Factors affecting anaerobic digester adoption in the West

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Introduction

• Recently, climate policy has recognized the role of non-CO_2 greenhouse gases (GHGs), particularly in agriculture.
•In 2009, U.S. Secretary of Agriculture announced an agreement to decrease GHG emissions on farms by 25% prior to 2020 with anaerobic digestion as the primary means to meet this goal (USDA, 2009)
•Dairy and swine farms are the most viable options for anaerobic digesters

• What does this mean for dairy farms?
 *Methane is shorter lived in the atmosphere than CO_2 , but has much higher capacity to trap heat.
 *One unit of methane emitted has a warming impact over 100 years that is 25 times greater than a unit of CO_2 (Shindel et al. 2009).
 *Anaerobic digesters (AD) on dairy farms represents a promising opportunity for cost effective GHG mitigation due to decreased methane emissions.

•Background
 *Dairy farms of all sizes (75 to 24,900 cows) have adopted ADs in 27 U.S. states. In the past 10 years, dairy ADs have increased from 41 to 193 operational (AgStar, 2014).
 *Electricity production provides the greatest benefit of AD adoption.
 *Despite benefits for farmers, AD adoption has not been widespread.
 *Dairies in the West have the greatest potential due to the number of cows and warmer climate for methane production.

• What can be done to increase adoption?
* Subsidy programs at a state and federal level
 → EQIP (Environmental Quality Incentive Program)
 → DSPP (Dairy Power Production Program (available in California)
*Carbon prices that align social and private benefits.

Research Objective

• Evaluate the effectiveness of subsidies for adoption of ADs that reduce GHG emissions on California dairy farms
•Evaluate the divergence between social and private benefits that occurs in the absence of a carbon price.

Methods

• Benefit-Cost framework

Data

• 12 dairies in California that adopted ADs through the use of public subsidy program
 →Dairy1-Dairy8 (Marsh et al. 2009)
 →Dairy9-Dairy12 (Cheremisinoff, Georgey, and Cohen, 2009)
 →Supplemental information AgSTAR EPA (2014)

• Variables : electricity production and consumption, price paid and received for electricity, AD cost, operating costs, and total subsidies received. Farm level characteristics include herd size, AD capacity, and type of digester system.

•Assumptions—financed the farmer cost with a 20 year loan at 7%, discount rate at 9%

Table 1: Private Costs and Benefits of AD Adoption

Dairy	System Type	In Operation (Jan 2014)	Capacity (kW)	Cows Feeding Digester*	Total Digester Cost** ($)	Monthly Operating Costs ($)	Digester cost per kW capacity ($/kW)	Digester cost per cow ($/cow)	Electricity Demand (kWh)	Electricity Production (kWh)
Dairy1	lagoon	Yes	75	365	334,680	329	4,462	917	244,500	252,792
Dairy2	lagoon	Yes	160	3,234	882,136	950	5,513	273	867,756	1,054,560
Dairy3	lagoon	Yes	300	5,616	2,498,038	6,200	8,327	445	10,898,400	2,133,084
Dairy4	lagoon	Yes	500	6,000	1,239,923	1,750	2,480	207	1,600,860	3,370,464
Dairy5	plug flow	No	180	1,100	802,810	1,500	4,460	730	279,768	453,168
Dairy6	plug flow	No	260	2,285	1,361,087	2,250	5,235	596	663,180	539,892
Dairy7	plug flow	Yes	160	2,566	720,605	560	4,504	281	867,000	1,098,636
Dairy8	plug flow	No	130	651	836,838	1,500	6,437	1,285	387,120	486,348
Dairy9	lagoon	Yes	80	360	625,000	1,102	7,813	1,736	698,615	430,072
Dairy10	plug flow	Yes	710	1,500	4,020,000	11,567	5,662	2,680	419,795	3,442,838
Dairy11	lagoon	Yes	212	1,050	1,700,000	3,333	8,019	1,619	293,856	618,766
Dairy12	lagoon	Yes	65	850	754,870	649	11,613	888	237,884	228,573

* Cows included lactating, dry, heifers, and bulls
**Total digester cost not including subsidies or other grant funding.

Table 3: External Benefits of AD Adoption

	(1)	(2)	(3)	(4)	(5)
	Methane Reduction (mt CO_2e/yr)	Displaced CO2 Emissions (mt/yr)	GHG Reduction per Farm (mt CO_2e/yr)	Annual Value of GHG Reduction* ($/yr)	Avg. GHG benefit per cow ($/cow/yr)*
Dairy1	1,385	140	1,525	54,895	150
Dairy2	12,271	584	12,855	462,777	143
Dairy3	21,310	1,180	22,490	809,647	144
Dairy4	22,767	1,865	24,632	886,753	148
Dairy5	6,048	251	6,299	226,749	206
Dairy6	12,563	299	12,862	463,022	203
Dairy7	14,108	608	14,716	529,771	206
Dairy8	3,579	269	3,848	138,540	213
Dairy9	1,366	238	1,604	57,744	160
Dairy10	8,247	1,905	10,152	365,480	244
Dairy11	3,984	342	4,327	155,758	148
Dairy12	3,225	126	3,352	120,665	142

*Valued at $36 per MT of CO2e

Table 4: Optimality of AD Adoption

	(1)	(2)	(3)	(4)	(5)	(6) = (4)+(5)	(7)	(8)	(9)	(10)
	System Type	PV Private Costs (excluding subsidies)*	PV Private Costs (with Subsidy)	PV Private Benefits	PV External Benefits	PV Total Benefits	Adopt (if (4)>(2))	Optimal** Mitigation (if (6)>(2))***	Adopt with Subsidy (if (4)>(3))	Operating (1=yes, 0=no)
Dairy1	lagoon	324,423	190,639	346,313	501,116	847,429	yes	yes	yes	1
Dairy2	lagoon	864,176	392,501	844,303	4,224,480	5,068,783	no	yes	yes	1
Dairy3	lagoon	2,831,649	2,107,846	7,441,593	7,390,900	14,832,494	yes	yes	yes	1
Dairy4	lagoon	1,260,104	829,269	1,868,712	8,094,763	9,963,475	yes	yes	yes	1
Dairy5	plug flow	856,071	597,570	226,258	2,069,889	2,296,147	no	yes	no	0
Dairy6	plug flow	1,419,279	1,254,764	363,232	4,226,715	4,589,948	no	yes	no	0
Dairy7	plug flow	682,268	283,789	559,447	4,836,037	5,395,484	no	yes	yes	1
Dairy8	plug flow	885,392	545,341	221,982	1,264,671	1,486,653	no	yes	no	0
Dairy9	lagoon	659,223	304,215	314,293	527,121	841,413	no	yes	yes	1
Dairy10	plug flow	4,730,956	2,764,625	3,711,089	3,336,300	7,047,389	no	yes	yes	1
Dairy11	lagoon	1,829,954	795,950	435,544	1,421,845	1,857,389	no	yes	no	1
Dairy12	lagoon	721,487	273,026	237,718	1,101,492	1,339,210	no	yes	no	1

*Equal to PV of Social Costs
**Assuming AD operates for 20 years
***With a carbon price of $36 per MT of CO2e

Summary Statistics

• Average cost of lagoon is $1.1 million while plug-flow is $1.5 millions
• Lagoon produces 573 kWh/cow while the plug-flow produces 824 kWh/cow, on average
•Average digester cost per cow and kW of capacity varies greatly → larger dairies tend to have higher capacities, but not necessarily lower costs.
• On average, subsidies covered ~50% of the initial investment

Results

•In all 12 cases, the social benefit of AD adoption exceeded its cost
• Only 3 ADs were privately optimal without subsidies
• 5 ADs were not privately optimal even with a subsidy
 → 3 of these ADs have shut down (built in 2004)
 → other 2 still operational (built in 2008)
• May need higher upfront subsidies to make the AD profitable on an annual basis. This decreases annual financing costs and could make the investment socially optimal.
•Assuming ADs are financed has a qualitative impact on the present value of AD costs.

Lagoons vs. Plug-flow

•Electricity production is lower for lagoon digesters than plug-flow digesters. However, the larger upfront costs for plug-flow digesters make them less economically feasible.
•3 of the 7 dairies with lagoon systems were privately optimal without subsidies.
•3 of the 5 plug-flow digesters should not have been adopted even with subsidies. In all 3 of these cases, the ADs have shut down.

Sensitivity to carbon prices

•A carbon price of $12/MT of CO_2e, less than 2/3 of ADs are socially optimal investments
•At $24/ MT of CO_2e, 90% are efficient investments
•Carbon price that reflects the social cost of carbon ($30-40/ton) aligns social and private incentives.

Conclusions

• ADs on dairy farms in semi-arid areas can efficiently reduce emissions on GHGs on farms
•Results show a notable difference between lagoons and plug-flow digesters.
•Loan financed ADs can be a socially optimal option to manage GHGs
•Important to balance the need for a subsidy with the possibility of over-subsidizing

Further Considerations

• Collect farm-level data via survey methods to have a larger data source to perform statistical and regression analysis.