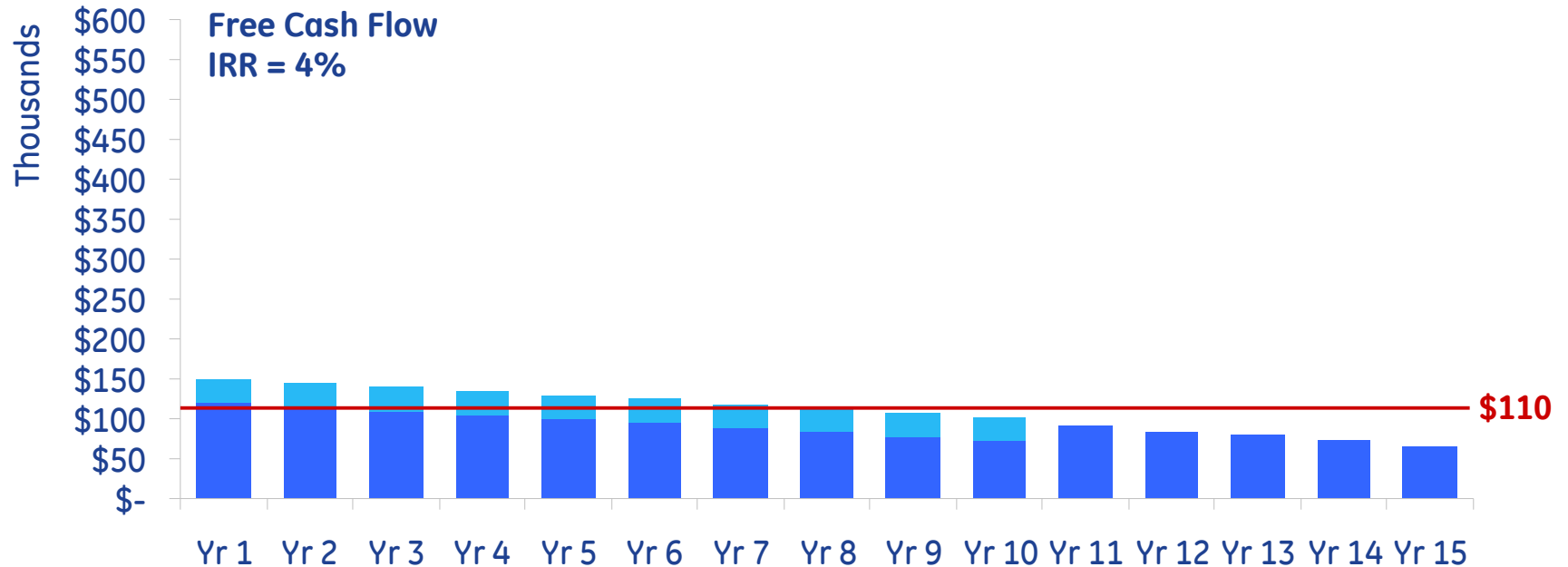


How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **710 kW** generator set @ 90% availability, **42% efficiency**, **55 ft³/cow/day**. **\$7/Ton CO₂**, \$0.02/kWh REC, **\$0.06/kWh PPA**, federal treasury grant (ARRA Sec. 1603). 15 year project life. No added organic waste. **CapEx, \$2.4M**.

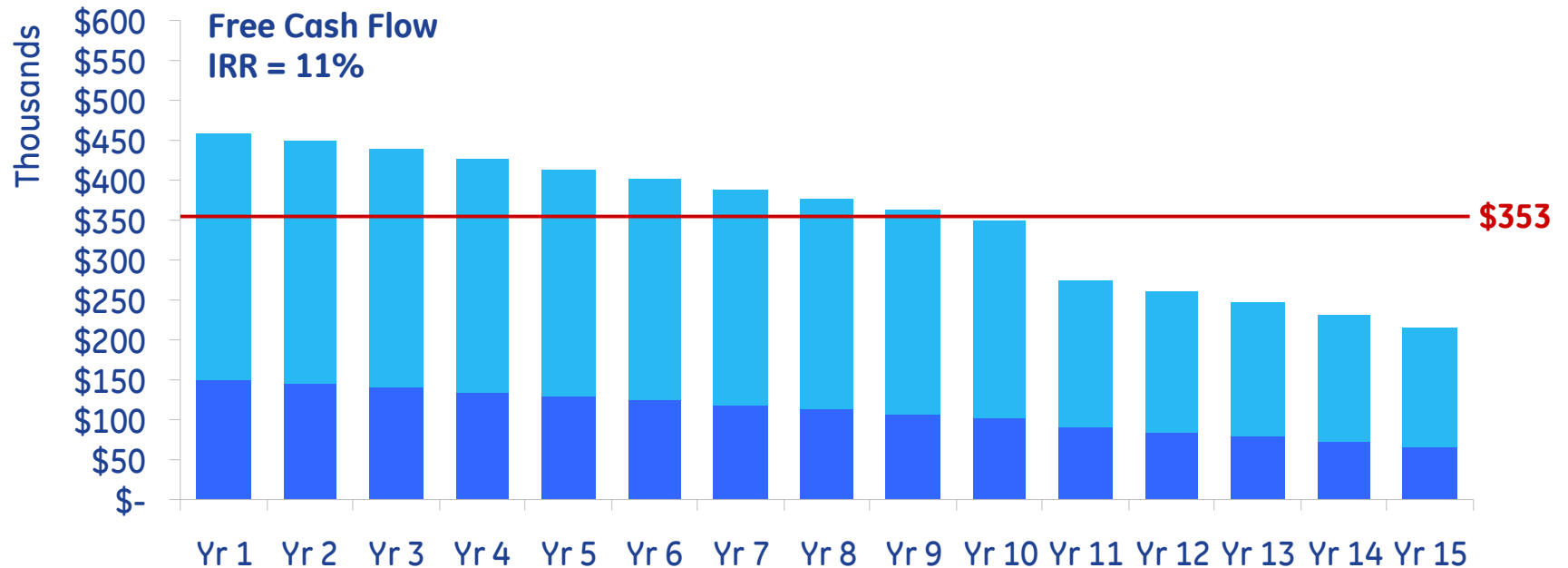


How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **1,780 kW** generator set @ 90% availability, **42% efficiency**, **55 ft³/cow/day**. **\$7/Ton CO₂**, \$0.02/kWh REC, **\$0.06/kWh PPA**, federal treasury grant (ARRA Sec. 1603). 15 year project life. **Substrate, +250%**. **CapEx, \$4.0M**.



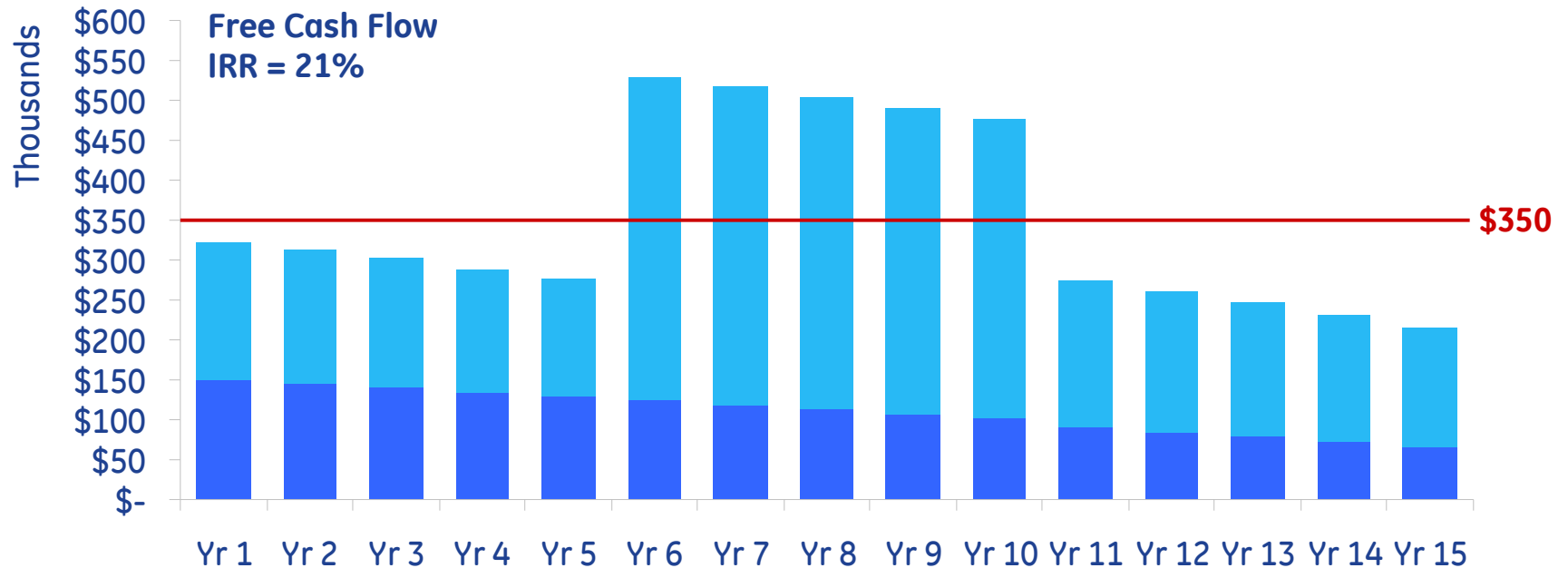
How much money?

Producer Bill's Dairy



2,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **1,780 kW** generator set @ 90% availability, **42% efficiency, 55 ft³/cow/day. \$7/Ton CO₂, \$0.02/kWh REC, \$0.06/kWh PPA,** federal treasury grant (ARRA Sec. 1603). 15 year project life. **Substrate, +250%. CapEx, \$2.3M.**

5 Year Engine Lease Program



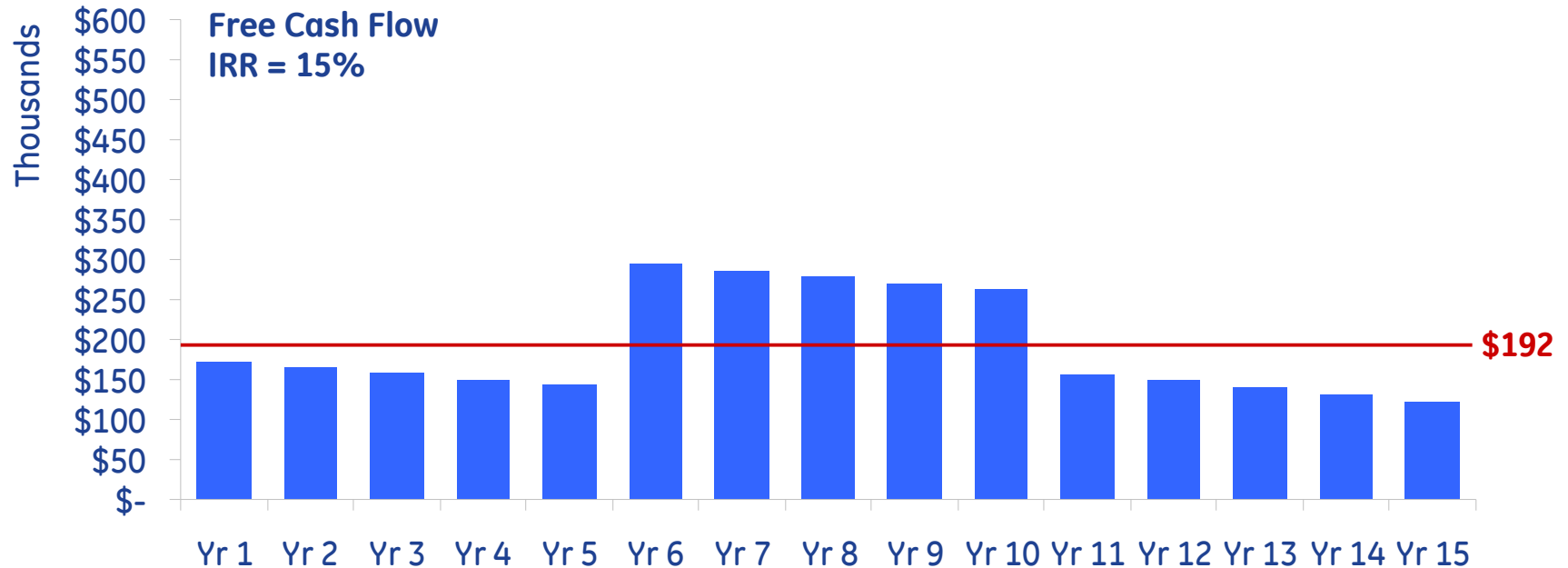
How much money?

Producer Jim's Dairy



1,500 head dairy. Project financed by 20% equity, debt at 6% interest for 10 years. **1,068 kW** generator set @ 90% availability, **42% efficiency, 55 ft³/cow/day. \$7/Ton CO₂, \$0.02/kWh REC, \$0.06/kWh PPA,** federal treasury grant (ARRA Sec. 1603). 15 year project life. **Substrate, +250%. CapEx, \$2.3M.**

5 Year Engine Lease Program



the end



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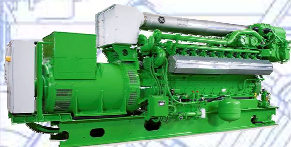
imagination at work

Our family of biogas engines More than 1,400 installed worldwide



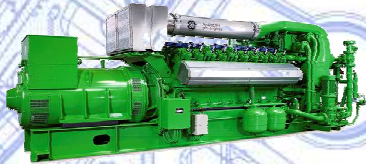
Type 2

Electrical Output: 250kW to 335kW
Biogas Flowrate: 105 scfm
Electric Efficiency: 36.2% to 46.7%
Est. Wet Cow Herd Size: 750 to 1,300



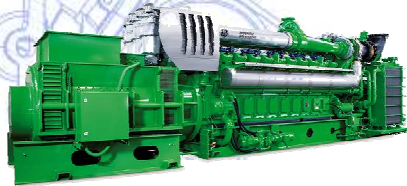
Type 3

Electrical Output: 500kW to 1,100kW
Flowrate: 189 to 309 scfm
Electric Efficiency: 36.2% to 46.7%
Est. Wet Cow Herd Size: 1,300 to 4,000



Type 4

Electrical Output: 800kW to 1,500kW
Flowrate: up to 390 scfm
Electric Efficiency: 36.2% to 46.7%
Est. Wet Cow Herd Size: 3,000 to 8,000



Type 6

Electrical Output: 1,700kW to 3,100kW
Flowrate: up to 695 scfm
Electric Efficiency: 36.2% to 46.7%
Est. Wet Cow Herd Size: 8,000 to 12,000



GE Energy's gas engine business is one of the world's leading manufacturers of gas-fueled reciprocating engines, packaged generator sets and cogeneration units for power generation. It is one of the only companies in the world focusing exclusively on gas engine technology.

For more information, visit ge.com/energy

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imagination at work

Electricity from biogas provides greatest GHG savings



Biogas utilisation – GHG-savings

Data Source:
 Optimierungen für einen nachhaltigen Ausbau der Biogaserzeugung und -nutzung in Deutschland (ifeu et al. 2008)

