Cost of Electricity & Pipeline Quality Natural Gas from Biogas

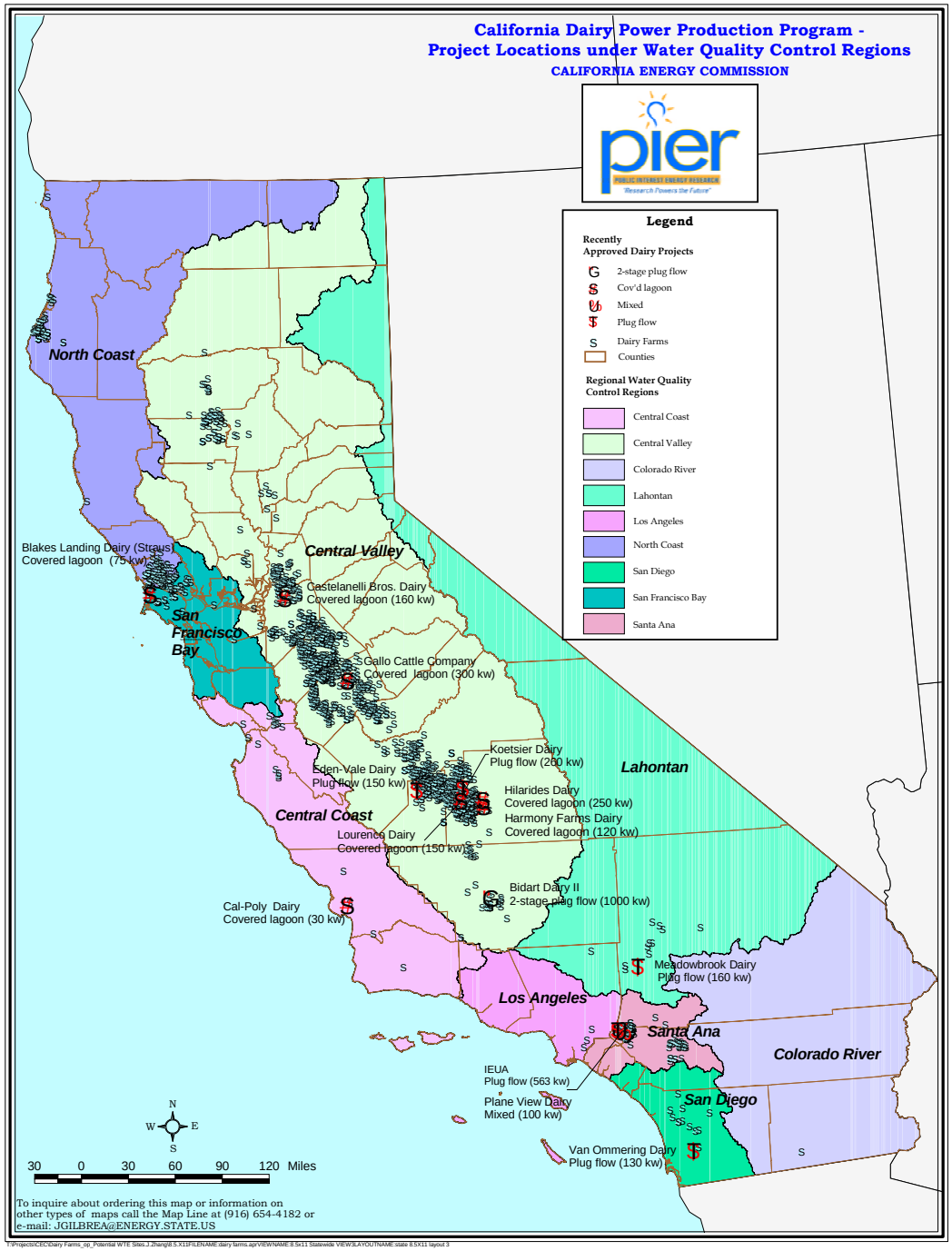
Zhiqin Zhang and Gerry Braun
California Energy Commission
Public Interest Energy Research (PIER) Program

Prepared for 24th Annual BioCycle West Coast Conference 2008

April 14 - 16, 2008 • San Diego, CA

Acknowledgement

- Princeton Energy Resources International (PERI)
  - Kathryn George
  - Joseph Cohen
  - Nicholas P. Cheremisinoff
- Science Applications International Corp. (SAIC)
  - Robin W. Taylor
- California Water Resources Control Board
  - Gary Wolf
  - Bob Languell
  - John Menke
- San Joaquin Valley Air Pollution Control District (SJVAPCD)
- Air Resources Board
- Pacific Gas and Electric Company (PG&E)
- San Diego Gas & Electric (SDG&E)
- Southern California Edison (SCE)
- SCS Engineers
  - Jeffrey L. Pierce



Background

Year	# of Cows in CA	# of Dairies in CA
2006	1,781,757	1,974
2007	1,868,608	1,950
2007/2006	5%	-1%

Source: California Dairy Statistics Annual 2007

- California Dairy Power Production Program (DPPP)
  - 18 dairies received awards with a total $5.8 million of SB5X fund by 2007
  - 10 dairies installed and operated biogas systems
  - 9 dairies collected cost and performance data on the biogas systems

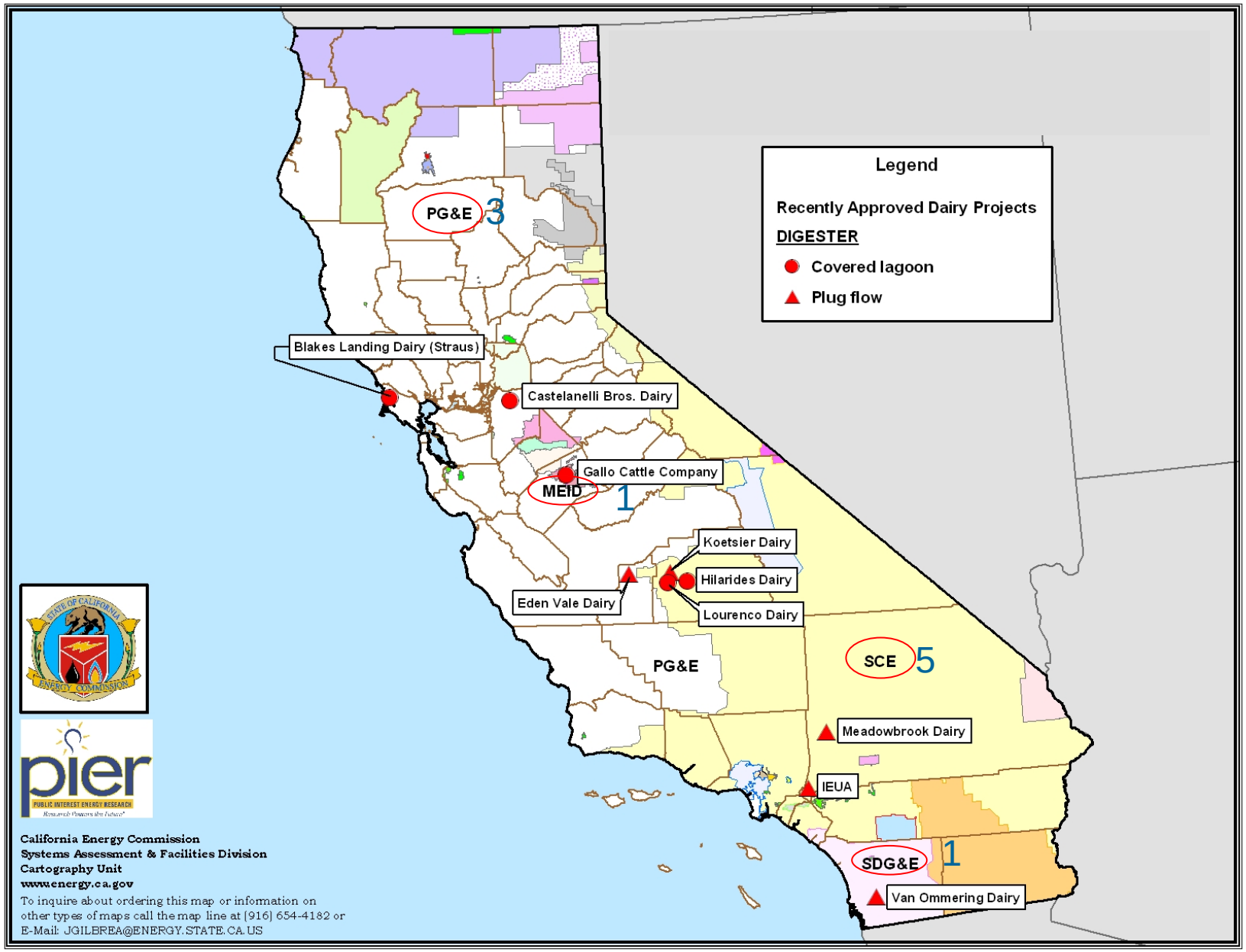
10 Digesters Installed under DPPP

Dairy Name	Digester Type	# of Milking Cows
Blakes Landing	Covered Lagoon	245
Castelanelli Bros	Covered Lagoon	1601
Cottonwood	Covered Lagoon	4971
Hilarides	Covered Lagoon	6000
Lourenco	Covered Lagoon	1390
Eden-Vale	Plug Flow	800
Koetsier	Plug Flow	1266
Meadowbrook	Plug Flow	2093
Van Ommering	Plug Flow	480
Inland Empire Utility Agency	Plug Flow	7931

10 Installed Engine Generators under DPPP

Dairy Name	Rated kW	Engine Generator
Blakes Lending	75	Waukesha
Castelanelli	160	Caterpillar
Cottonwood	300	Caterpillar
Hilarides	500	Caterpillar
Lourenco	150	Caterpillar
Eden-Vale	180	Caterpillar
Koetsier	260	Caterpillar
Meadowbrook	160	Caterpillar
Van Ommering	130	Waukesha
IEUA	943	Waukesha

Ten Digester Locations by Utility Service Areas



Objectives Of Dairy Digester Economic Study

- Study the economics of dairy biogas systems installed under the California Dairy Power Production program to quantify
  - Net incremental costs and levelized financial cost of electricity (LCOE in $/kWh)
  - Levelized financial cost of biogas (in $/therm) if the dairy biogas produced from the digesters installed under the DPPP will be used to produce pipeline gas meeting natural gas quality standard (and or PG&E standards)
  - Net incremental costs and levelized financial costs of electricity and pipeline quality biogas of adding anaerobic digestion capabilities to California dairies in an environmentally superior way

Methodology

- PERI developed custom designed dairy power discounted cash flow models (Excel) for each dairy installed under the DPPP to
  - study the economics of dairy biogas by calculating
    - 1) Internal Rate of Return (IRR), given the capital cost, performance, and operating expenses, and revenues reported for the nine dairy power plants, and
    - 2) Cost of Energy (COE), by varying revenues, to achieve a target IRR of 17%
- IRR is calculated when the net present value of future cash flows equals the present value of the investment outlay
- COE is calculated by levelizing net present value (NPV) using either the nominal or constant dollar discount rate

Assumptions

For actual cases

- After tax revenue, cost of energy are calculated based on data collected under the California dairy power production program.
- Data collected include capital cost, O&M cost, on-farm offset rate, utility net metering rate, biogas production, electricity generation, any thermal generation, and any byproduct revenues.
- Earnings were projected, as pro forma revenues are estimated for 20 years, expenses are estimated and subtracted to determine operating income, non-cash deductions like depreciation are deducted, income tax is subtracted, and after-tax income is left.
- Cash flows are projected from before-tax income, to which is added back non-cash expenses and from which is subtracted non-deductible charges such as principal on a loan. There is no debt here, however. This leaves before-tax cash, from which taxes are subtracted, to leave after-tax cash.
- Both federal and California state taxes are applied by assuming farmers are in the maximum corporate tax bracket.
- SB5x grants that farmers received under the DPPP are included.

Assumptions (cont'd)

For no-subsidy cases

- SB5x grants are excluded.
- Because the net incremental cost to build an AD system and produce energy was sought, a few costs sometimes were removed. For example, the cost to dig a lagoon was removed because lagoons are considered part of the normal course of dairy operation.
- A small financing load, for construction financing, tax advice, and a working capital reserve was added up front. Property tax and insurance were broken out and added to annual expenses.
- All power or pipeline-quality gas is assumed sold to the local utility. Therefore, on-farm retail sales are removed, any thermal sales are removed, and any other subsidies such as carbon credits are removed.
- For three plants with low plant factors, it was assumed that when attractive utility rates were available, that they would operate with improved plant capacity factors and heat rates.
- All cases were run to achieve a target IRR of 17% (hurdle rate).

Sensitivity Study

- For both power and pipeline-quality gas, a break-even analysis was run, where IRR was just over zero, to learn the break-even COE. From this, the farmer and his engineer may estimate how much reducing capital cost and improving plant performance may help.
- Costs of energy are projected with carbon credits. The carbon credit is estimated at a conservative \$3/Metric Ton CO_2eq. (Credit prices have ranged from about \$1.00 to about \$4.00 from 2004 through 2007 at the Chicago Climate Exchange, CCX. Credit prices recently hit \$6.00.)
- For power, added the Section 45 Production Tax Credit (PTC).
- For three plants, added 50% Bonus Depreciation (where 50% of cost is expensed in year one).
- For special cases, looked at market price reference (MPR) rate.

Other inputs

- Pipeline gas meeting PG&E quality standard.
- Costs of upgrading biogas to pipeline gas are supplied by SCS Engineers.
- Distances from dairy farm to pipeline are supplied by the Energy Commission.
- Costs of double liners are supplied by developers, field engineers, and water resources control board.

Performance of Biogas to Electricity Systems for Actual Cases

Dairy: Digester Type	Size (kW)	Plant Capacity Factor (%)	Annual Energy (MWh/Yr)	Heat Rate (Btu/kWh)	Biomethane Production (Mft^3/day)
Hilarides: Covered lagoon	500	77	3,383	13,132	233
Cottonwood: Covered lagoon	300	81	2,133	12,235	113
Blakes Landing: Covered lagoon	75	38	253	13,813	14
Castelanelli: Covered lagoon	160	81	1,135	17,912	89
Koetsier: Plug-flow	260	24	540	16,645	44
Van Ommering: Plug-flow	130	43	489	17,103	34
Meadowbrook: Plug-flow	160	79	1,100	15,673	81
IEUA: Modified Plug-flow	943	92	7,572	12,000	113
Eden-Vale: Plug-flow	180	29	457	17,785	40
1 Mft^3 = 1000 ft^3					

Cost of Biogas to Electricity For Actual Cases (With Grant)

Dairy: Digester Type	Cap Cost ($/kW)	(Debt/Grant/Equity) (%)	After-tax IRR (%)	Year 1 Retail2	Year 1 Whole-sale2
Hilarides:	2,480;	0-40-60	22.82	.0600;	.0400;
covered lagoon	2005 $			2006 $	2006 $
Cottonwood:	8,993;	0-31-69	8.64	.0748;	.0400;
covered lagoon.	2004 $			2005 $	2005 $
Blakes Landing:	4,504;	0-46-54	19.02	.1200;	.1000;
covered lagoon	2004 $			2005 $	2005 $
Castelanelli:	6,043;	0-57-43	21.27	.0724;	.0576;
covered lagoon	2004 $			2005 $	2005 $
Koetsier:	5,264;	0-0-100	-13.25	.0600;	.0300;
plug-flow	2005 $	Incentive		2006 $	2006 $
Van Ommering:	6,668;	0-46-54	-0.12	.0500;	.0500;
plug-flow	2005 $			2006 $	2006 $
Meadowbrook:	6,379;	0-45-55	4.76	.0600;	.0400;
plug-flow	2004 $			2005 $	2005 $
IEUA:	13,734;	0-01-99	-13.78	.0800;	.0400;
Modified mix plug-flow	2005 $	Incentive		2006 $	2006 $
Eden-Vale:	4,471;	0-37-63	-13.97	.0700;	.0300;
plug-flow	2005 $			2006 $	2006 $

Cost of Biogas to Electricity without Grant

No Subsidy Power COE and Components (nominal levelized 2007$)

Dairy Name	No Subsidy Power COE – 17% IRR (¢/kWh)	After-tax O&M Component[1] (¢/kWh)	Capital Component (¢/kWh)
Hilarides	10.16	0.45	9.71
Eden-Vale[2]	17.63	1.16	16.47
Koetsier[2]	20.40	1.15	19.25
Castelanelli Bros.	22.69	0.94	21.75
Van Ommering[2]	26.14	1.61	24.53
Meadowbrook	27.63	2.71	24.92
IEUA	34.34	10.20	24.14
Cottonwood	35.46	4.34	31.12
Blakes Landing	37.19	1.16	36.03

1 Except for IEUA, after-tax O&M is O&M multiplied by (1 – 0.4075), where 40.75% is the combined tax rate. IEUA is tax-free, so no factor is applied to its O&M.

2 For Eden-Vale, Koetsier, and Van Ommering, adjustments to show more realistic plant operation were employed. These are that plant capacity factor was set to 83.45% and heat rates were reduced to 13,500 Btu/kWh.

Cost of Biogas to Pipeline Gas without Grant

No Subsidy Pipeline-Quality Gas COE and Components (nominal levelized 2007$)

Dairy Name	No Subsidy Gas COE, with 17% IRR ($/therm)	After-tax O&M Component[1] ($/therm)	Capital Component ($/therm)
Hilarides	1.245	0.068	1.178
Eden-Vale	2.812	0.169	2.643
Koetsier	2.923	0.151	2.771
Meadowbrook	3.226	0.095	3.131
IEUA	4.004	1.151	2.853
Van Ommering	4.025	0.234	3.791
Castelanelli Bros. (~5 mile pipeline)	4.233	0.103	4.130
Cottonwood	4.801	0.511	4.290
Blakes Landing (~12 mile pipeline)	34.400	0.390	34.010

1 Except for IEUA, after-tax O&M is O&M multiplied by (1 – 0.4075), where 40.75% is the combined tax rate. IEUA is tax-free, so no factor is applied to its O&M.

2 To produce pipeline-quality gas, all plants were assumed to operate with a plant capacity factor of 90.00%.

Enhanced Environmental Quality Power without Grant

Enhanced Environmental Quality Power COE and Components (nominal levelized 2007$)

Dairy Name	EEQ Power COE – 17% IRR (¢/kWh)	After-tax O&M Component[1] (¢/kWh)	Capital Component (¢/kWh)
Hilarides covered lagoon	18.55	0.60	17.95
Eden-Vale[2] plug-flow	18.86	1.55	17.31
Koetsier[2] plug-flow	21.32	1.41	19.91
Van Ommering[2] plug-flow	27.68	2.14	25.54
Castelanelli Bros. covered lagoon	28.79	1.39	27.40
Meadowbrook plug-flow	29.10	3.17	25.93
IEUA modified mix plug-flow	34.54	10.31	24.23
Blakes Landing covered lagoon	44.65	3.18	41.47
Cottonwood covered lagoon	44.86	4.58	40.28

1 For all plants except IEUA, after-tax O&M is O&M multiplied by a tax factor, reflecting a reduction for the combined tax rate of 40.75%. Since IEUA is tax-free, no factor is applied for it.

2 Eden-Vale, Koetsier, and Van Ommering were adjusted to employ a better plant capacity factor, at 83.45%, and an improved heat rate, of 13,500 Btu/kWh.

Enhanced Environmental Quality Pipeline-Quality Gas without Grant

Enhanced Environmental Quality Pipeline-Quality Gas COE and Components (nominal levelized 2007$)

Dairy Name	EEQ Gas COE, with 17% IRR ($/therm)	After-tax O&M Component[1] ($/therm)	Capital Component ($/therm)
Hilarides covered lagoon	2.096	0.083	2.013
Eden-Vale plug-flow	2.927	0.207	2.720
Koetsier plug-flow	3.011	0.178	2.834
Meadowbrook plug-flow	3.354	0.134	3.220
IEUA modified mix plug-flow	4.025	1.164	2.861
Van Ommering plug-flow	4.172	0.287	3.885
Castelanelli Bros. (~5 mile pipeline) covered lagoon	4.683	0.137	4.546
Cottonwood covered lagoon	5.819	0.537	5.282
Blakes Landing (~12 mile pipeline) covered lagoon	35.128	0.584	34.544

1 For all plants except IEUA, after-tax O&M is O&M multiplied by a tax factor, reflecting a reduction for the combined tax rate of 40.75%. Since IEUA is tax-free, no factor is applied for it.

2 To produce pipeline-quality gas, all plants were assumed to operate with a plant capacity factor of 90.00%.

Cost of Biogas to Electricity without Grant but with Carbon Credit at $3/ton CO_2eq and PTC

No Subsidy Power COE (nominal levelized 2007$) with carbon credit and PTC

Dairy Name	No Subsidy Power COE – 17% IRR (¢/kWh)	COE for 17% IRR with carbon credit (¢/kWh)	COE for 17% IRR with carbon credit and PTC (¢/kWh)
Hilarides	10.16	8.32	6.80
Eden-Vale[1]	17.63	15.79	14.25
Koetsier[1]	20.40	18.55	17.02
Castelanelli Bros.	22.69	20.28	18.70
Van Ommering[1]	26.14	24.19	n/a[2]
Meadowbrook	27.63	25.43	23.95
IEUA	34.34	32.60	n/a[3]
Cottonwood	35.46	33.73	32.25
Blakes Landing	37.19	35.20	n/a[2]

1 Eden-Vale, Koetsier, and Van Ommering were adjusted to employ an improved 83.45% capacity factor and a heat rate reduced to 13,500 Btu/kWh.

2 Engine must be sized at 150 kW or greater to be eligible for Section 45 PTC.

3 IEUA is tax-exempt and cannot take the Section 45 PTC. It might be eligible for the Renewable Energy Production Incentive payment, but would need to apply

Cost of Biogas to Pipeline Gas without Grant but with Carbon Credit

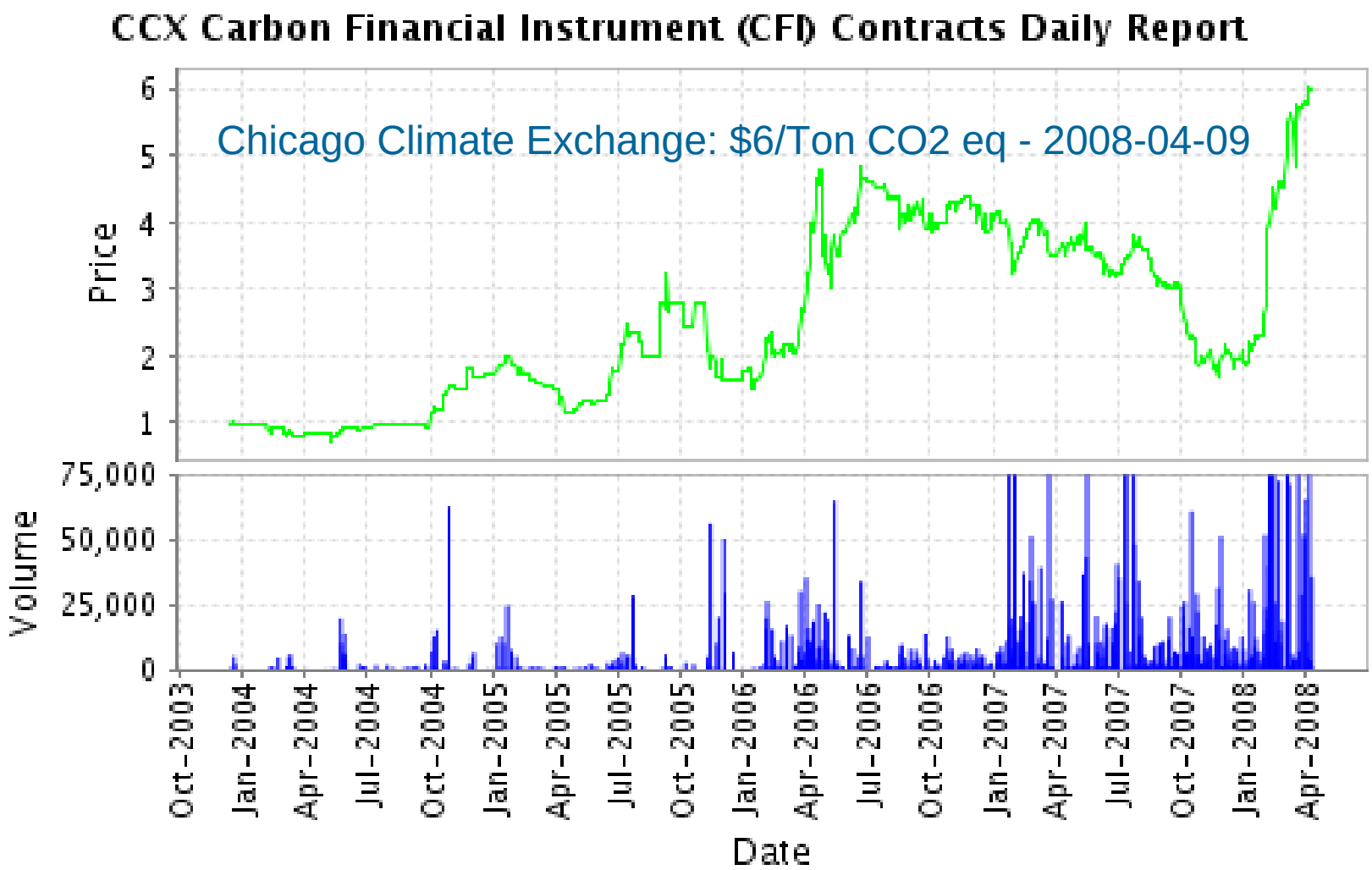
No Subsidy Pipeline-Quality Gas COE (nominal levelized 2007$) with Carbon Credit

Dairy Name	No Subsidy Gas COE, with 17% IRR ($/therm)	COE for 17% IRR with carbon credit ($/therm)
Hilarides	1.245	1.056
Eden-Vale	2.812	2.624
Koetsier	2.923	2.729
Meadowbrook	3.226	3.033
IEUA	4.004	3.806
Van Ommering	4.025	3.827
Castelanelli Bros. (~5 mile pipeline)	4.233	4.029
Cottonwood	4.801	4.608
Blakes Landing (~12 mile pipeline)	34.400	34.239

1 For pipeline-quality gas, all plants operate with a plant capacity factor of 90.00%.

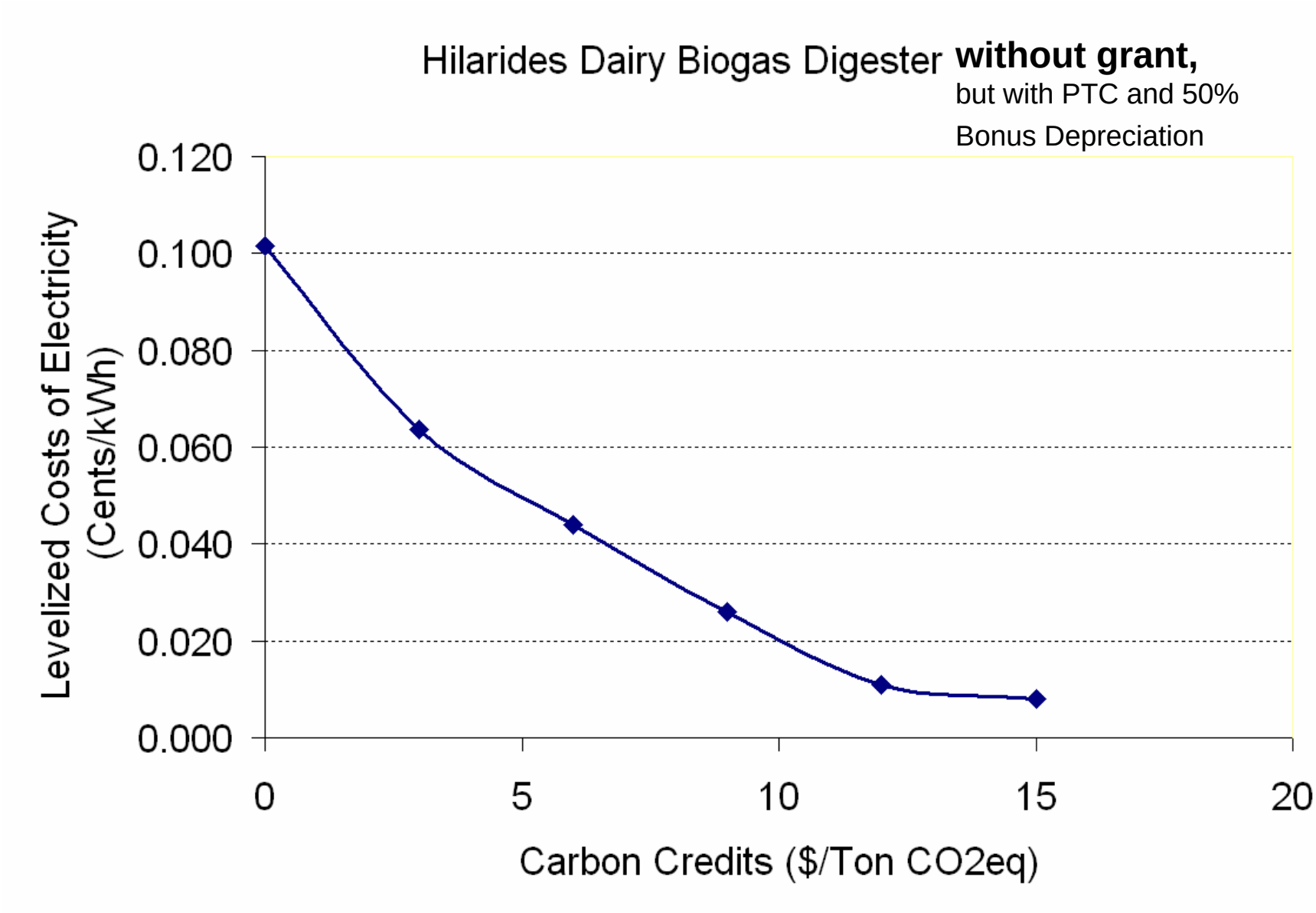
2 Plant must produce electricity to be eligible for Section 45 PTC.

Chicago Climate Exchange for trading carbon dioxide emissions

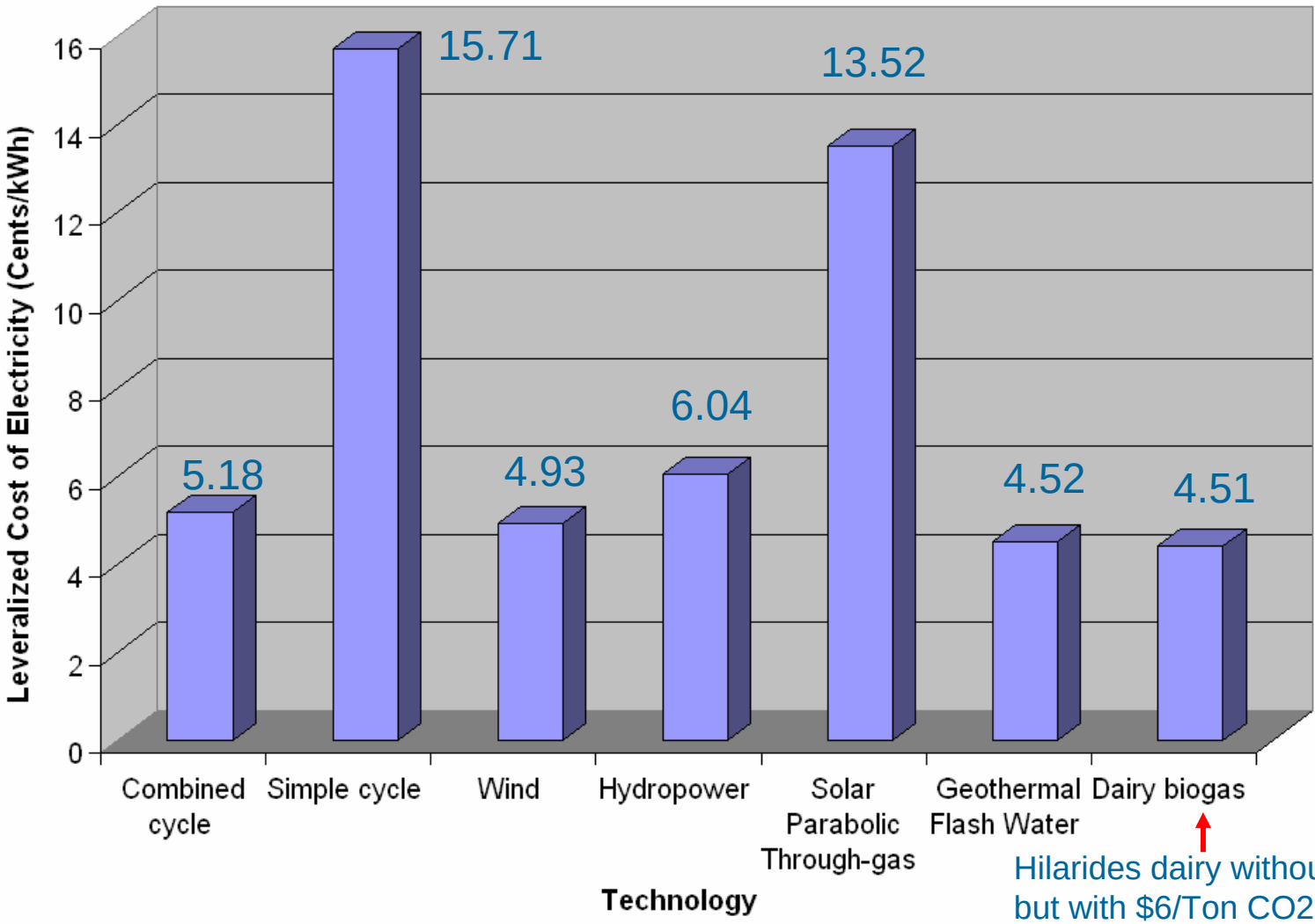


Source: http://www.chicagoclimateexchange.com/market/data/daily.jsf

Cost of Electricity vs Carbon Credit at 17% IRR



Comparison of Levelized Costs of Electricity Production by Technology



Hilarides dairy without grant but with $6/Ton CO2eq carbon credit, PTC, and Bonus Depreciation

Reference: Comparative cost of California central station electricity generation technologies, California Energy Commission, CEC 100-03-001F

Existing Critical Issues

- **Net-Energy Metering**
  - Utility 12 month true-ups (by the end of 12 months, utility keeps the excess power and pays the farmer nothing)
  - Demand payments and standby demand charge
- **Feed-in Tariff with Power Purchase Agreement**
  - Utilities offer flat price that holds for 10-, 15-, or 20-year for plants under 1 or 1.5 MW.
  - For Market Price Referent, for plants starting up in 2008, it is 9.271 cents/kWh for 10-year contract and 9.572 c/kWh for 20-year contract.
  - SCE offers as-delivered capacity for plants under 1 MW, so there is no penalty as with a firm capacity contract if the farmer's plant goes down briefly.
  - PG&E offers time of day rates on top of MPR with their Standard Contract.
  - SDG&E is smaller but welcomes farmers to meet with them to negotiate mutually beneficial contract terms.
- **Production Tax Credit**
  - The section 45 10-yr PTC for dairy waste is 0.01 cents/kWh under the open loop biomass classification. This is half the closed loop price. Credits escalate with inflation.

Existing Critical Issues (cont'd)

- High Capital and O&M Costs
  - Engine cost is high
  - Lack of operating experience and standard design
- Commodity market for co-products (liquid or solid fertilizer)
- Environmental benefit
  - odor reduction
  - pathogen reduction

Research Needed for Potential Biogas System Development in California

- Policies
  - Collaboration among utility, permit, and funding agencies to resolve existing issues on net metering, feed-in tariffs with long term contract, permitting, engine emission and sustainability standards.
- Lower capital cost
  - Standardized digester design
  - Invest in low capital cost systems meeting air and water emission standard
  - Gas cleanup and upgrading
  - Engine emission reduction
  - Alternative power system design
- Efficiency improvement
  - Feed and feedstock optimization
  - Digester optimization
  - Engine design and application
  - Heat utilization
- Peaking power production
  - Utilization of economy of scales by allowing centralized, co- or multi-feedstock biogas systems, which might allow non-recourse project finance with debt.
  - Hybrid systems
- Better performance data

Conclusions

- Some biogas power system proved to be economically feasible without grant
  - Hilarides dairy biogas digester – no subsidy power
    - Capital cost at $2,480/kW
    - O&M at 0.45 cents/kWh
    - Plant capacity factor at 77%
    - Carbon credit at $3/ton CO_2 eq and PTC of 1 cent/kWh
    - Electricity purchase price at 6.8 cents/kWh
    - With 50% Bonus Depreciation, electricity purchase price is 6.4 cents/kWh
- Biogas to pipeline gas system has not proved to be economically feasible without a grant subsidy due to the small biogas volume production (less then 500 Mft^3/day). When the farm is far from a utility pipeline, cost increases significantly.
- Grants are still needed for most systems to encourage future development
  - high capital and O&M costs
    - customized system for each digester
    - a few developers to choose
  - requirement to meet different environmental standards from different funding resources
- Most plants are all equity financed, so there is some room for an aggregator or other developer, but it is likely many farmers will continue to use all equity.
- Costs of energy are increased by 85% in one case and by about 5% to 20% otherwise when environmental enhanced dairy digestion systems are required.
- Research needs to be continued to ensure innovation in biogas system design to reduce capital cost and operating expenses, and to improve efficiency.

Thank you for your time and attention!

With any questions, please contact us at:

Zhiqin Zhang
California Energy Commission
Phone: 916-654-4063
Email: Zzhang@energy.state.ca.us