A Technoeconomic Analysis of Biomethane Production from Biogas and Pipeline Delivery

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Objectives

- Develop a cost-analysis model, H2A Biomethane, focusing on biogas upgrading process and pipeline delivery with post compression.
- Collect, qualify, and analyze data:
  - GIS data for California—geo-spatial biogas potential from landfills, dairy farms, and sewage treatment plants; distances of biogas sites from the natural gas pipelines and load centers; and energy consumption.
  - Cost data—biogas purification/upgrading systems and pipeline transport of biomethane.
- Perform techno-economic analyses focusing on:
  - Biomethane production from biogas.
  - Export of the product gas to the natural gas grid.
  - Cost structure of biomethane production and pipeline delivery.

The project objectives have been achieved.

Drivers and Benefits

- Fuel cells operating on biomethane or on hydrogen derived from biomethane can mitigate energy and environmental issues and provide an opportunity for their commercialization.

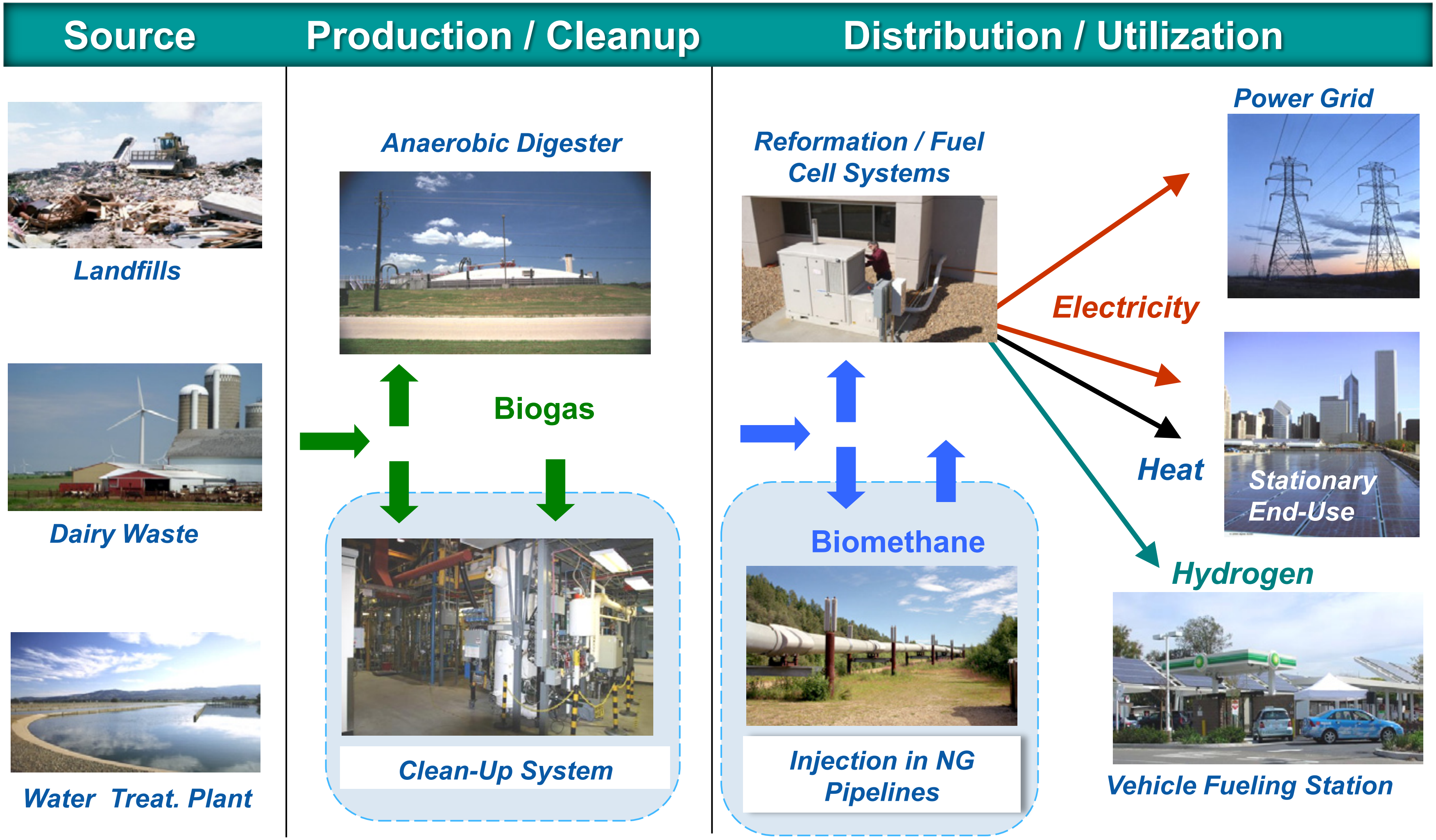
- The availability of incentives and requirements for renewables such as:
  - California RPS requirements: 20% by 2010 and 33% by 2020
  - SB1505 renewable content requirement for hydrogen production.
  - Self-generation incentive program (SGIP)

- The project can provide valuable insights and information to the stakeholders—utilities, municipalities, and policy makers (macro-level) and producers of biogas (micro-level).

Approach

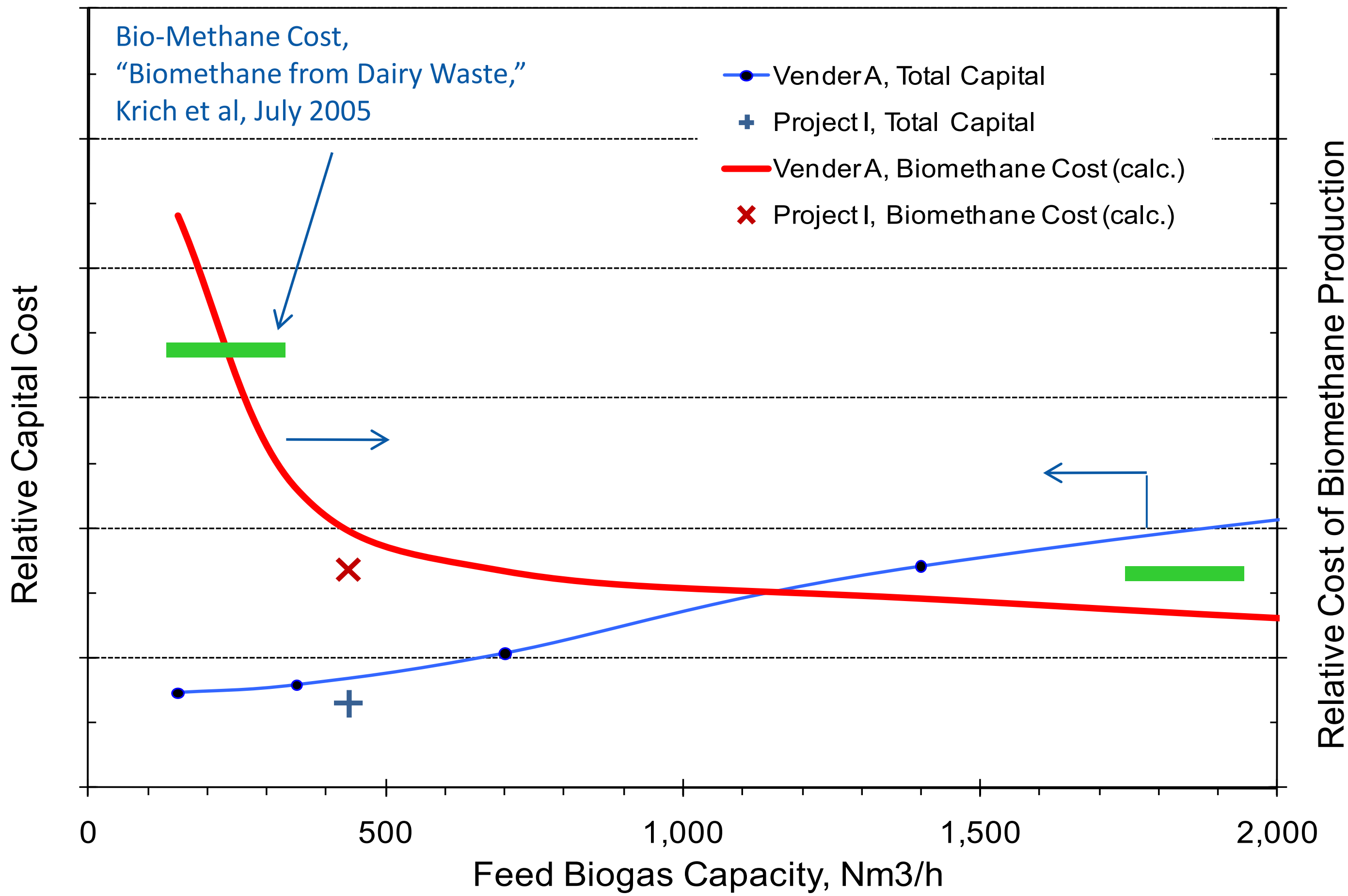
- Developed the new analysis tool based on the vetted H2A Production and H2A Delivery models.
- Interacted with the industry and experts for input:
  - Held an introductory panel discussion with the stakeholders in November 2009 to facilitate information/data gathering.
  - Obtained cost data on biogas upgrading system from vendors and publications.
  - Completed the first round of the external review process for the H2A Biomethane via a webinar in August 2010.
- Applied the H2A Biomethane Model to scenario analyses for dairy farms.

Approach: Project Concept



Shaded areas represent the boundaries of the current project.

Approach: Qualification of Cost Data



The differences are reflective of the uncertainties in the estimates.

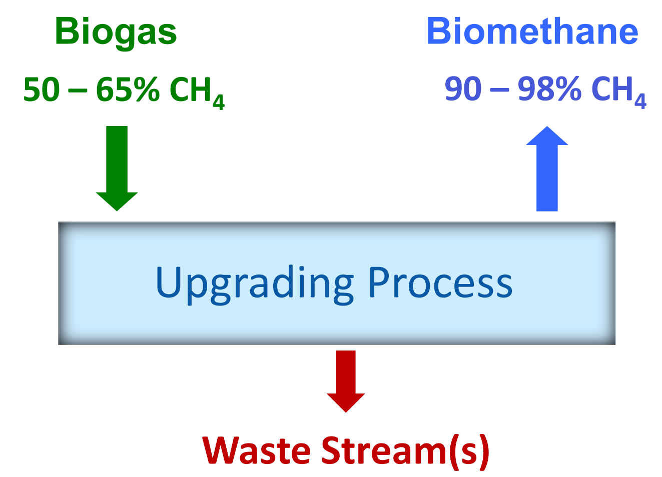
Model: Key Input Data / Assumptions

System Characterization

- Feed biogas chemical composition.
- Product Biomethane chemical composition.
- Process electricity usage: kW/ Nm^3 biogas.
- Reference capital cost and scaling factor.
- Operating capacity factor and life span.

Economic Assumptions

- Internal rate of return, inflation rate, and tax rates.
- Analysis period, depreciation type, etc.

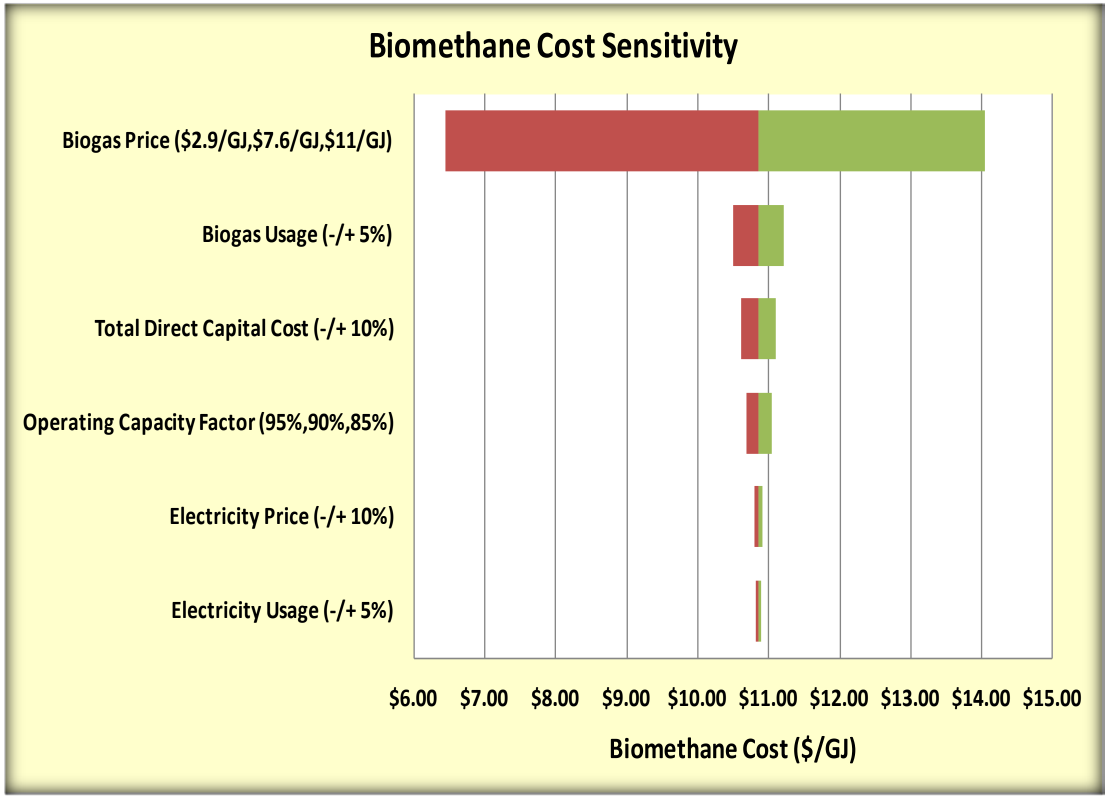


Upgrading Techniques
Pressure swing adsorption
High-pressure water scrubbing
Cryogenic separation
Chemical absorption
Membrane separation

Default values are provided for upgrading biogas from dairy farms.

Model: Output Metrics

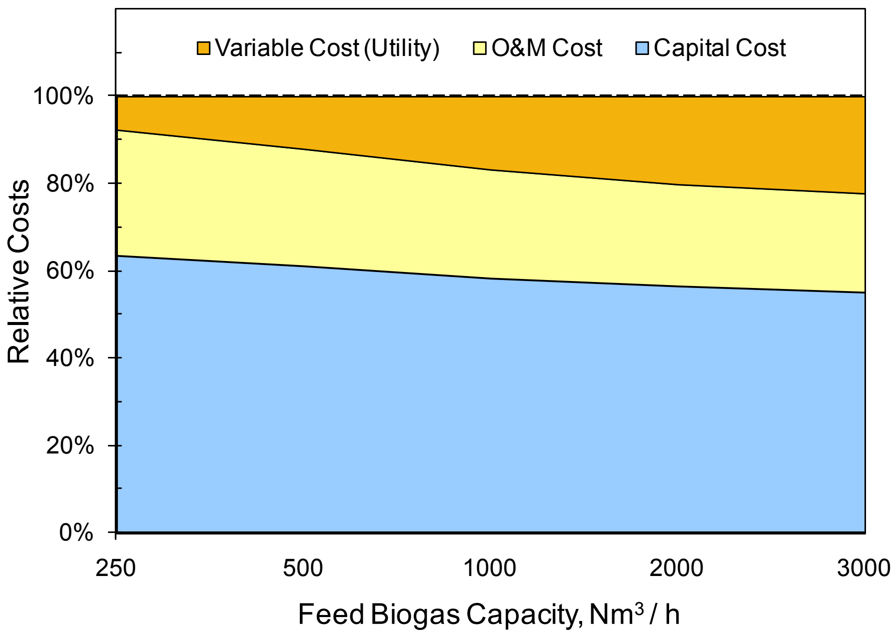
Key Results	
Costs	Cost components and relative values
	Total unit cost of bio-methane
Energy	Process energy usage
	Upstream energy usage
	Process energy efficiency
Emissions	Process emissions
	Upstream emissions
Sensitivity	Tornado chart depicting sensitivity of bio-methane cost to key variables.

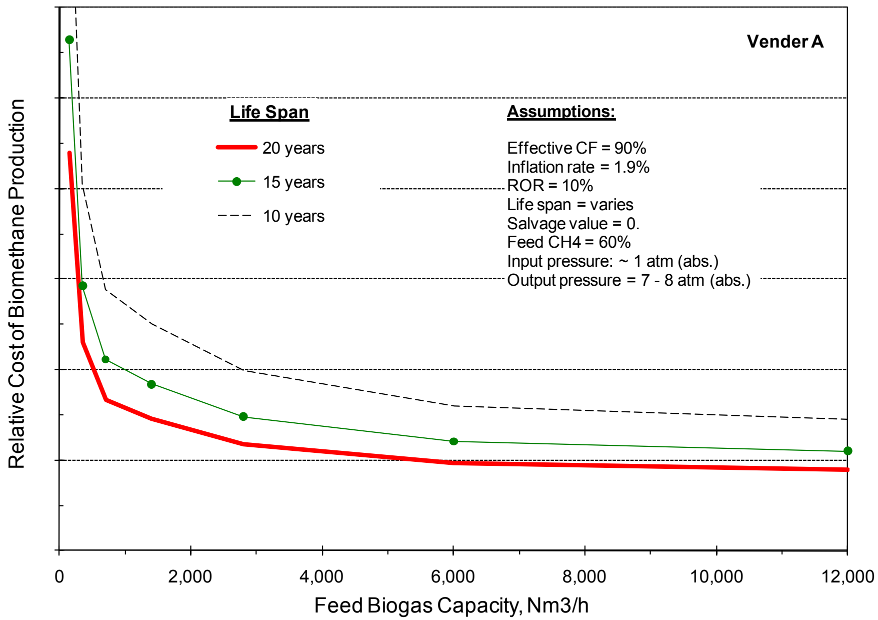


- The results are normalized (e.g., $/kg and $/GJ)

- Key variables for sensitivity analysis: biogas cost, biogas usage, capital cost, capacity factor, electricity price, and electricity usage.

Model: Exploratory Analyses

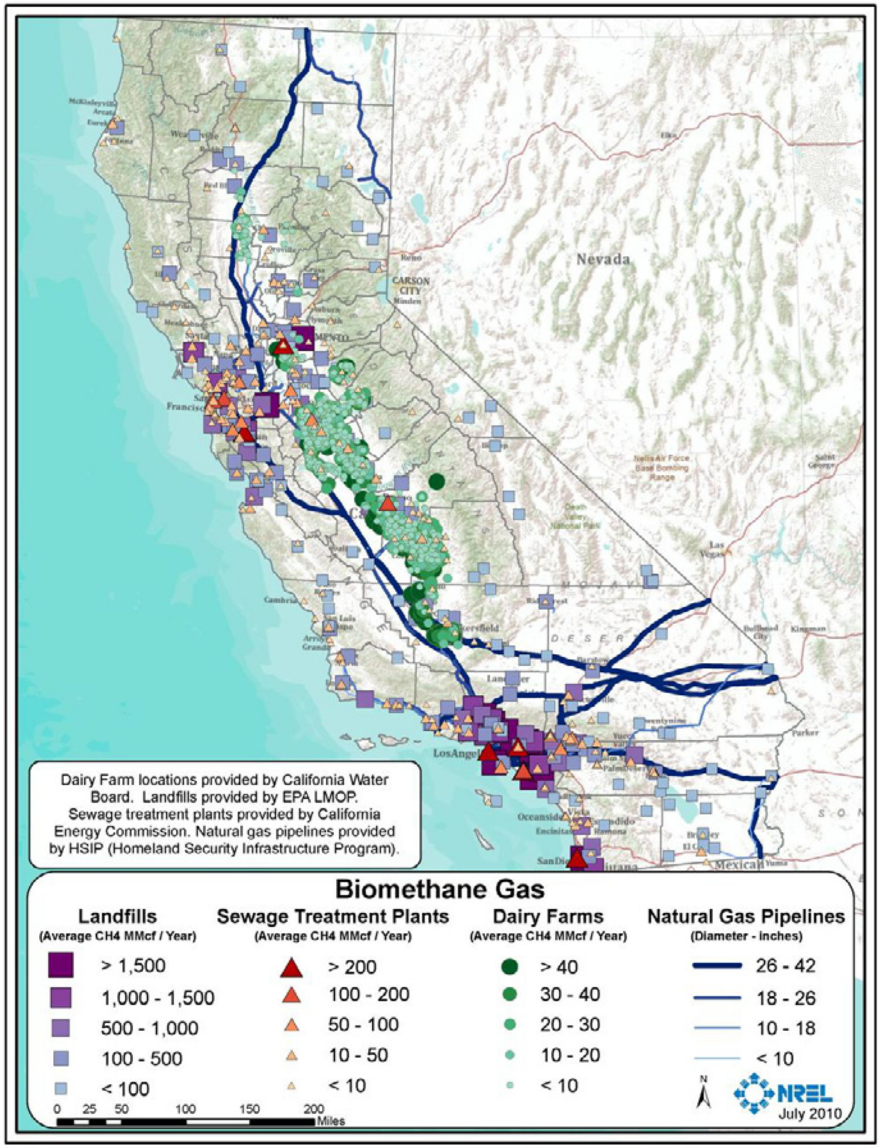




- Energy efficiency takes on greater importance at larger capacities.
- Clustering sources of biogas may be imperative to achieving economy of scale.
- Impact of system life on the economics.
- Significant uncertainty in life span is reflected in vendors' data and literature.

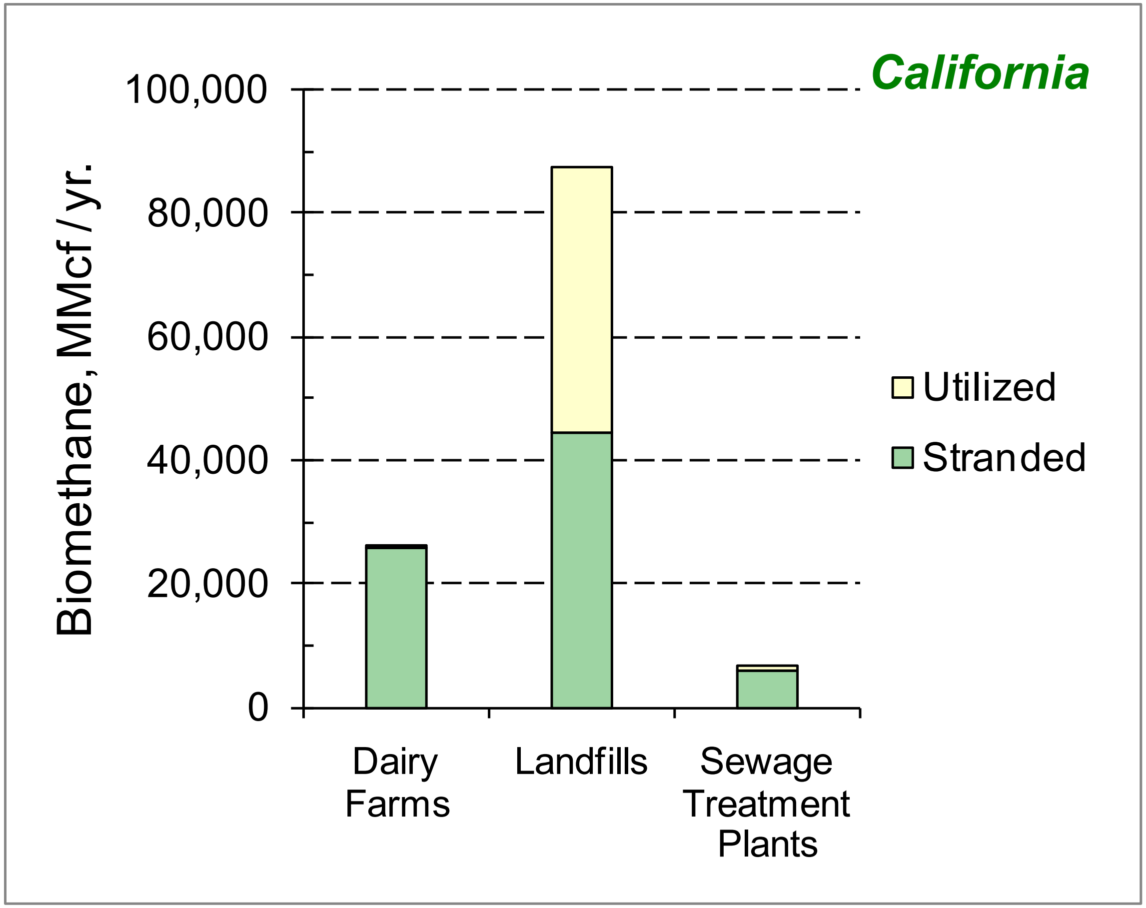
The model can lend itself to exploratory or "what-if" analyses for valuable insights.

GIS Analysis



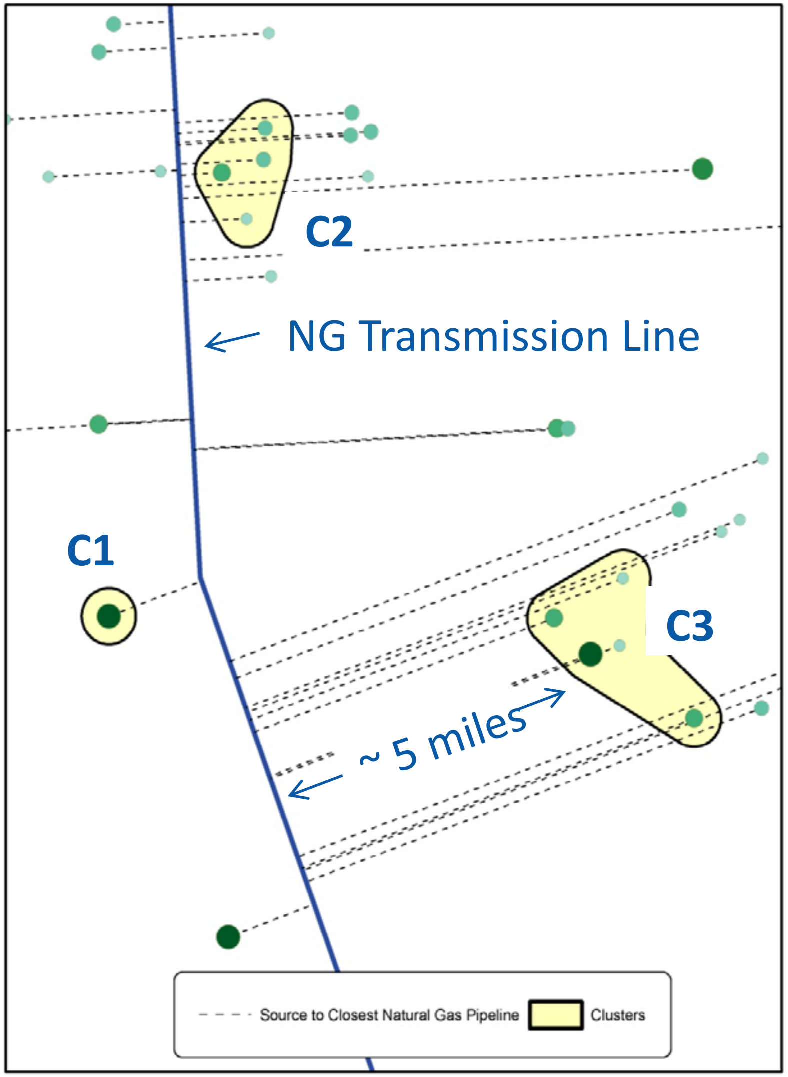
- Select biogas resources: Landfills, sewage treatment plants, and dairy farms.
- Landfills offer greater biogas potential.
- Transmission lines are reasonably accessible to most of biogas sources.
- Majority of GIS data are for the central valley due to systematic tracking.
- Data were unavailable for a number of dairy farms in California.

GIS Analysis (cont.)



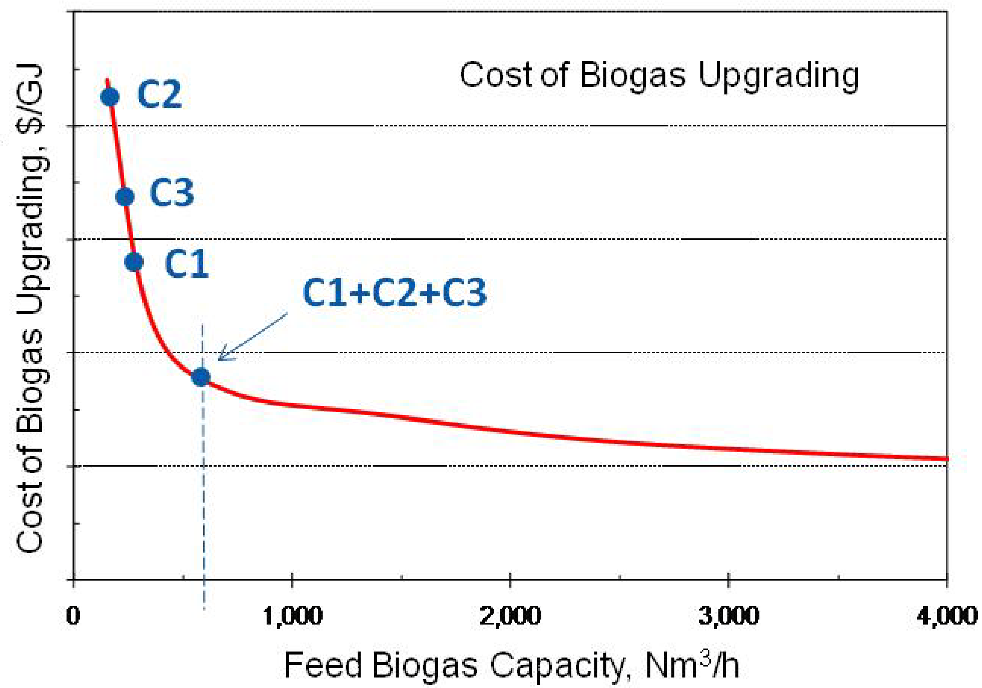
- Landfills have the dominant share at 75%, followed by dairy farms at 22%.
- Total biomethane potential is about 5% of NG consumption.

GIS Analysis: Clustering Dairy Farms for Economy of Scale



- Bio-methane potentials:
  C1: 2,020,000 Nm^3/yr (~ 80,200 GJ/yr.)
  C2: 1,316,000 Nm^3/yr (~ 52,200 GJ/yr.)
  C3: 1,860,000 Nm^3/yr (~ 73,800 GJ/yr.)

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



Scenario Analysis—Key Assumptions

- Facility: Bio-methane production from dairy farm biogas.
- Feed biogas capacity: Varies
- Overall capacity factor = 90%.
- Length of pipeline from production site to NG transmission line = 10 miles.
- Bio-methane pressure at the output of purification system = ~ 8 bar (abs.)
- NG transmission line pressure = ~ 40 bar.
- Rate of return = 10%
- Inflation rate = 1.9%
- System Life = 20yrs.

Cost Estimates—Biogas Cost

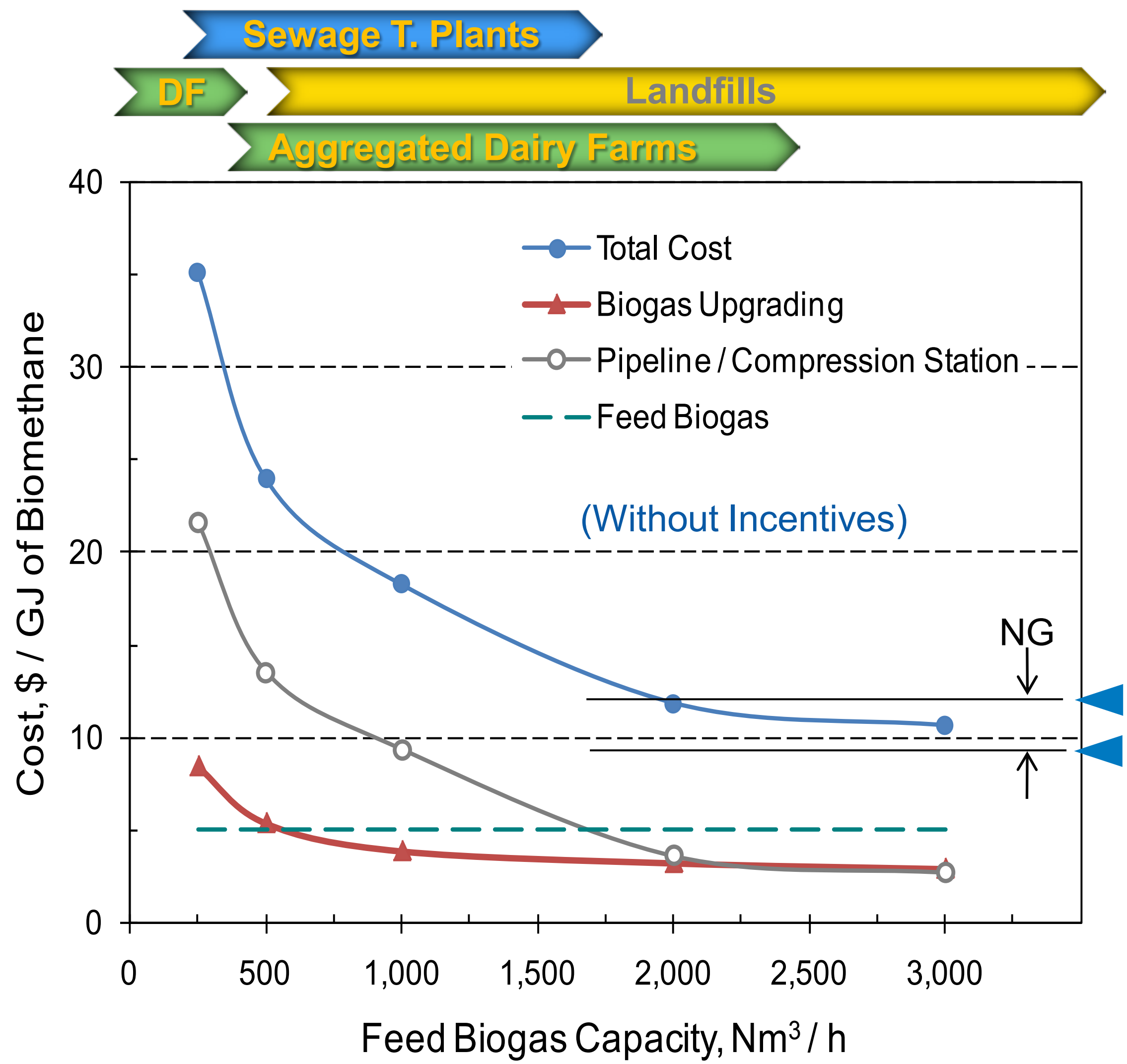
Upgrading biogas from dairy-farm anaerobic digesters (AD)

AD Type	Reported elec. gen. costs*	Estimated biogas*cost	Biomethane Cost = AD + Upgrade Cost	Remarks / Assumptions
				Estimates are in 2010 USD.
Covered lagoon	$12.59/GJ ($0.045 /kWh)	$2.9 / GJ	~ $6 / GJ	Upgrading cost of $3.2/GJ of biomethane was used for aggregate feed biogas capacity of about 2,000 Nm^3/h.
Plug-flow	$34.82 ($0.13/kWh)	$7.6 / GJ	~ $11 / GJ	
Mixed	$52.39 ($0.19/kWh)	$11.0 / GJ	~ $14 / GJ	Ancillary (e.g., storage) costs are not included.

* **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.

Cost Estimates—Impact of Biogas Capacity

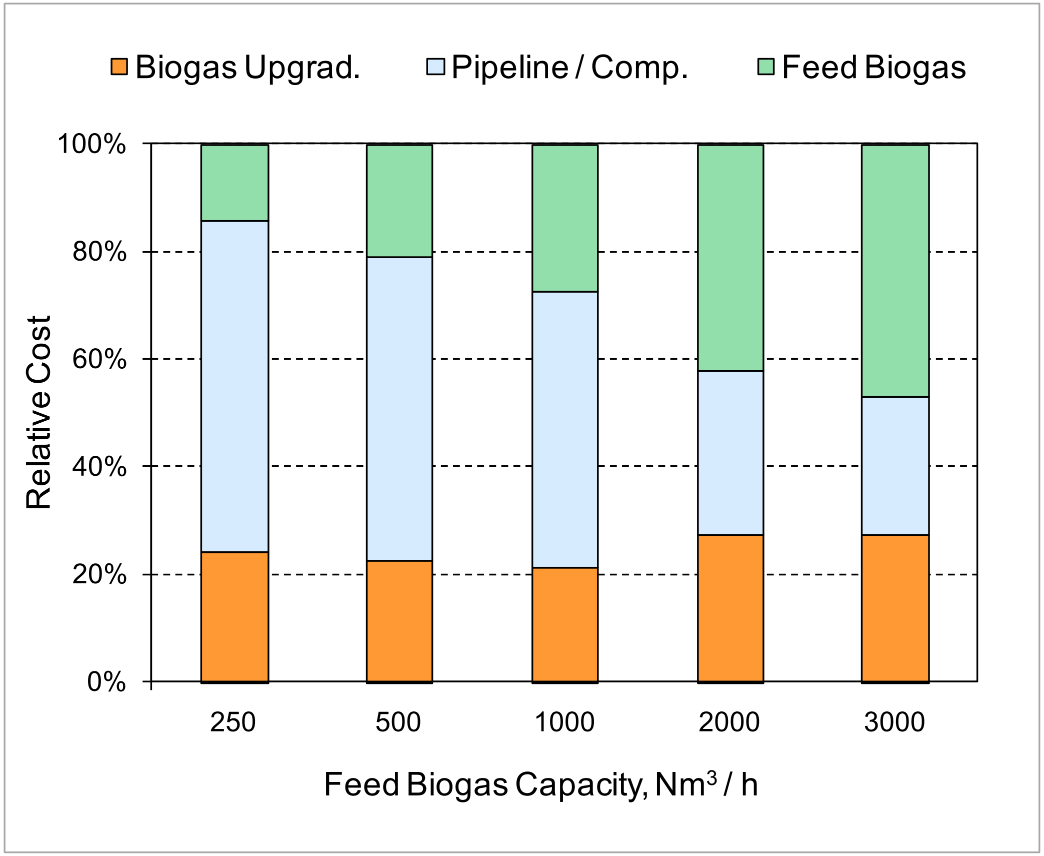
- Export of biomethane from individual dairy farms or limited aggregates is not economical without incentives.
- Clustering sources of biogas (e.g., dairy farms) may be imperative for economic competition.
- If permissible, injection of biomethane into a distribution pipeline can reduce the transport cost (due to shorter distance and lower pressure).



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

Cost Estimates: Relative Contributions

- Depending on the source, feed biogas cost can take on greater significance at high capacities.
- Pipeline delivery cost is dominant at low feed capacities (e.g., < 2,000 Nm^3/h).
- The relative contribution of the cleanup-system cost does not significantly change with the feed biogas capacity.



Note: Costs of ancillary components (e.g., storage) are not included.

Conclusions

- Through the economy of scale, biomethane production via purification of biogas from dairy farms can be economically competitive for on- or near-site utilization even without incentives.

- The economics of pipeline delivery of biomethane to the natural gas grid or another end-use site are influenced by the distance and the operating pressure at the point of delivery—incentives may be necessary for economic justification.

- Clustering farms to facilitate use of a semi-central upgrading system is imperative for achieving the economy of scale.

- Landfills can provide low-cost biogas, favorable economy of scale for biomethane production, and an opportunity for emissions control. However, sustainability of biogas supply, biomethane quality requirements for end-use applications, and restrictive guidelines for grid interconnection are among the prevailing challenges.

- The H2A Biomethane Model can lend itself to analyses of biomethane production and delivery scenarios and assist the stakeholders in their decision making process.

Potential Future Work

- Include the waste-stream oxidization and sequestration aspects of the biogas upgrading process in the model from the economic, energy, and environmental standpoints.

- Explore the possibility of formulating a correlation between the cost of the biogas upgrading system and the purification requirements.

- Investigate the effect of combining biogas products from multiple sites/sources on temporal variation of the feed chemical composition for the clean-up process.

  Implication:

  - Possible mitigation of variation in the impurity level of feed biogas for upgrading process—in addition to achieving the economy of scale.

Acknowledgement

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Questions / Comments?

Thank You!

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