The Digest's 2026 Multi-Slide Guide to Skid-Mounted RNG Units

Why a cheap factory-built upgrader still produces a clustered industry

Three ways to move a cow's methane

These three architectures deliver the same product—pipeline- or vehicle-grade renewable natural gas—but differ in scale, cost structure, and operational complexity. The choice depends on farm size, biogas volume, interconnection costs, and local fuel demand. Understanding these trade-offs frames the central question: which architecture fits best, and when?

Per-Farm Upgrading and Injection	• Each farm captures biogas from its anaerobic digester, upgrades it on-site to pipeline or vehicle fuel quality, and injects it individually into the gas network. • This approach requires a separate upgrading skid and interconnection for every farm, leading to higher fixed costs per site. • Operating costs and permitting are repeated for each location, increasing total expenditures. • Best suited for very large farms that can meet injection thresholds independently. • Offers maximum control and independence for individual farms but limited economies of scale.
Shared Upgrading with Hub-and-Spoke Cluster	• Multiple farms capture biogas independently but feed it via gathering pipelines to a shared upgrading facility (skid) and a single interconnection point. • This hub-and-spoke architecture reduces per-farm capital and operating costs by sharing interconnection and pipeline expenses. • Permitting and oxidizer costs are centralized, lowering site-specific fixed expenses. • Clusters typically achieve the injection threshold collectively, overcoming the minimum flow requirements economically. • Widely adopted model due to cost savings and regulatory advantages.
On-Site Fuelling Avoiding the Pipeline	• Biogas is upgraded on-site to vehicle fuel quality but used directly on the farm or local fleet, bypassing pipeline injection requirements. • Feasible at much lower flow rates, as low as 50 scfm, making it suitable for smaller farms. • Eliminates high interconnection and pipeline costs. • Requires a captive vehicle fleet or reliable local fuel demand to consume the RNG. • Offers operational simplicity but limits market flexibility and scale.

The number that organises the industry: 800–1,000 scfm

The 800 to 1,000 scfm flow range sets a key technical eligibility gate for renewable natural gas pipeline injection, while on-site fueling works at much lower flows. This threshold is a practical condition defined by technology and cost, not an economic crossover point. Operators must consider this when planning RNG architectures.

800–1,000 scfm

Pipeline Injection Threshold

Injection generally requires this biogas flow rate; below this, oxygen removal becomes cost-prohibitive, making pipeline injection technically unfeasible.

50–600 scfm

On-Site Fuelling Range

On-site vehicle fueling can operate at significantly lower biogas flows, starting as low as 50 scfm, avoiding pipeline interconnection costs.

<1,000 scfm

Oxygen Removal Cost Barrier

Oxygen removal equipment is typically cost-prohibitive below 1,000 scfm, limiting economic feasibility of small-scale pipeline injection projects.

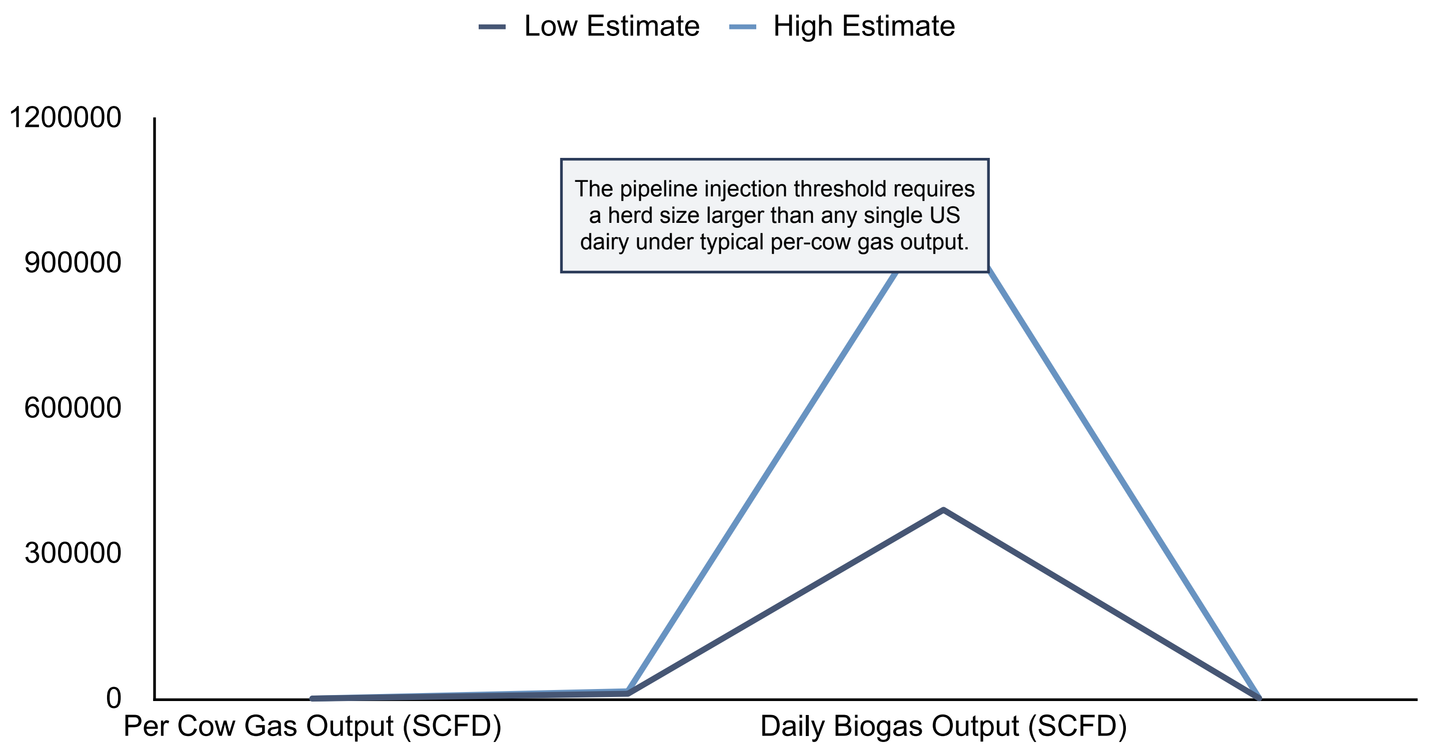
The threshold, translated into cows

The injection threshold of 800 to 1,000 scfm corresponds to a herd size of approximately 10,000 to 15,000 cows based on per-cow biogas output from two disclosed plants. This threshold exceeds the size of any single US dairy, explaining the clustering of farms for shared upgrading. Co-digestion can significantly increase gas output per cow, altering this mapping.

Conversion analysis and implications

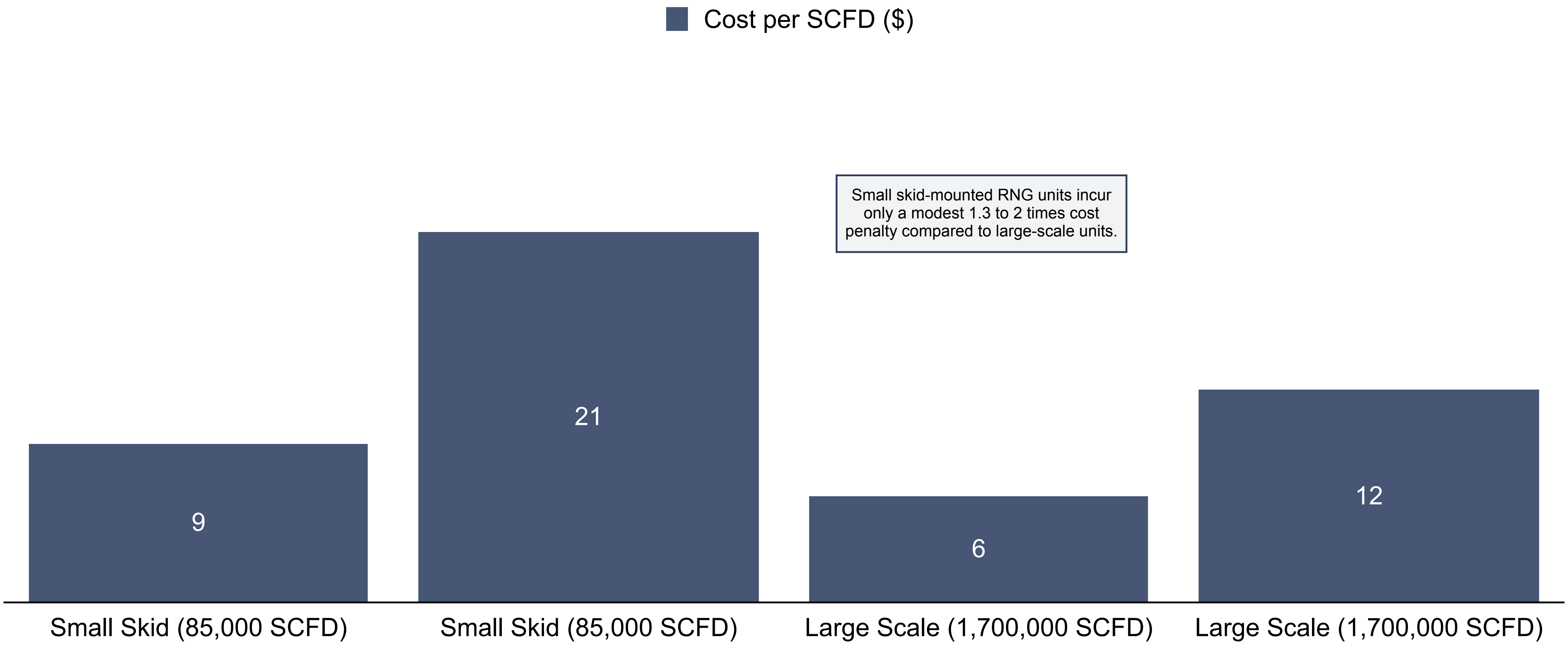
- Two disclosed plants provide per-cow gas output estimates of roughly 39 and 69 SCFD respectively.
- The injection threshold of 800 to 1,000 scfm translates to about 10,000 to 15,000+ cows required for pipeline injection.
- This herd size exceeds any single US dairy, illustrating why farms cluster for shared upgrading and injection.
- Co-digestion can double to quadruple gas per cow, relaxing the herd size threshold significantly.
- Understanding this conversion is key to evaluating the economic feasibility of different RNG architectures.

Conversion Ladder: Herd Size to Biogas Output to Injection Threshold



So the skid must be the problem. It is not.

The commonly held belief that small, skid-mounted RNG upgrading units are the main source of small-scale economic penalties is incorrect. Vendor pricing data shows only a modest 1.3 to 2 times cost penalty per standard cubic foot per day (SCFD) at small scale compared to large scale. The real economic challenges lie elsewhere, not in the skid itself.



What does not scale down

The primary economic penalties for small-scale skid-mounted RNG operations arise not from the skid cost itself but from fixed, per-site costs that do not decrease with volume. These include high interconnection fees, gathering pipeline capital costs, mandatory oxidizer equipment, and duplicated permit and compliance expenses. Understanding and managing these fixed costs is critical to evaluating the real economics of farm-scale RNG projects and explains the industry tendency toward clustered hub-and-spoke models.

Interconnection Costs

Interconnection fees are substantial and fixed per site, ranging from $2 million to $5 million per port regardless of the gas volume handled.

These costs are published in utility tariffs and do not decrease with smaller scale operations.

The pricing structure creates a significant barrier for single-farm injection projects due to the lack of scale economies.

Shared interconnection points across clusters of farms help distribute this fixed cost efficiently.

Gathering Pipeline Expenses

Gathering pipelines carry biogas from multiple farms to a central upgrader or injection point and are priced per mile, not per volume.

For distances under one mile, pipeline costs are approximately $600,000 per mile, a fixed capital investment that doesn't scale down with smaller volumes.

This cost incentivizes clustering farms geographically to minimize pipeline length and cost per unit of gas.

Longer pipeline runs add significant fixed costs independent of individual farm output.

Oxidizer Equipment

Each site requires an oxidizer or flare to safely destroy residual methane or other gases from upgrading or tail gas streams.

Oxidizers are fixed capital equipment and their cost does not reduce with smaller throughput volumes.

This mandatory safety and environmental compliance equipment imposes a fixed cost burden on each farm or node.

Oxidizer operation and maintenance costs further add to this fixed per-site expense.

Permit and Compliance Burdens

Regulatory permits and compliance requirements are required at every site independently, incurring fixed fees and administrative costs.

These permit costs do not scale with throughput and must be maintained regardless of the size of the operation.

Compliance includes environmental monitoring, safety inspections, and reporting, which require dedicated personnel and resources per site.

The duplication of permit-related costs at each farm or node significantly contributes to the small-scale penalty.

The cluster arithmetic

Shared upgrading and injection infrastructure in a hub-and-spoke cluster significantly reduces per-unit operating and interconnection costs compared to single-farm setups, driving industry clustering.

Comparison of Single Dairy vs. Dairy Cluster Costs (2017 USD)

Cost Item	Single Dairy	Dairy Cluster
Operating & Maintenance Cost (per MCF)	***$8***	***$2***
Annual Operating Cost (% of Capital)	6%	3.5%
Interconnection Cost (million $)	$1 - $2	$5.5

Notes Modelled assumptions; not audited; no real gathering system data

Cluster vs. Single Dairy Cost Analysis

- Upgrading O&M cost is $8 per MCF for a single dairy but only $2 per MCF for a cluster.
- Annual operating costs are 6% of capital for single dairy facilities versus 3.5% for clustered systems.
- Interconnection costs range from $1–2 million per dairy farm individually, compared to $5.5 million shared across a cluster.
- These figures are modelled assumptions from California Air Resources Board in 2017 dollars, not audited or based on real gathering systems.

Twenty-one farms, one injection point

The California hub-and-spoke cluster shows that shared infrastructure enables multiple small dairies to achieve pipeline-scale RNG injection. By aggregating gas from many farms, the cluster overcomes individual site barriers and demonstrates the economic viability of this model since early 2019.

Overview	
	• Started with 12 dairies, expanded to 21 in California. • Over 40 miles of gathering pipeline connect all farms. • Shared interconnection enables pipeline injection for small farms. • Cluster has injected RNG since early 2019, sustaining operations.

Problem

- No single dairy could meet the 800–1,000 scfm injection threshold, blocking solo projects.
- Interconnection fees and pipeline costs are fixed per site, not reduced by smaller scale.
- O&M costs are nearly double for single-site upgrading compared to clusters.
- Managing utilization and compliance is harder for many small, separate sites.

Solution

- Adopted a hub-and-spoke model linking 21 dairies to one injection point.
- Shared pipeline gathers gas, enabling economic upgrading and injection.
- Centralized upgrading cuts per-unit O&M and interconnection costs.
- Cluster has operated successfully since early 2019, validating the model.

Who paid for it

144

Dairy Digesters Funded

Number of dairy digesters funded by the state in California between 2015 and 2023.

$226M

Grant Amount

Total state grant funding awarded to dairy digesters in California during 2015-2023, supporting cluster development.

21 farms

Cluster Scale

Number of dairies in the functioning California cluster demonstrating the N-to-1 architecture under subsidy.

The California dairy digesters cluster exemplifies a successful hub-and-spoke RNG architecture enabled by significant state subsidies. While the model works operationally, its economics have not been proven without this financial support, highlighting the critical role of public funding in early sector development.

The other way through: routing around the gate

On-site RNG fueling at this Indiana dairy shows a practical path when pipeline injection is out of reach. By fueling its own truck fleet, the farm avoids costly interconnection and maintains long-term RNG use. This approach, however, depends on having a captive fleet and is not widely replicable.

Overview

- Indiana dairy with 11,500 cows, below pipeline injection threshold.
- Built $18.5M on-site RNG fueling plant in 2009.
- Plant produces 1.5M diesel-gallon-equivalents per year for trucks.
- System has run for 17 years, fueling 42 milk trucks on-site.

Problem

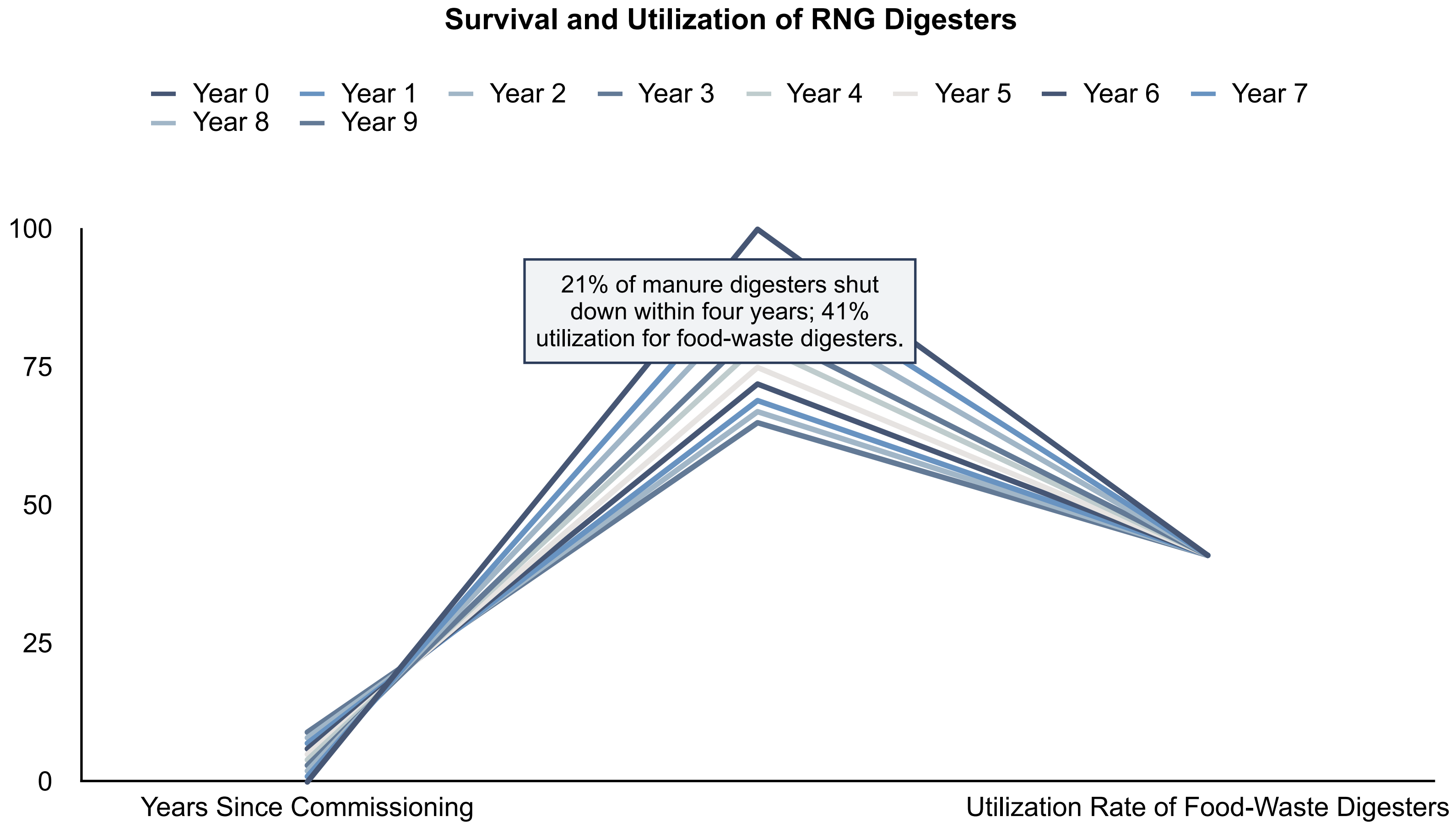
- Biogas output was below the 800–1,000 scfm threshold needed for pipeline injection.
- Interconnection and pipeline costs were too high for the farm's gas production scale.
- No nearby utility receipt point or sufficient volume for off-site gas sales.

Solution

- Converted biogas to CNG on-site to fuel the farm's own truck fleet.
- Bypassed pipeline injection and avoided interconnection costs.
- Created steady RNG demand by fueling a captive fleet on the farm.
- Model depends on on-site fleet, limiting transferability to other farms.

What a distributed fleet actually fails on

Distributed small-scale RNG digester fleets experience high failure rates primarily due to operational maintenance and revenue challenges rather than technical or chemical issues. Nearly 21% of manure digesters built since 2000 have shut down at a median lifespan of four years, while food-waste digesters operate at roughly 41% capacity utilization. These patterns highlight the critical importance of robust maintenance programs and ensuring sufficient revenue streams for sustainability.



Fleet Survival Analysis

- Of manure digesters built since 2000, 98 units (about 21%) have shut down, with a median operational life of four years.
- EPA observed roughly 41% capacity utilization across 99 food-waste digesters, indicating underperformance.
- Survivor bias exists: units built after 2008 have not had sufficient time to fail, suggesting potential future declines in survival rates.
- Failures are linked to maintenance and revenue challenges, not chemical or technical shortcomings.

What the operator must execute

Fleet Maintenance and Spares

Establish a dedicated, staffed maintenance team responsible for regular inspection, troubleshooting, and repair across all distributed RNG sites.

Maintain an inventory of critical spare parts to minimize downtime and ensure rapid response to equipment failures.

Implement predictive maintenance strategies using monitoring data to optimize resource allocation and prevent unexpected breakdowns.

Coordinate scheduling and logistics for maintenance crews to efficiently cover dispersed farm and cluster locations.

Operating a Gathering System under Pipeline Safety Rules

Manage a centralized gathering infrastructure that complies with stringent pipeline safety and regulatory requirements rather than treating sites as standalone upgraders.

Ensure continuous monitoring of gas quality, pressure, and flow to maintain safe and reliable operation of the gathering network.

Train personnel on pipeline safety protocols, emergency response procedures, and regulatory compliance to mitigate risks.

Coordinate with utility and regulatory bodies for inspections, permits, and reporting obligations associated with pipeline interconnections.

Holding Utilization Above the Economic Threshold

Maintain high utilization rates across the cluster or single facility to ensure interconnection and operational costs are economically justified.

Balance feedstock inflows and operational uptime to consistently meet or exceed the injection threshold volume (typically 800 to 1,000 scfm for pipeline injection).

Implement operational controls and demand management to avoid underutilization that would jeopardize the financial viability of the interconnection.

Regularly analyze utilization data to identify and address bottlenecks or downtime causes that reduce system efficiency and profitability.

Effective operation of RNG systems requires robust fleet maintenance, rigorous compliance with pipeline safety regulations, and maintaining utilization above critical economic thresholds. These capabilities are essential regardless of the chosen architecture—distributed, clustered, or on-site—to ensure reliability and economic viability.

What we cannot see

Current evidence on skid-mounted RNG units and clustered systems is constrained by missing operational and financial data, model-based assumptions, and limited sample sizes. Caution is advised when interpreting cost and performance claims, emphasizing the need for transparency and real-world validation.

Staffing and Fleet Availability

- No published data exists detailing staffing requirements per site for maintenance and operation of skid-mounted RNG units.
- Fleet-wide availability statistics for distributed RNG fleets are not publicly disclosed, limiting insight into operational reliability.
- Without these figures, it is challenging to assess the true operational burden and downtime risks across multiple sites.

Gathering System Costs

- No disclosed capital or operating costs are available for fully audited, real-world gathering systems aggregating gas from multiple farms.
- Existing cost estimates for gathering infrastructure are modelled projections, not based on verified builds or financial audits.
- This absence of data complicates accurate economic modeling and investment risk assessments for clustered RNG architectures.

Cluster Economics and Gas Conversion

- Published cluster cost comparisons stem from state regulator models rather than actual constructed projects, limiting empirical validation.
- Per-cow biogas output figures are derived from only two disclosed plants, not a statistically representative sample of farms.
- Co-digestion effects can significantly alter per-cow gas yields, further complicating extrapolation and economic feasibility analyses.

The interconnection test

Before committing to a skid-mounted RNG unit architecture, developers and lenders must rigorously screen projects through a four-step interconnection test. This ensures economic viability by estimating biogas flow, assessing co-digestion benefits, evaluating interconnect sharing potential, and confirming offtake and fixed cost implications. This disciplined approach avoids costly missteps and aligns project design with scale and market realities.

Estimate herd size & biogas flow

Activities

- Calculate herd size and apply per-cow gas output rates (e.g., 39 to 69 SCFD per cow).
- Convert daily gas volume to standard cubic feet per minute (scfm) for pipeline eligibility.
- Identify if raw biogas flow approaches the 800 to 1,000 scfm injection technical gate from EPA LMOP.
- Use site-specific feedstock data to improve flow estimates, accounting for manure type and farm management practices.

Deliverables

- Quantify expected biogas production to compare against injection thresholds.

Assess co-digestion impact & threshold

Activities

- Determine availability and type of co-digestion organic materials that can boost gas per cow.
- Model potential biogas uplift from co-digestion, noting it can double or quadruple gas output.
- Confirm whether combined gas flow exceeds the 800–1,000 scfm gate, enabling pipeline injection.
- Recognize that oxygen removal cost is typically prohibitive below 1,000 scfm, influencing technology choice.

Deliverables

- Evaluate if co-digestion can increase biogas yield sufficiently to surpass the pipeline injection threshold.

Map distance to receipt & sharing

Activities

- Identify nearest utility receipt points and assess pipeline capacity at each point.
- Calculate distance and cost implications for gathering pipelines to connect farms to the interconnect.
- Estimate the number of farms that can economically share a single interconnection port to reduce fixed costs.
- Consider utility tariffs showing $2–5 million interconnection cost per port regardless of size.

Deliverables

- Map proximity to pipeline interconnection points and quantify how many farms can share the interconnect.

Confirm offtake & price fixed stack

Activities

- Choose appropriate RNG use case: pipeline injection, onsite vehicle fueling, or captive fleet use.
- Price fixed costs including interconnection port, gathering pipe, oxidizer, permit, and operating crew per site.
- Evaluate if utilization rates are sufficient to justify shared infrastructure costs.
- Incorporate operational capabilities such as fleet maintenance and regulatory compliance into cost assessment.

Deliverables

- Define the end use (pipeline injection, vehicle fueling, captive fleet) and quantify fixed per-site costs.

Count interconnections, not farms

The key to understanding farm-scale RNG economics is to count interconnections, not the number of farms. Fixed site-specific costs such as interconnection ports, gathering pipelines, oxidizers, permits, and crew dominate the economics and do not scale down. The skid itself carries only a modest small-scale penalty. Careful interpretation of all data is essential due to modelling assumptions and survivor bias. This perspective explains why the industry clusters rather than disperses into many small single-farm units.

Focus on Fixed Per-Site Costs

- Interconnection ports cost $2 to $5 million each, regardless of the farm size or gas volume.
- Gathering pipelines are priced per mile and do not scale down with fewer farms.
- Oxidizers are required at every site, adding a fixed equipment cost per location.
- Permits and compliance costs are site-specific and recur at every node in the system.

Skid Penalty is Modest

- Factory-built skids have a small-scale penalty between 1.3x and 2x compared to large centralized units.
- This penalty is relatively minor compared to the fixed costs that do not scale down.
- Vendor pricing and utility tariffs confirm that the skid is not the main economic barrier.
- The cluster industry forms because fixed per-site costs dominate, not because of the skid.

Read All Numbers with Caution

- Cluster economics are based on modelled assumptions, not audited real-world builds.
- Conversion rates from cows to biogas are calculated from limited disclosed plants, not a broad sample.
- Survivorship bias affects interpretation: newer units have not had enough time to fail.
- Always qualify cost and performance figures alongside their data sources and assumptions.

Thank you