Biogas Resources Characterization

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Project ID: AN005

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Overview

Timeline

- Project start: August 2009
- Project finish: September 2010
- Percent complete: ~ 80%

Barriers

- Stove-piped/Siloed Analytical Capability (4.5.B)
- Inconsistent Data, Assumptions and Guidelines (4.5.C)
- Suite of Models and Tools (4.5.D)

Budget

- Total project funding: $326K (100% DOE-funded)
- Funding in FY2009: $326K
- Funding in FY2010: None

Partners

- None

Relevance

Objectives

- Develop a cost-analysis tool for bio-methane production from biogas based on the H2A Production model.
- Gather GIS data on biogas resources in California and cost data on biogas purification systems.
- Perform techno-economic analyses for various scenarios involving production and utilization of bio-methane.

Drivers / Benefits

- Fuel cells operating on bio-methane or on hydrogen derived from bio-methane can mitigate energy and environmental issues and provide an opportunity for their commercialization.
- The availability of incentives and requirements for renewables such as:
  - California RPS requirements: 20% by 2010 and 33% by 2020
  - SB1505 renewable content requirement: 33% by 2020 (under review).
  - SGIP (self-generation incentive program.)
- The project can provide valuable insights and information to the stakeholders—utilities, municipalities, and policy makers (at a macro-level) and producers of biogas (at a micro-level).

Approach

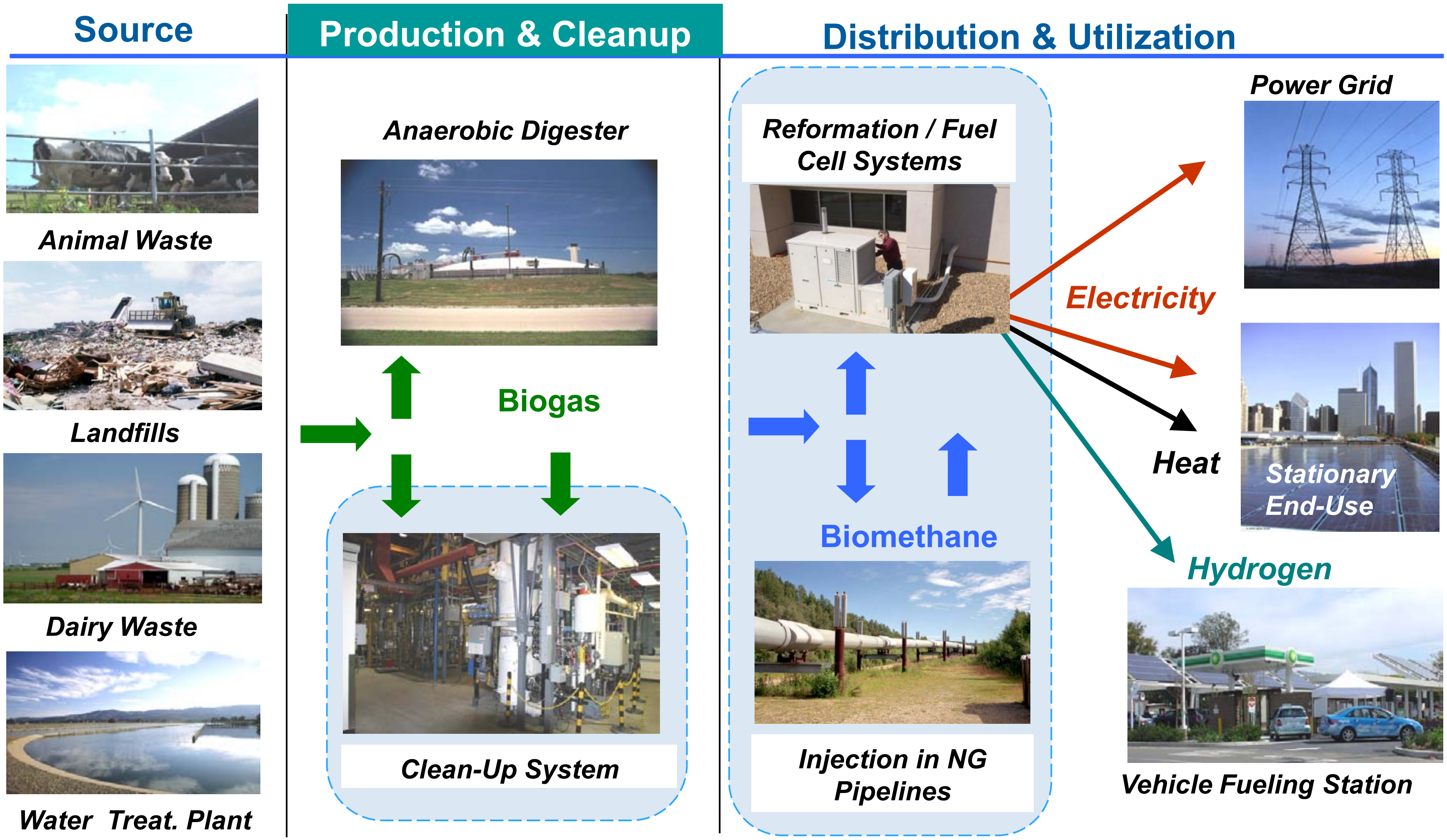
- Develop a cost-analysis tool based on the H2A Production model that is transparent and vetted. The model focuses on biogas upgrading process with optional post compression.

- Collect, qualify, and analyze GIS and cost data:
  - Selected sources of biogas—landfills, dairy farms, and sewage treatment plants.
  - GIS data—biogas potential in California, energy consumption, distances of biogas sites from the load centers and utility grids.
  - Cost data—purification systems, pipeline extension, and fuel cells.

- Perform techno-economic analyses focusing on:
  - Bio-methane production via biogas purification / upgrading.
  - Bio-methane utilization via on-site fuel cell technologies and/or injection into natural gas pipeline for expanded market.

- Evaluate impact of federal and state incentives on the cost of bio-methane.

Approach: Project Concept



Shaded areas represent the boundaries of the current project.

Approach: Milestones

Milestone	Title	Date	Status
2.11.1	Provide update on the collection of GIS, cost and technical biogas data and information.	2/26/2010	Complete
2.11.2	Complete Upstream H2A biogas model.	May 2010	Complete
2.11.3	Hold Stakeholder workshop on biogas systems.	Sept 2010	In Progress

Progress: Cost Analysis Model (H2A)

New feature: Input data tab characterizing biogas purification system.

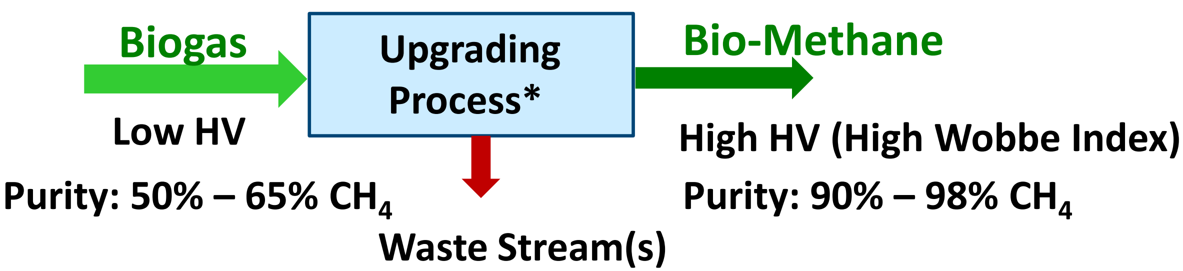
Input Biogas Composition		Notes	Output Biomethane Requirement		
Rate (Nm3/h)	1400		Rate (Nm3/hr)	857	634 kg/hr
Methane (CH4) (%)	60%	by volume	CH4 Recovery Factor	99%	
CO2 (%)	38%	by volume	Methane (CH4) (%)	97%	595 kg/hr
Nitrogen (%)	2%	by volume	CO2 (%)	1%	17 kg/hr
H2S (ppm)	600-800		Nitrogen (%)	2%	21 kg/hr
Siloxane (mg/m3)	60-80		H2S (ppm)	<4	
			Siloxane (ppb)	<30	
Biogas Density	1.201 kg/Nm3		Biomethane Density	0.739 kg/Nm3	

Energy Content		
Methane (CH4) LHV	0.052	GJ/kg methane
LHV Biogas	0.0223	GJ/Nm3 biogas
LHV Biomethane	0.0361	GJ/Nm3 biomethane

Electricity Consumption	0.230

Energy Usage		Units
Total Electricity Usage	**0.508**	kWh/kg biomethane
Compression	0	kWh/kg biomethane
Process	0.508	kWh/kg biomethane
Biogas Usage	**2.209**	Nm3 biogas/kg biomethane

- Can facilitate quantification of capital cost as a function of purification requirements.
- Allows use of scaling factor.



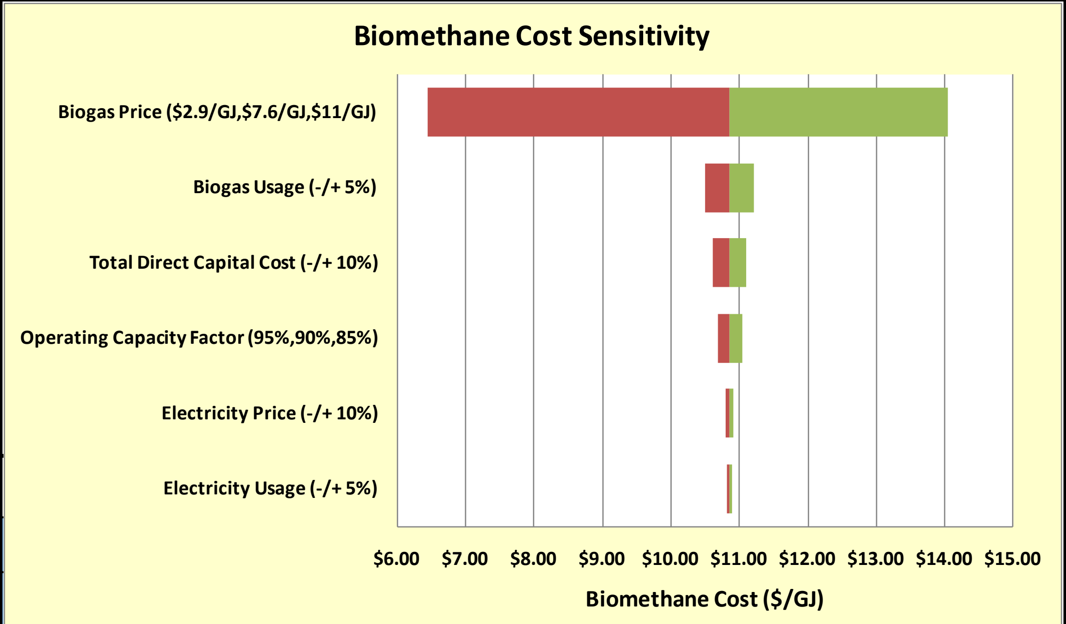
Schematic of biogas upgrading process

Upgrading Techniques
Pressure swing adsorption
High-pressure water scrubbing
Cryogenic separation
Chemical absorption
Membrane separation

Progress: Sample Results of Model

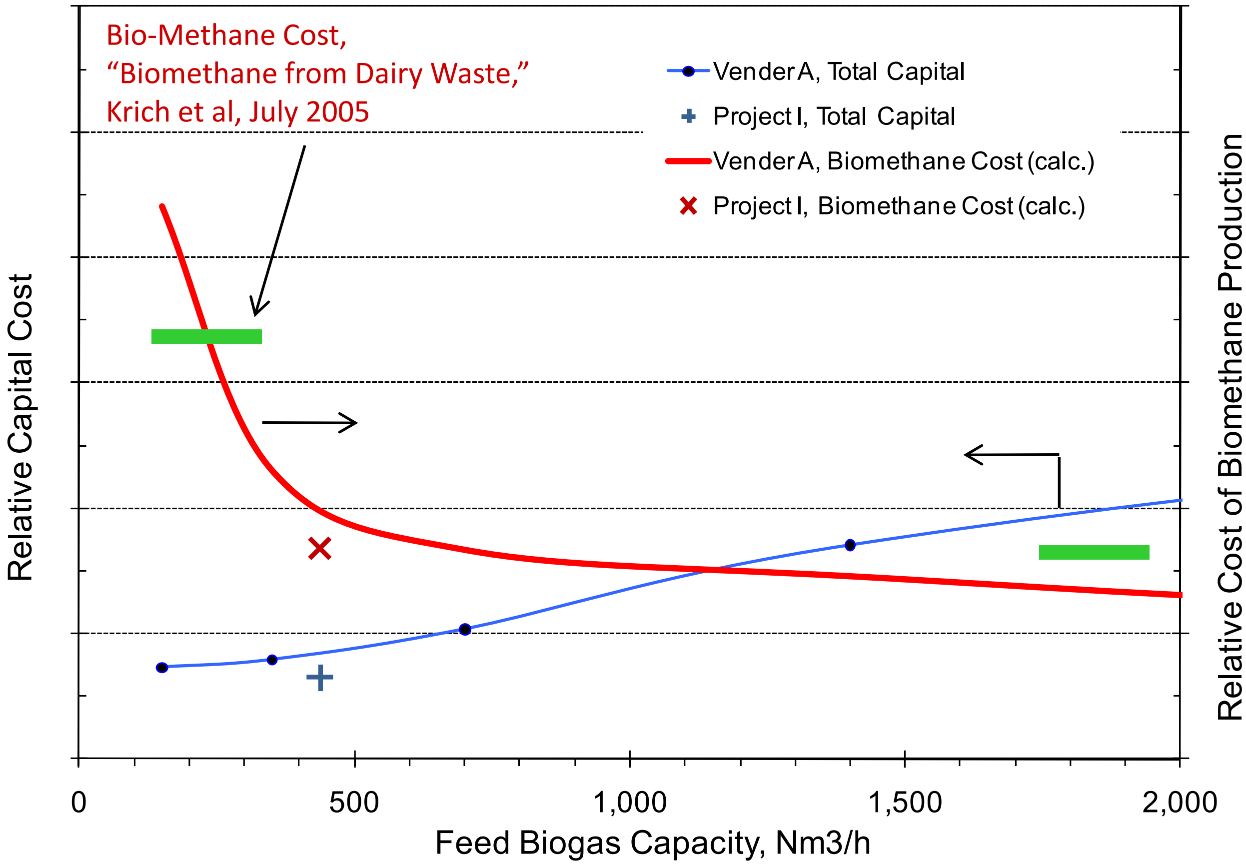
Key Results	
Costs	Cost components and relative values
	Total unit cost of bio-methane
Energy	Process energy usage
	Upstream energy usage
	Process energy efficiency
Emissions	Process emissions
	Upstream emissions
Sensitivity	Tornado chart depicting sensitivity of bio-methane cost to key variables.

Specific Item Cost Calculation		**$0.53/kg**	**$10.86/GJ**
Cost Component	**Biomethane Production Cost Contribution ($/kg)**	**Percentage of Cost**	**Biomethane Production Cost Contribution ($/GJ)**
Capital Costs	$0.11	21.22%	$2.30
Decommissioning Costs	$0.00	0.24%	$0.03
Fixed O&M	$0.05	9.13%	$0.99
Feedstock Costs	$0.34	64.03%	$6.95
Other Raw Material Costs	$0.00	0.00%	$0.00
Byproduct Credits	$0.00	0.00%	$0.00
Other Variable Costs (including utilities)	$0.03	5.37%	$0.58
Total	**$0.53**		$10.86



Emissions Summary	**CO2**	**CH4**	**N2O**	**Total GHG (CO2 eq)**
Total upstream emissions (kg/kg biomethane)	-1.96	2.27E-03	2.47E-05	-1.898
Total process emissions (kg/kg biomethane)	1.62	0.01	0.00	1.84

Progress: Qualification of Cost Data



Note: Project "I" represents an actual installation in California.

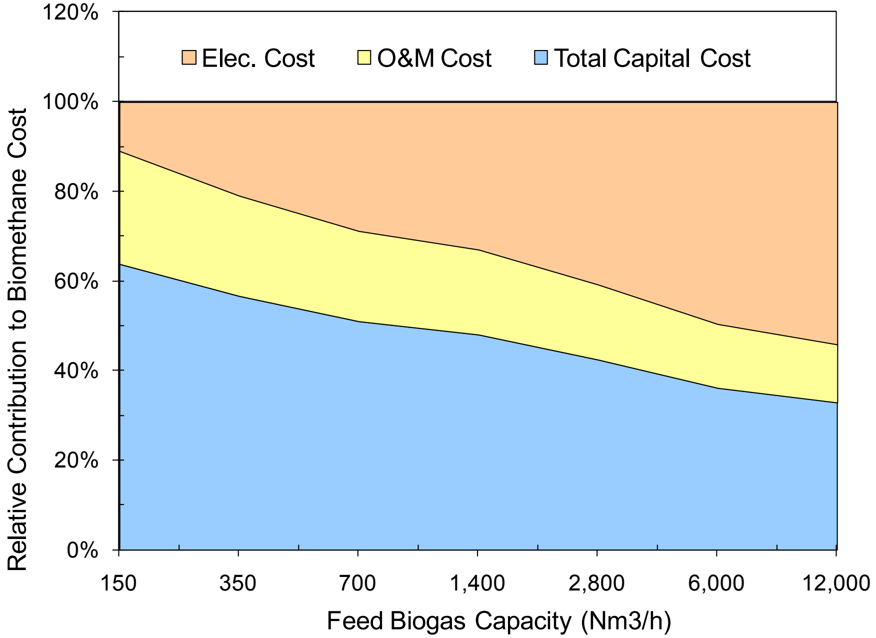
Assumptions:

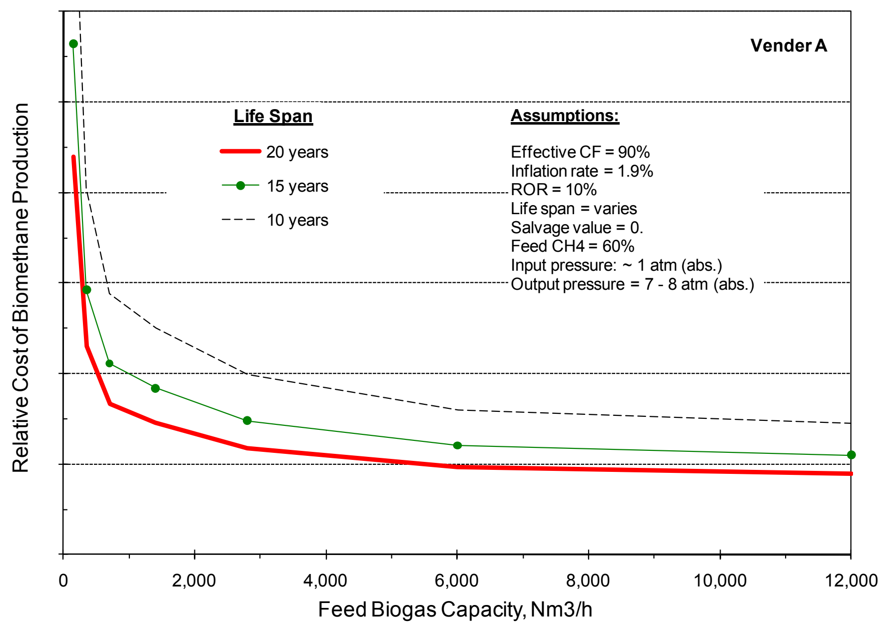
Effective CF = 90%
Inflation rate = 1.9%
ROR = 10%
Life span = 20 yrs. Salvage value = 0.

Feed CH4 = 50% - 60%
Input pressure= 1 bar (abs.)
Output pressure = ~ 7 - 8 bar

The differences are in part due to the uncertainty in the estimated biogas capacity and in underlying assumptions of other sources of data.

Progress: Preliminary / Exploratory Analysis





- Energy efficiency takes on greater importance at larger capacities.
- Clustering sources of biogas may be imperative to achieving economy of scale.
- Impact of system life on product cost diminishes at higher biogas capacities.
- Significant uncertainty in life span is reflected in the literature and vendors' data.

Exploratory / "what-if" analyses can be instrumental in strategic planning for the next steps in the analysis and provide valuable insights to stakeholders.

Progress: Preliminary Cost Estimates

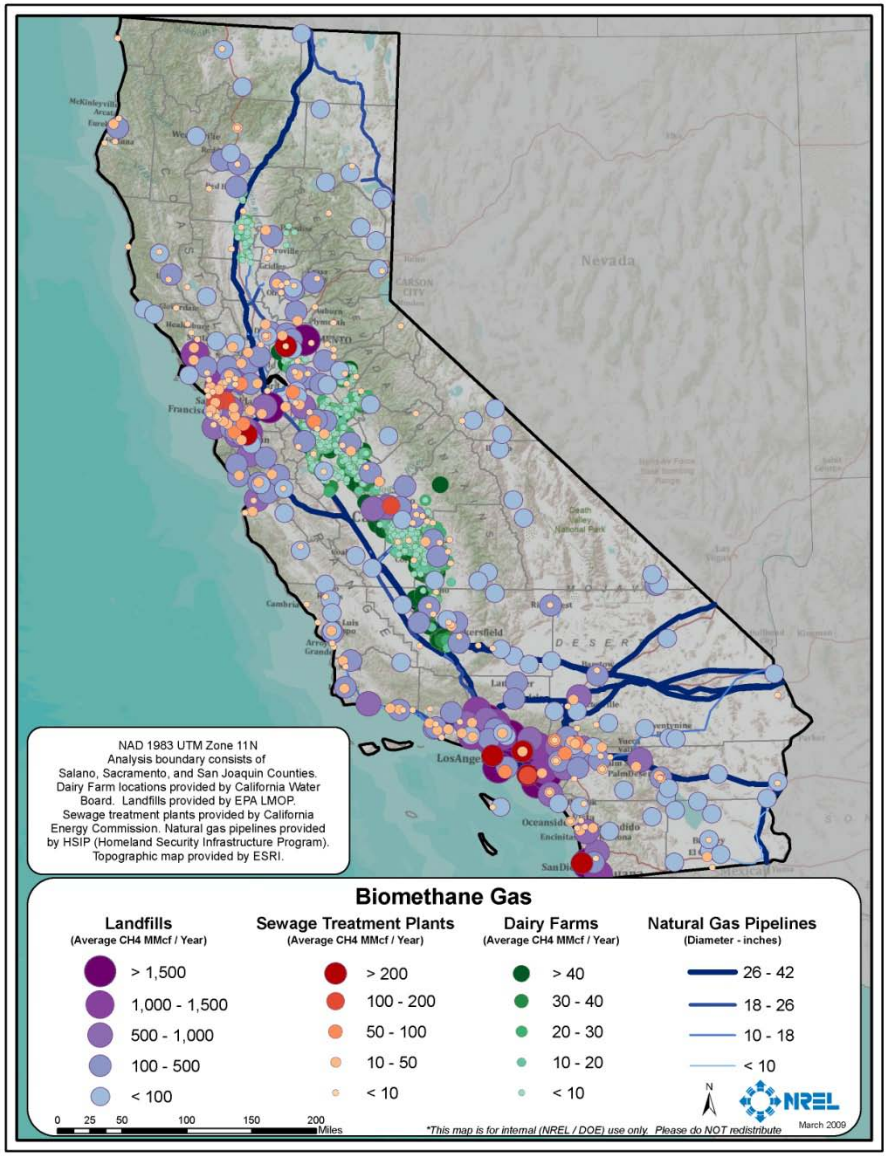
Upgrading biogas from dairy-farm anaerobic digesters.

Select AD Type	*Reported elec. gen. costs*, $ / GJ of elec.*	Estimated biogas*, cost, $/GJ	Approx. Biometh. Cost = AD + Upgrad. Cost, $/GJ	**Remarks / Assumptions** The reported values are compilation of data from number of AD case studies with a wide range of biogas output capacities.
Covered AD—Dairy	*$12.59*	$2.9	$4.4	Estimates are in 2010 USD. The reported cost data were adjusted for inflation.
Plug-flow—Dairy	*$34.82*	$7.6	$9.1	Upgrading cost of ~$1.5 per GJ of bio-methane was used for relatively large biogas capacities.
Mixed—Dairy	*$52.39*	$11.0	$12.5	Estimates for total cost of bio-methane neglect cost of AD/upgrading system integration and other indirect costs.

* Source: "An Analysis of Energy Production Costs from Anaerobic Digestion Systems on U.S. Livestock Production Facilities," Technical Note No. 1, Natural Resources Conservation Service, USDA, October 2007.

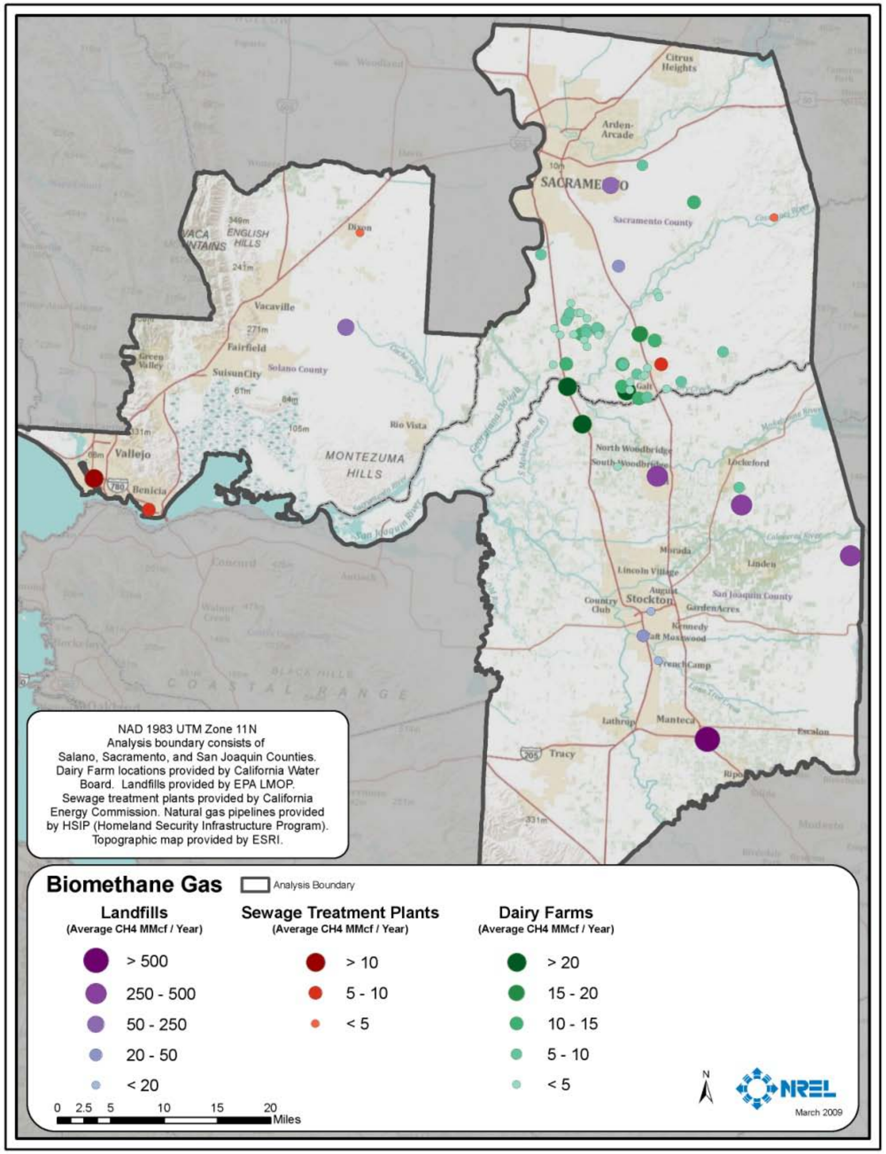
Price of natural gas (residential) is approx. $9.5/GJ for CA and $11.7 for U.S. based on EIA data: http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA

Progress: GIS Map for California



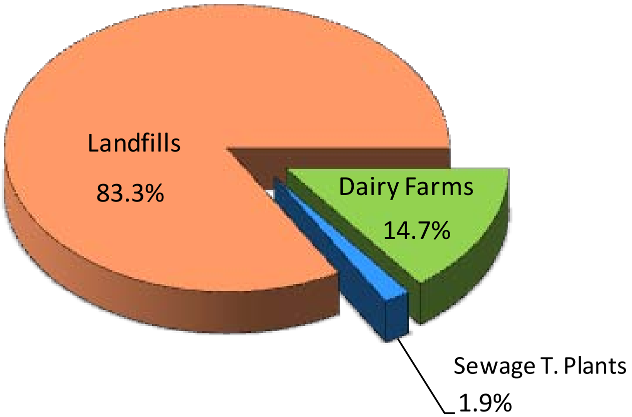
- Select categories of biogas resources: Landfills, sewage treatment plants, and dairy farms.
- Landfills offer greater biogas potential.
- Transmission lines are reasonably accessible to most of biogas sources in select categories.
- Majority of GIS data are for the central valley due to systematic tracking.
- GIS data for a number of counties, including Sacramento, San Joaquin, and Solano, have been verified. Data validation continues.
- Data may be unavailable for a number of dairy farms in California.

Progress: GIS Map for Select Counties

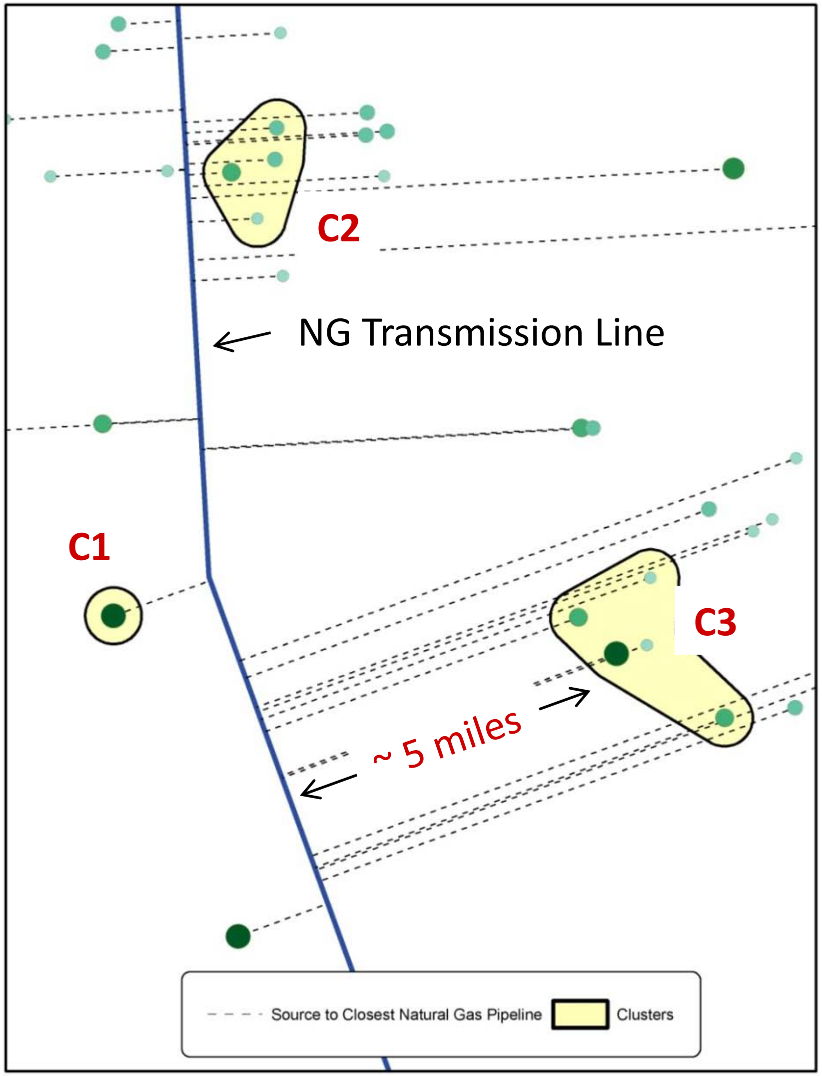


- Validated data for three counties: Sacramento, San Joaquin, and Solano.
- Select biogas resources: landfills, dairy farms, and sewage treatment plants.
- Aggregate potential of three biogas resources: Less than 3% of the NG consumption (~160 x 10^6 GJ/yr).

Of the select resources, landfills have the dominant share of the biogas potential in these counties.

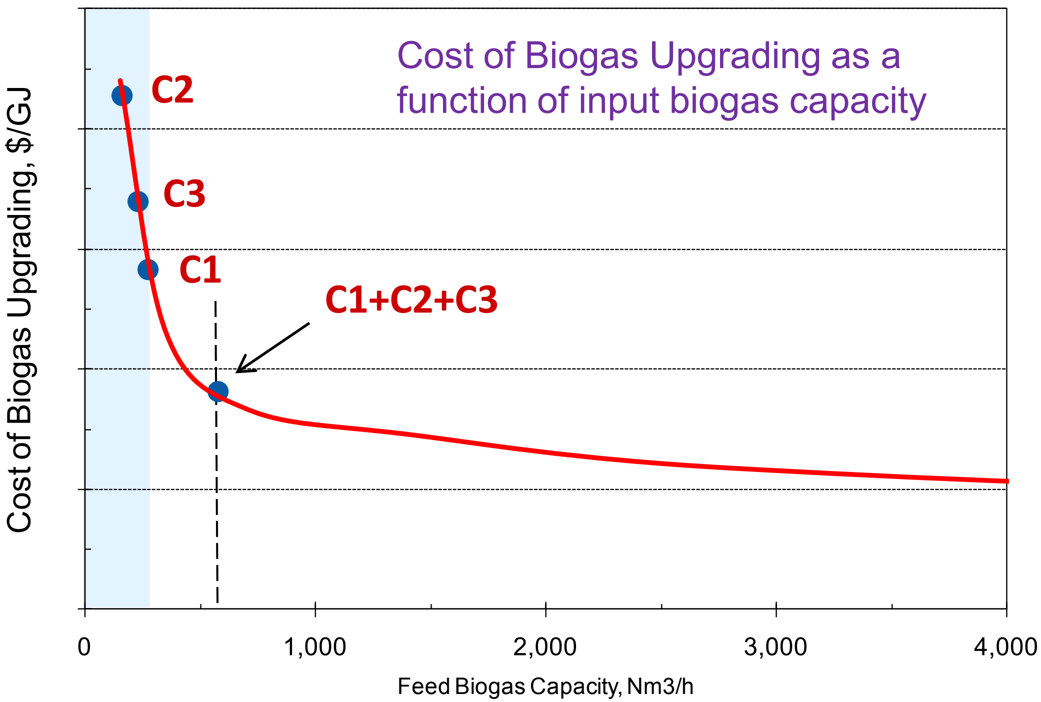


Progress: A Scenario Analysis / Clustering Dairy Farms



- Bio-methane potentials:
  C1: 2,020,000 Nm³/yr (~ 80,200 GJ/yr.)
  C2: 1,316,000 Nm³/yr (~ 52,200 GJ/yr.)
  C3: 1,860,000 Nm³/yr (~ 73,800 GJ/yr.)

- Achieving economy of scale for biogas upgrading can be challenging for dairy farms.



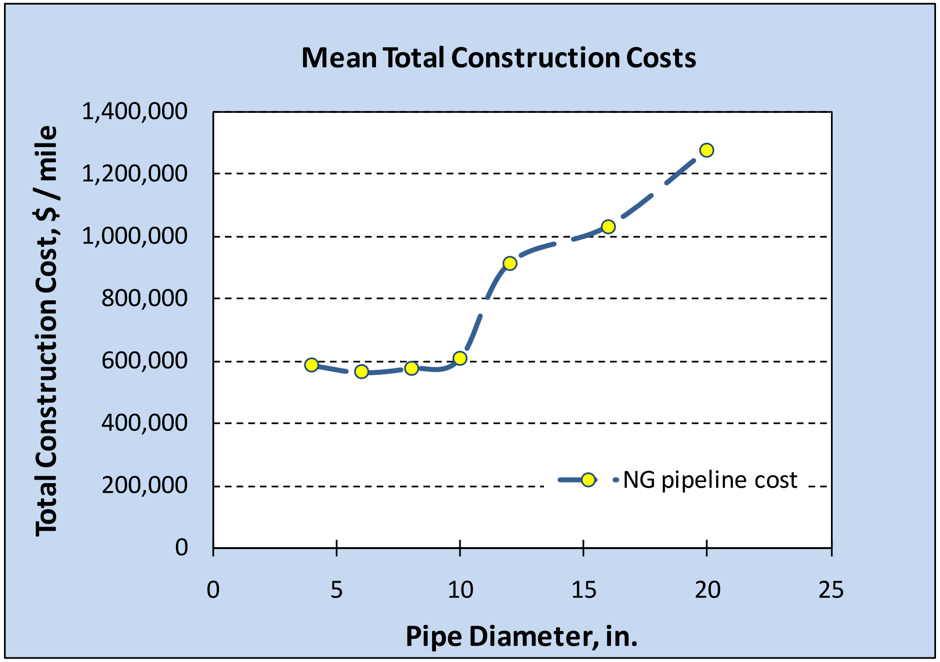
Progress: A Scenario Analysis / Bio-Methane Export to NG Grid

Upgrading / Purification System Cost Evaluation

- A bio-methane production facility—anaerobic digester coupled with an upgrading process.
- Biogas capacity= 2,000 Nm^3/h (17.5 x 10^6 Nm^3 /year).
- Overall capacity factor= 85%.
- Length of pipeline from production site to nearest NG transmission line = 10 miles.
- H2A assumptions: Rate of return = 10% ; Inflation rate = 1.9%; Life span = 20yrs.
- Bio-methane pressure at the output of purification system= ~ 8 bar (abs.)
- NG transmission line pressure= ~ 40 bar.

Pipeline Cost

- Pipeline costs are based on data reported in "*Using Natural Gas Transmission Pipeline Costs to Estimate Hydrogen Pipeline Costs" (UCD-ITS-RR-04-35).*
- Large scatters were reported for labor and right of way costs.



Progress: Bio-Methane Export to NG Grid (cont.)

Cost Items	Cost	Relative Capital Cost	Bio-methane Cost, $/GJ
Biogas Feedstock	3 – 11 $/GJ of CH4	-------	5.0
Upgrading System	$4.0 M	40%	3.5
Pipeline—10 miles	$5.8 M	58%	-------
Compression	$0.2 M	2%	-------
Pipeline + Compression	-------	-------	4.6
Balance of Plant	-------	-------	N/A
Total:	-------	-------	**~ 13 $/GJ**

Notes:

1) The new cost-analysis model (H2A) was used in the scenario analysis.
2) Storage for 2-day worth bio-methane production will increase the cost by about $2/GJ—based on estimates from "*Bio-methane from Dairy Waste*," Krich et al, July 2005.

- Cost of biogas can play a critical role in the economics of bio-methane.
- If permissible, injection of bio-methane into a distribution pipeline can reduce the transport cost (due to likely shorter pipeline and lower pressure).
- Incentives and policies, such as SGIP, RPS and SB1505 can render renewable biogas economically more attractive.

Collaboration

- As a strategy to acquire realistic data and to generate results that are beneficial to the stakeholders, efforts in communicating with equipment vendors, manufacturers, and municipalities are ongoing.

- Held a panel discussion, "*Renewable Biogas: A Commercialization Opportunity for Fuel Cells*," at the 2009 Fuel Cell Seminar and Exposition. The event aimed to get feedbacks from the stakeholders on the objectives and facets of this project and to facilitate data collection for the analysis.

- A workshop for dissemination of the results and feedbacks from the industry and stakeholders may also be arranged prior to the conclusion of the current project.

Summary / Conclusions

- This project intends to develop a vetted cost-analysis tool based on the H2A Production model, collect GIS / cost data, and perform techno-economic analyses of upgrading biogas and utilizing the resulting bio-methane.

- To facilitate realistic analyses and improve the usefulness of the results, inputs from industry and stakeholders are sought. The objectives and approach of this project lend themselves to overcoming the identified barriers (4.5.B, 4.5.C, and 4.5.D).

- The preliminary analysis indicates that, by taking advantage of economy of scale, bio-methane production via purification of biogas from dairy farms can be cost-effective .

- Focusing on large dairy farms and/or clustered farms to facilitate use of a central AD/upgrading system is a key for realizing economy of scale, albeit it can be challenging.

- Landfills can offer a greater potential due to the potentially lower cost of biogas, favorable economy of scale, and significance in emissions control. However, constant supply of biogas from landfills may not be sustainable.

- The economics of producing and exporting bio-methane to natural gas grid is subject to variations in the costs of biogas and transport of bio-methane.

Future Work

Planned Work:

- Continue collection and validation of GIS and cost data.
- Perform additional techno-economic analyses to encompass on-site utilization of bio-methane in conjunction with fuel cell technologies.

Recommended Work:

- Purging / sequestration of the waste stream(s) with high concentrations of impurities should also be addressed from the economic and environmental standpoints.
- An in-depth evaluation of the correlation between the cost of the biogas upgrading system and the purification requirements is recommended. The currently available cost data do not readily lend themselves to formulating such relationship.