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OPPORTUNITIES AND IMPACTS OF RENEWABLE NATURAL GAS AS A HEAVY-DUTY VEHICLE FUEL

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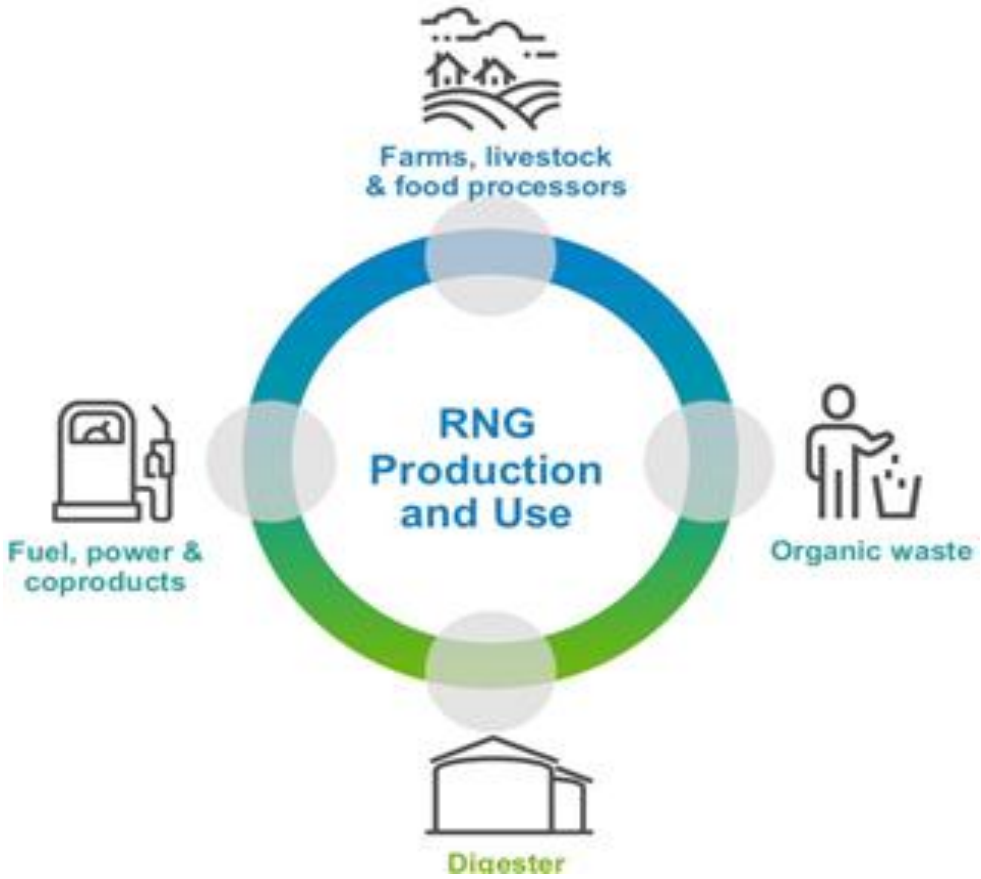
OUTLINE

- Why RNG?
- RNG project and production trends
- Practical Future RNG Production Potential
- RNG Coverage

WHY IS RNG A KEY ALTERNATIVE FUEL?

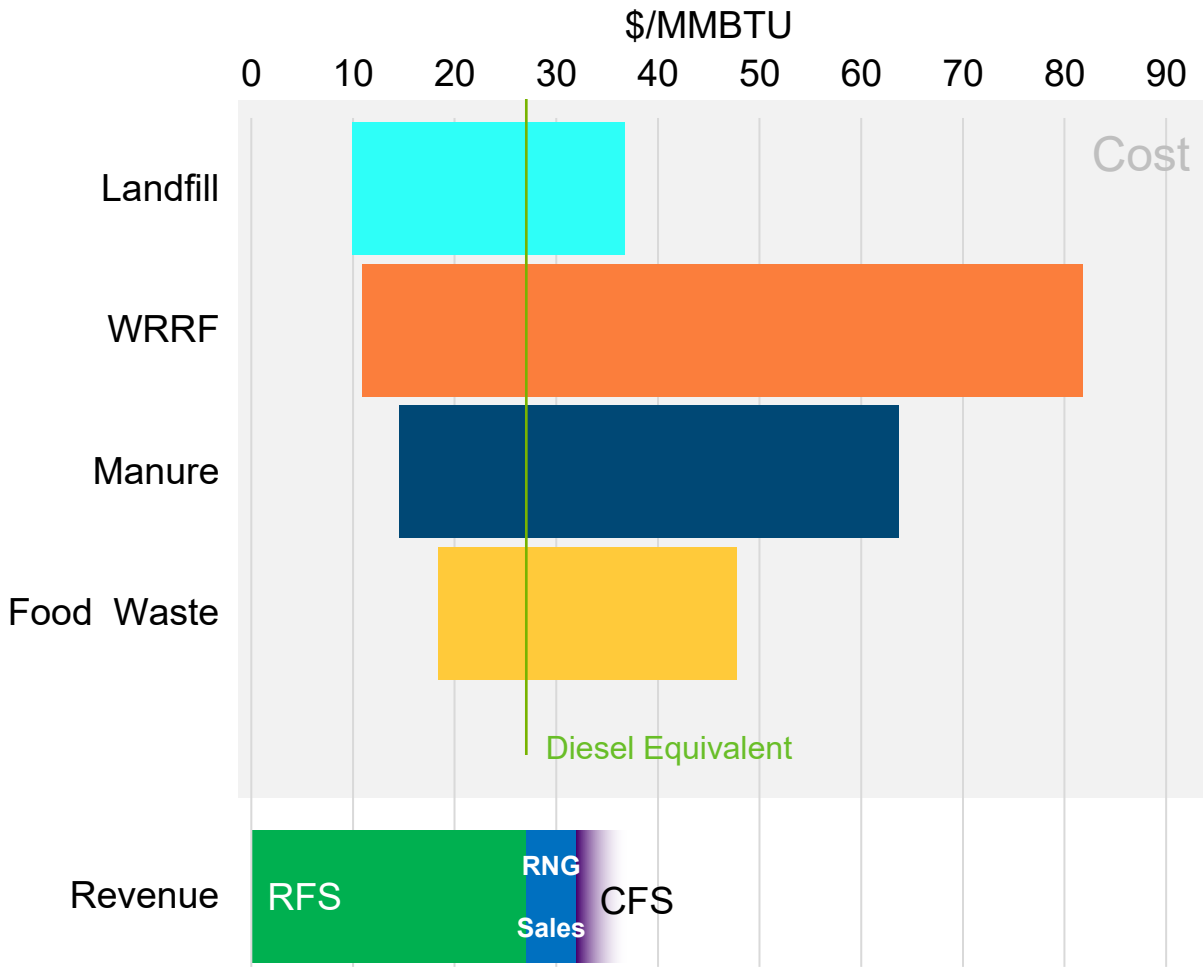
- ✓ Affordable
- ✓ Plentiful (and steady) supply and demand
- ✓ Environmentally beneficial
- ✓ A drop-in renewable fuel for heavy-duty natural gas engines
- ✓ Fills gap where other technologies struggle



Renewable Natural Gas (RNG) for Transportation: Frequently Asked Questions, Argonne National Lab, https://www.anl.gov/es/reference/renewable-natural-gas-rng-for-transportation-frequently-asked-questions.

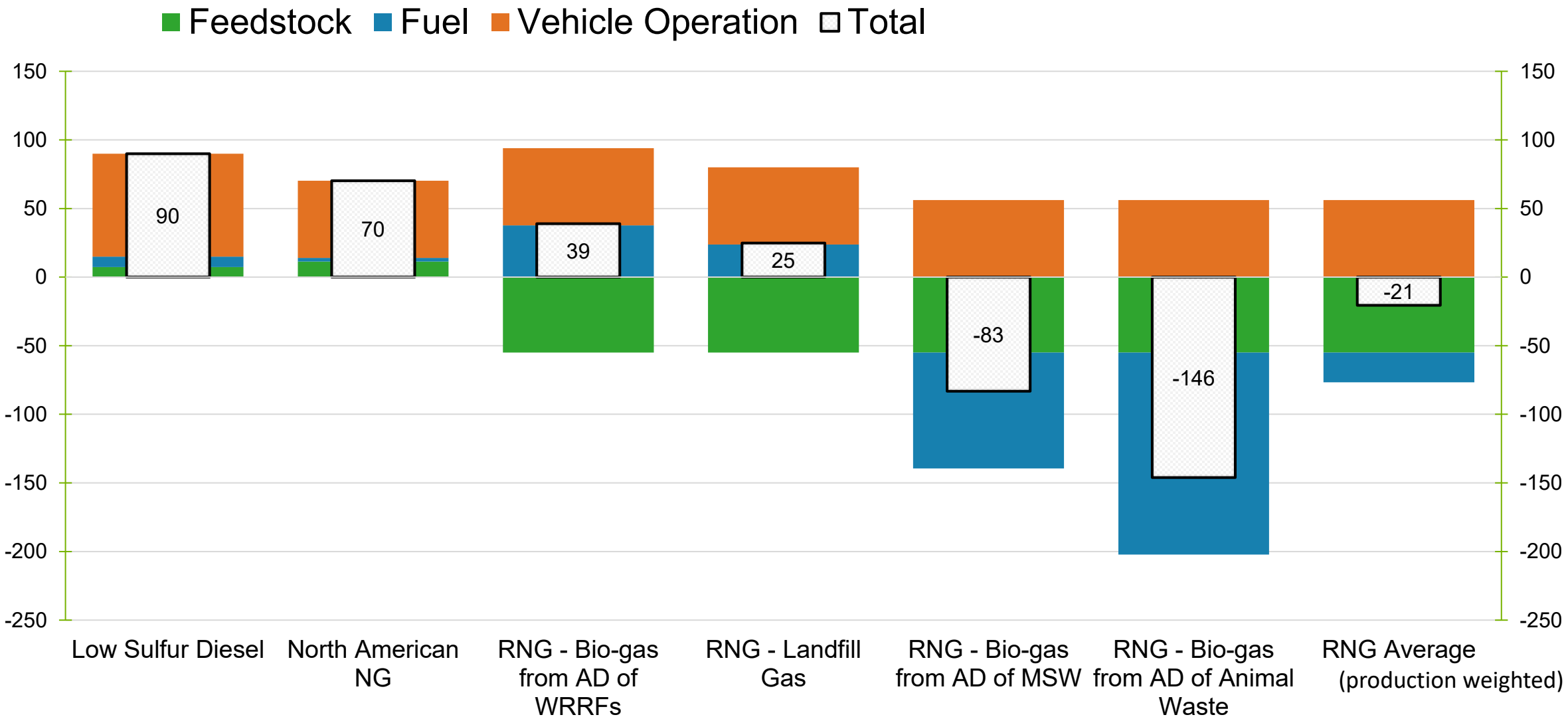
FEDERAL AND STATE INCENTIVES MAKE RNG PROFITABLE

- Above producer's share of ~$3.30/DGE pump price
- Renewable Fuel Standard (RFS)
  - Requires obligated parties to produce or purchase renewable fuel credits
  - Most RNG qualifies as cellulosic biofuel, credit currently $3.30/DGE or ~$27/MMBtu
- State Clean Fuel Standard (CFS) credits are "stackable" with RINs
- While AFTC has expired & IRA extension is uncertain, bipartisan legislation for $1/DGE tax credit



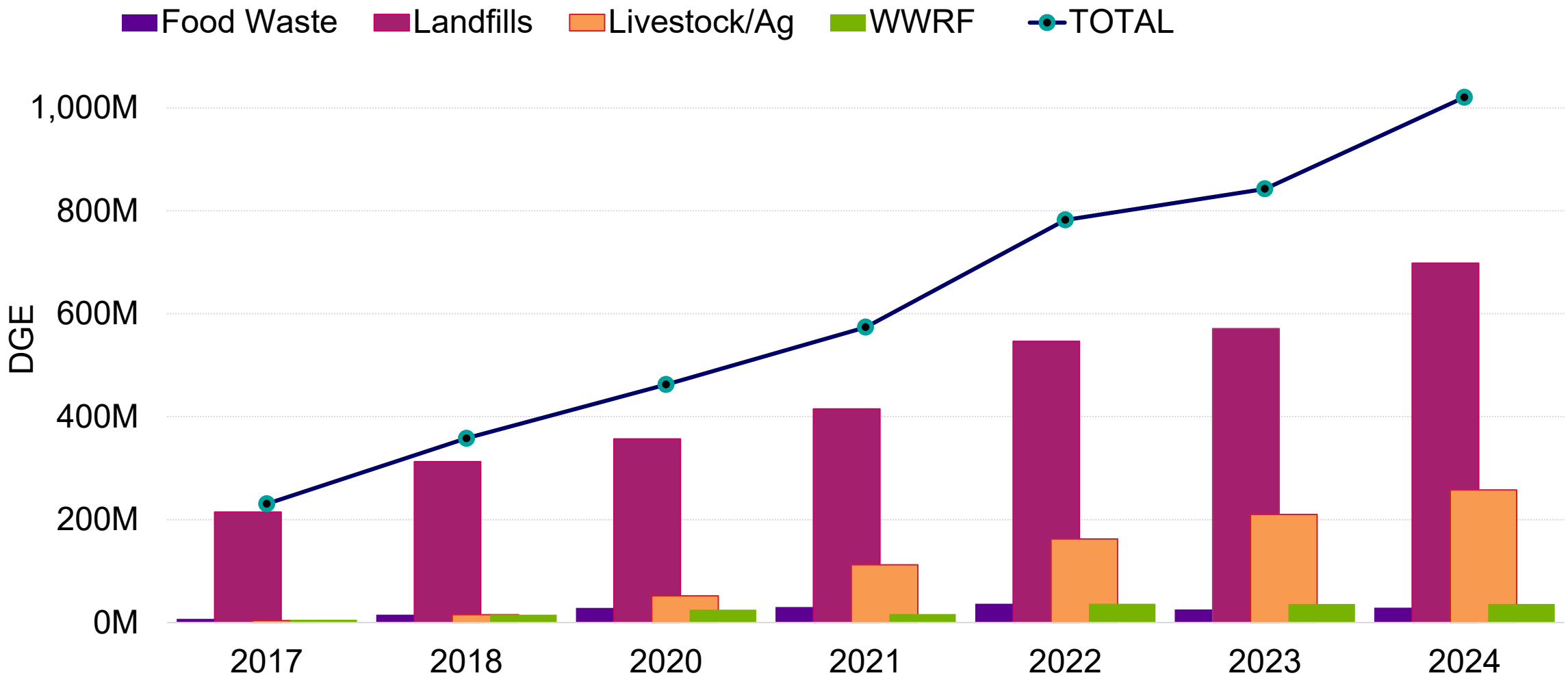
Source of cost estimates: Michigan Renewable Natural Gas Study (2022)
https://www.michigan.gov/mpsc/-/media/Project/Websites/mpsc/workgroups/RenewableNaturalGas/MI-RNG-Study-Final-Report-9-23-22.pdf

CLASS 8 LONG-HAUL TRUCKS WTW GHG (G/MJ)



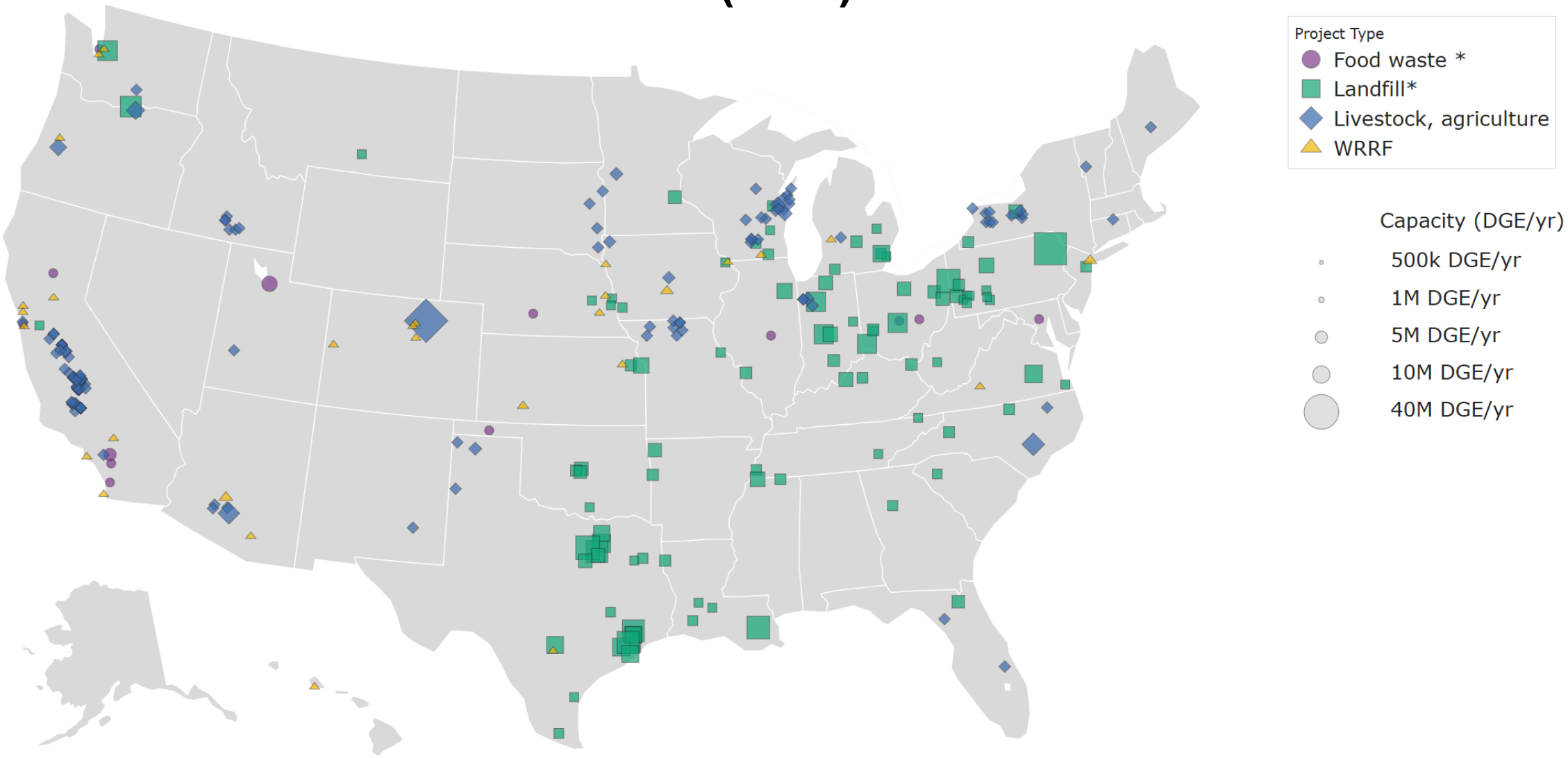
Source: GREET 2024

1.02 BILLION DGE RNG PRODUCED IN 2024



Source: Argonne RNG Database (2024)

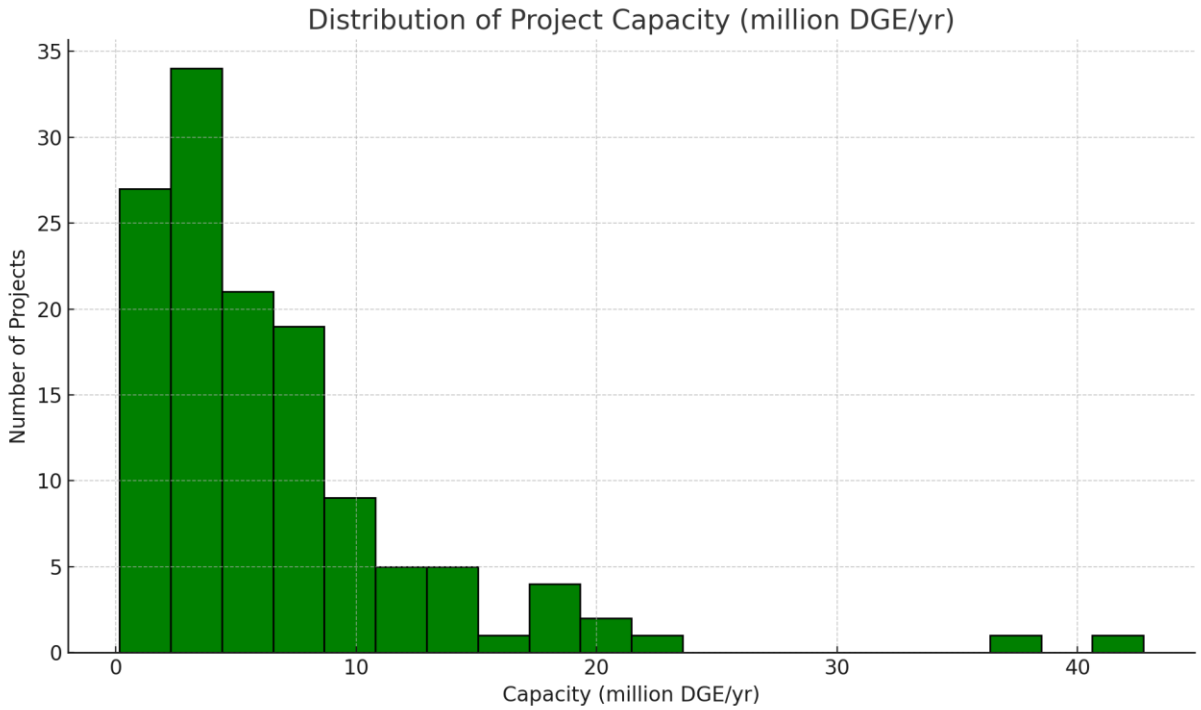
REGIONAL DISTRIBUTION OF RNG PROJECTS (2023)

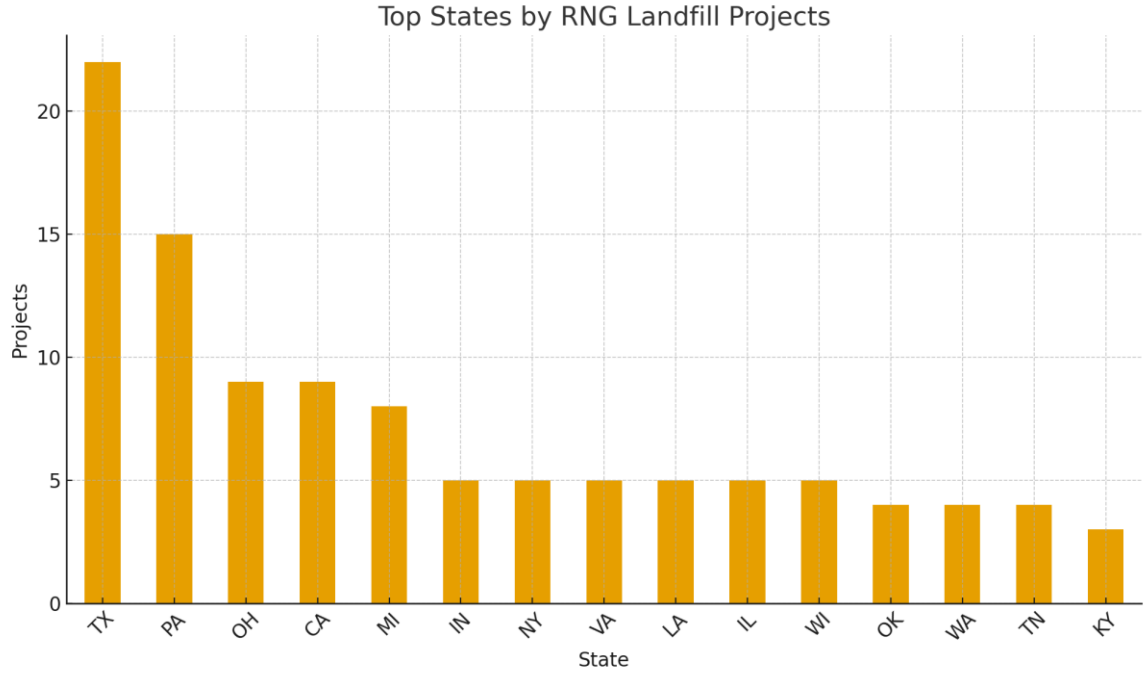


Source: Argonne RNG Database (2023)

LANDFILL PROJECTS IN NUMBERS

- 132 Operational Projects - producing 700M DGE/year
- Average Project: 5.29 M DGE/Year





Source: Argonne RNG Database (2023)

WITH MORE NGVS AVAILABLE, SUPPLIERS & LARGE CUSTOMERS SEE THE RNG ADVANTAGE

- ✓ **Paccar (Kenworth, Peterbilt) and Daimler (Freightliner/Cascadia):** offer Cummins X15N
- ✓ **Walmart:** BEV~200 mi; H2 ~500 mi; RNG: 700+ mi
- ✓ **UPS:** >5,000 NGVs, 87% RNG fueled; largest buyer
- ✓ **Republic:** >3,000 NGVs
- ✓ **CA & NYC:** rolled back M/HDV ZEV targets
- ✓ **Chevron & Clean Energy:** 2-week demos of Cummins' X15N with access to fueling
- ✓ **Cummins, Clean Energy & Hexagon Agility** form HD leasing/support Pioneer Clean Fleet Solutions

LOCAL AIR POLLUTANT BENEFITS FROM RNG VEHICLE DEPLOYMENT

- Heavy-duty diesel trucks are a leading source of NO_x and particulate matter ($PM_{2.5}$, PM_{10}) in freight corridors and urban centers.
- RNG combustion significantly lowers these emissions while maintaining diesel-like performance.
- Benefits are greatest in high-mileage long-haul and refuse operations.

Average Annual Pollutant Reductions for Long-haul Trucks

- **$PM_{2.5}$** ↓ 7.8 kg/truck
- **PM_{10}** ↓ 8.2 kg/truck
- **NO_x** ↓ 190 kg/truck

National Air Quality Benefits:

Scenario	$PM_{2.5}$ (tons/yr)	PM_{10} (tons/yr)	NO_x (tons/yr)
Current (1.02B DGE)	576	605	14,100
Future Low (2.4B DGE)	1,460	1,530	35,700
Future High (3.95B DGE)	2,400	2,520	58,700

Key Takeaways:
- Largest gains in freight corridors and nonattainment regions.
- Reductions are immediate and cumulative across fleets.
- Provides near-term air-quality benefits while supporting future clean transport

Thank you!

Questions/Comments: csiddique@anl.gov

LANDFILL PROJECTS IN ILLINOIS

Landfill/Project Name	Projected status 12/31/2023	Owner	Waste In Place (tons)	County	Total LFG Collected (mmscfd)	RNG DGE/year
Milam Recycling and Disposal Facility (Waste Management)	Operational	Waste Management, Inc.	29,903,905	St. Clair	4.556	5,888,657
Will County Renewable Natural Gas Facility at Prairie View Landfill	Operational	Will County	10,510,812	Will	4.252	10,068,366
Countryside Landfill	Under Construction	Landfill, WMI; upgrading operation, Terreva Renewables	15,569,533	Lake		-
Roxana	Under Construction	Landfill: Republic Services; upgrading: Ameresco	28,399,509	Madison	6.63	13,004,118
Winnebago LF	Under Construction	Waste Connections Inc.	23,175,993	Winnebago	7.433	13,188,138

PRACTICAL FUTURE RNG PRODUCTION POTENTIAL BY FEEDSTOCK

Feedstock	Practical Potential (Million DGE/year)	Key Assumptions and Sensitivities	Comparison to Literature
Landfill Gas	**1,000-1,700**	1,500 landfills; 250-400 scfm/site; 67.5% efficiency	EPA LMOP datasets suggest gross methane >4-5B DGE
Livestock Manure	**900-1,400**	2,000-3,000 digesters; 350k-550k DGE/site; 78% efficiency	Milbrandt et al. (2018): ~4,172M
Food Waste	**300-500**	15-25M tons recoverable; 20-30% losses; energy content 2.5-3.8 MMBtu/ton	Milbrandt et al. (2018): ~593M
Wastewater Sludge	**200-350**	1,200-1,400 POTWs; 60-70% recovery; 0.8-1.0 scf/person/day	Milbrandt et al. (2018): ~1,376M
Total Estimated Potential	**2,400-3,950**		~7,700 M (total technical potential Milbrandt 2018)

ESTIMATED RNG COVERAGE POTENTIAL FOR HDV USE CASES

RNG Supply Scenario	Supported Long-Haul Trucks	% of Fleet (Long-Haul)	Supported High-Mileage Trucks	% of Fleet (High-Mileage)	Supported Refuse Trucks	% of Fleet (Refuse)
2024 Supply (1.02 B DGE)	51,000 – 85,000	7–12%	51,000 – 102,000	18–36%	102,000 – 170,000	57–94%
Future Low (2.4B DGE)	120,000 – 200,000	20–33%	120,000 – 240,000	44–89%	240,000 – 400,000	133–222%
Future High (3.95B DGE)	197,500– 329,000	33–55%	197,500 – 395,000	73–146%	395,000 – 658,000	219–366%

UNDERLYING ASSUMPTIONS AND ANALYTICAL BOUNDARIES

Feedstock & Production

- Practical yields constrained by economic, infrastructure, and siting factors
- Methane recovery: 70–85%; upgrading efficiency: 85–90%
- Viable sources: ~1,500 landfills, 2,000–3,000 large farms, 1,200–1,400 Publicly Owned Treatment Works
- Food waste losses: 20–30% from collection and preprocessing
- Excludes thermal gasification and non-transportation RNG use

Vehicle Energy Use & Scenarios

- Long-haul Class 8 trucks: 96,000 mi/yr, 6–7 mpg (~12k–20k DGE/yr)
- Refuse trucks: 25,000 mi/yr, 2.5–3.5 mpg (~6k–10k DGE/yr)
- Fuel economy parity assumed between RNG and diesel engines
- Current supply: 1.02B DGE/yr (2024)
- Future potential: 2.4–3.95B DGE/yr under practical deployment
- Focus on CNG/LNG-compatible fleets and existing fueling corridors

Lifecycle & Emissions

- GREET 2024 used for WTW analysis with avoided methane crediting
- Negative carbon intensities for manure and food waste pathways
- Air quality benefits include CO_2e, NO_x, and PM reductions
- Results emphasize realistic, feedstock-weighted performance

KEY TAKEAWAYS FROM THE STUDY

- Current U.S. RNG production is about 1.02 billion DGE/year, with a practical potential of 2.4–3.95 billion DGE/year.
- Feedstock mix is evolving: landfills supply ~70% today, but will decline as livestock manure, food waste, and wastewater sources expand.
- RNG could displace 7–12% of long-haul diesel use today, scaling up to 33–55% under future supply, and fully meet refuse fleet demand.
- Deployment could avoid 15–64 million metric tons of CO_2e annually while reducing PM and NO_x emissions in freight corridors.
- RNG offers a near-term, practical pathway to improve energy security and reduce air pollutants in freight transportation.