

Oregon Department of Energy

Oregon Biogas / Renewable
Natural Gas Inventory - SB 334
(2017)

Senate Interim Committee
On Environment and Natural
Resources

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SB 334 (2017) – Overview

- Conduct a detailed feedstock inventory related to biogas and renewable natural gas (RNG) resources within the state of Oregon. Look at feedstock potential for gas production. Technologies include anaerobic digestion and thermal gasification.
- Examine existing biogas / Renewable Natural Gas sites and their supply chains.
- Estimate GHG emission and air pollution improvements based on using RNG as stationary fuel and transportation fuel.
- Form an Advisory Committee to specifically provide input on barriers to developing and utilizing biogas and renewable natural gas and to provide recommendations to the department on policy to promote RNG production and use.

Fuel Production Pathways

Anaerobic Digestion

Agricultural Manure
Landfills
Municipal Wastewater
Waste Food

Thermal Gasification

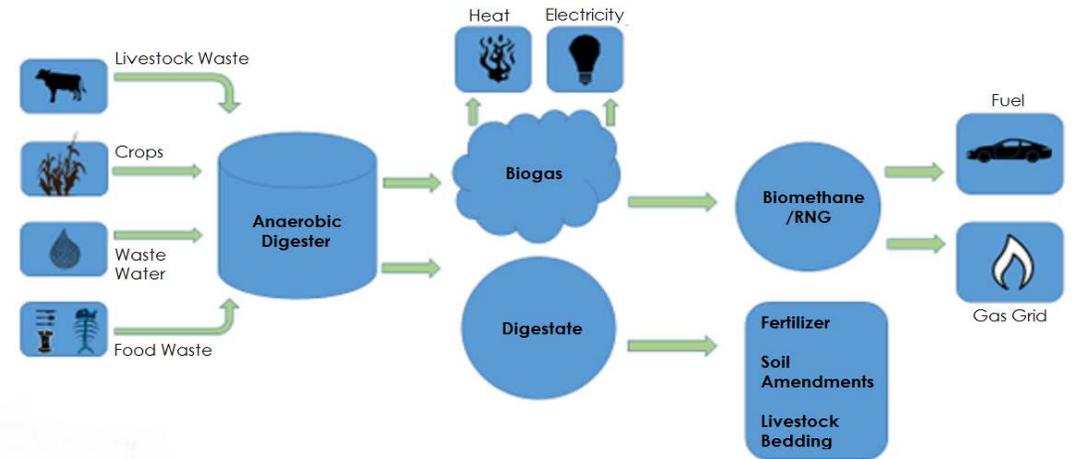
Forest Harvest Residuals
Agricultural Harvest Residuals

Other Near-Commercial Technologies

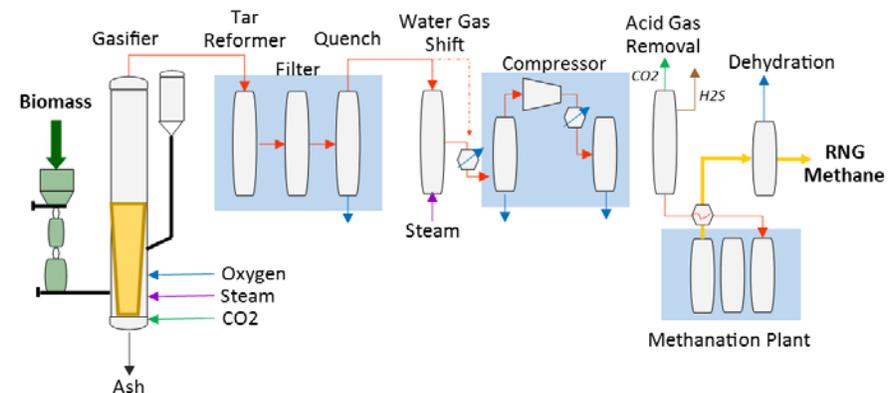
Power-to-Gas
PyroCatalytic Hydrogenation
Hydrothermal Liquefaction

See pages 2 and 7 in the report

Anaerobic Digestion Pathway



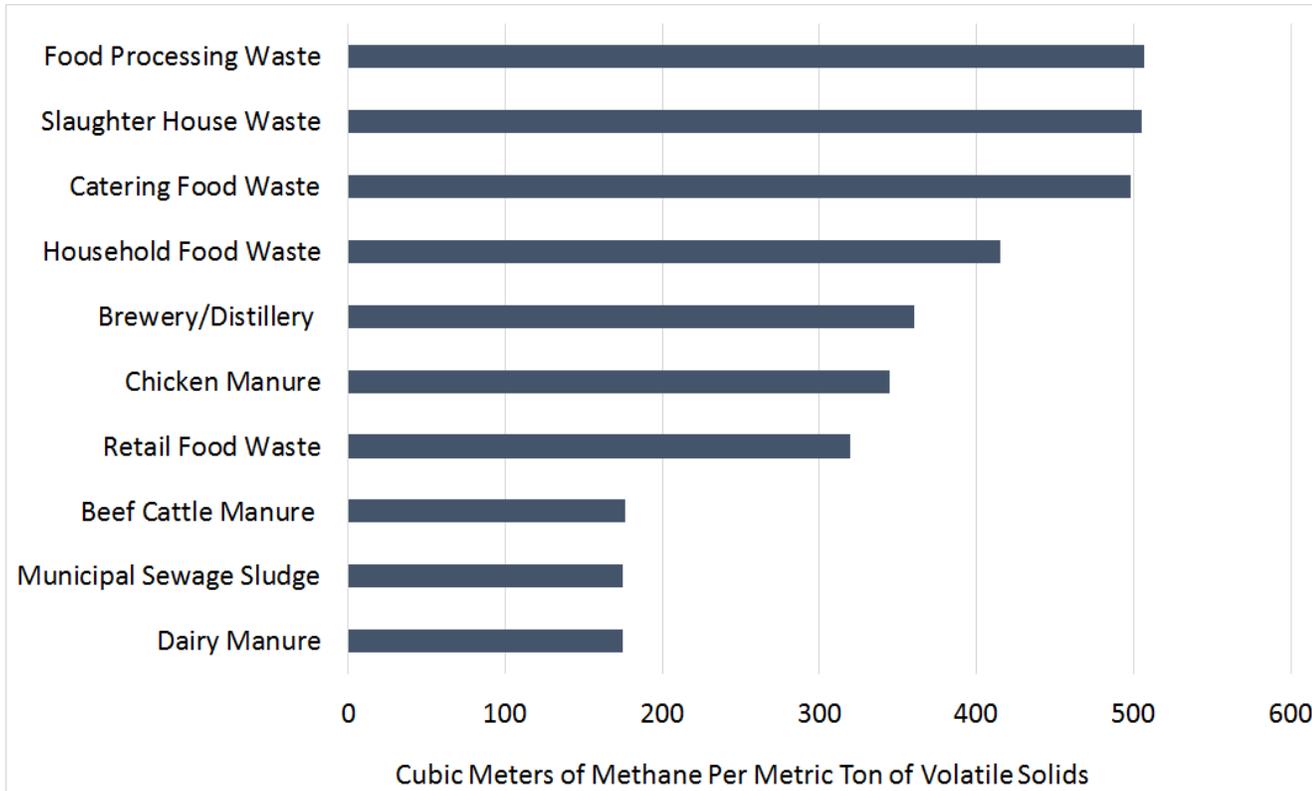
Thermal Gasification Pathway



- ✓ Dry the biomass with waste heat
- ✓ Feed dry biomass to gasifier
- ✓ Remove tars and dust
- ✓ Shift to get H₂:CO ratio = 3:1
- ✓ Compress to pipeline pressure
- ✓ Remove acid gases including CO₂
- ✓ Convert syngas to methane
- ✓ Remove remaining moisture
- ✓ 65% conversion efficiency

Methane Potential of Digestible Feedstocks

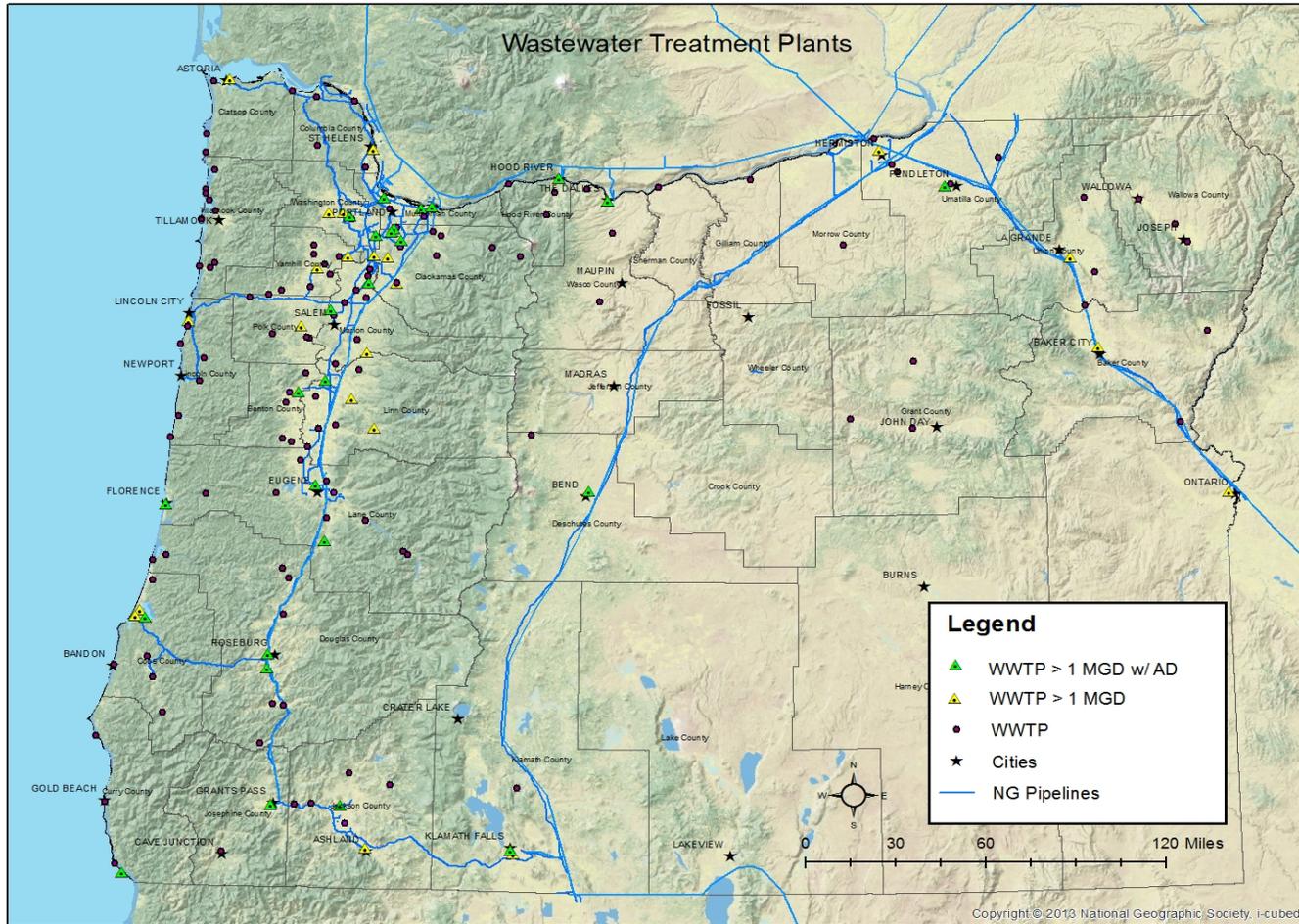
Methane Potential of Digestible Feedstocks (m³/metric ton VS)



These values represent theoretical laboratory results. Many variables are involved in actual gas production.

See page 3 in the report

AD Pathway: Municipal Wastewater

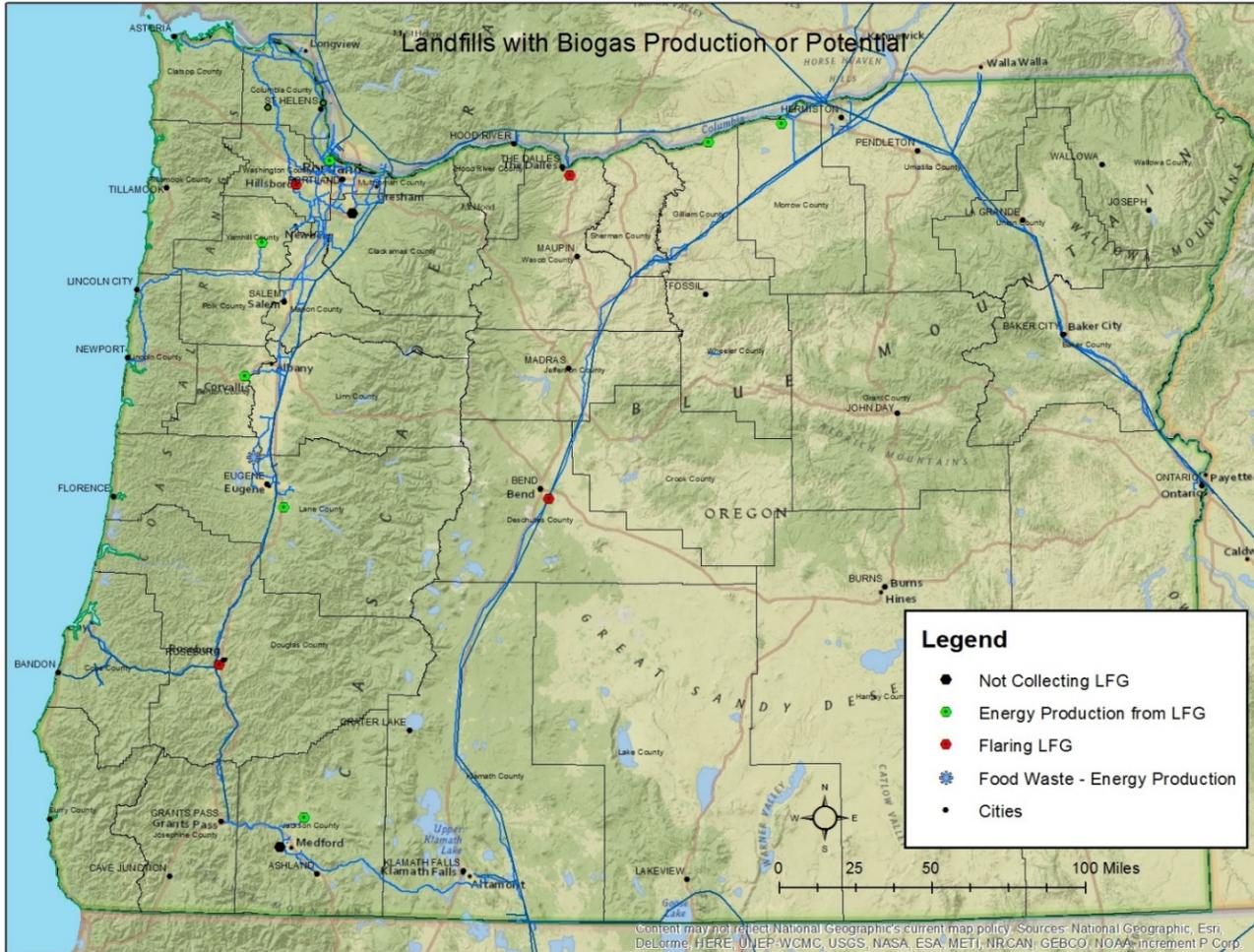


County	Total Biogas Production Using Calculated Column Figures (scf/yr)			Total Biogas Production Using Metered Column Figures (scf/yr)		
	Calculated At 55% Methane (scf/yr)	Calculated At 60% Methane (scf/yr)	Calculated At 65% Methane (scf/yr)	Metered At 55% a (scf/yr)	Metered At 60% Methane (scf/yr)	Metered At 65% Methane (scf/yr)
Baker	3,626,281	3,955,942	4,285,604	3,546,160	3,868,539	4,190,917
Benton	21,535,853	23,493,658	25,451,463	21,060,033	22,974,582	24,889,130
Clackamas	77,213,377	84,232,775	91,252,173	75,507,400	82,371,709	89,236,018
Clatsop	3,569,448	3,893,943	4,218,439	3,490,584	3,807,909	4,125,235
Columbia	4,854,596	5,295,923	5,737,250	4,747,337	5,178,913	5,610,489
Coos	9,685,359	10,565,846	11,446,334	9,471,368	10,332,401	11,193,435
Curry	2,418,131	2,637,962	2,857,792	2,364,705	2,579,678	2,794,651
Deschutes	28,476,752	31,065,548	33,654,344	27,847,578	30,379,176	32,910,774
Douglas	10,789,010	11,769,829	12,750,648	10,550,634	11,509,782	12,468,931
Hood River	2,916,791	3,181,954	3,447,117	2,852,346	3,111,651	3,370,955
Jackson	80,188,834	87,478,728	94,768,622	78,417,116	85,545,945	92,674,774
Josephine	13,615,969	14,853,784	16,091,599	13,315,133	14,525,600	15,736,066
Klamath	7,982,217	8,707,873	9,433,529	7,805,856	8,515,479	9,225,102
Lane	96,651,928	105,438,466	114,225,005	94,516,469	103,108,875	111,701,282
Lincoln	3,177,120	3,465,950	3,754,779	3,106,924	3,389,372	3,671,819
Linn	29,463,071	32,141,533	34,819,994	28,812,105	31,431,387	34,050,670
Malheur	4,203,772	4,585,933	4,968,094	4,110,893	4,484,610	4,858,328
Marion	95,865,439	104,580,479	113,295,519	93,747,357	102,269,844	110,792,332
Multnomah	297,681,337	324,743,277	351,805,216	291,104,271	317,568,295	344,032,320
Polk	5,708,917	6,227,909	6,746,902	5,582,782	6,090,308	6,597,834
Umatilla	12,787,314	13,949,797	15,112,280	12,504,787	13,641,586	14,778,385
Union	4,856,429	5,297,923	5,739,417	4,749,130	5,180,869	5,612,608
Wasco	5,362,422	5,849,915	6,337,408	5,243,943	5,720,665	6,197,387
Washington	200,509,117	218,737,218	236,965,320	196,079,005	213,904,369	231,729,733
Yamhill	20,952,862	22,857,668	24,762,473	20,489,923	22,352,643	24,215,363
STATE TOTAL:	1,044,092,347	1,139,009,833	1,233,927,319	1,021,023,838	1,113,844,187	1,206,664,536

in annual cubic feet of methane

Total Potential Annual CH₄ = 1.2 billion scf

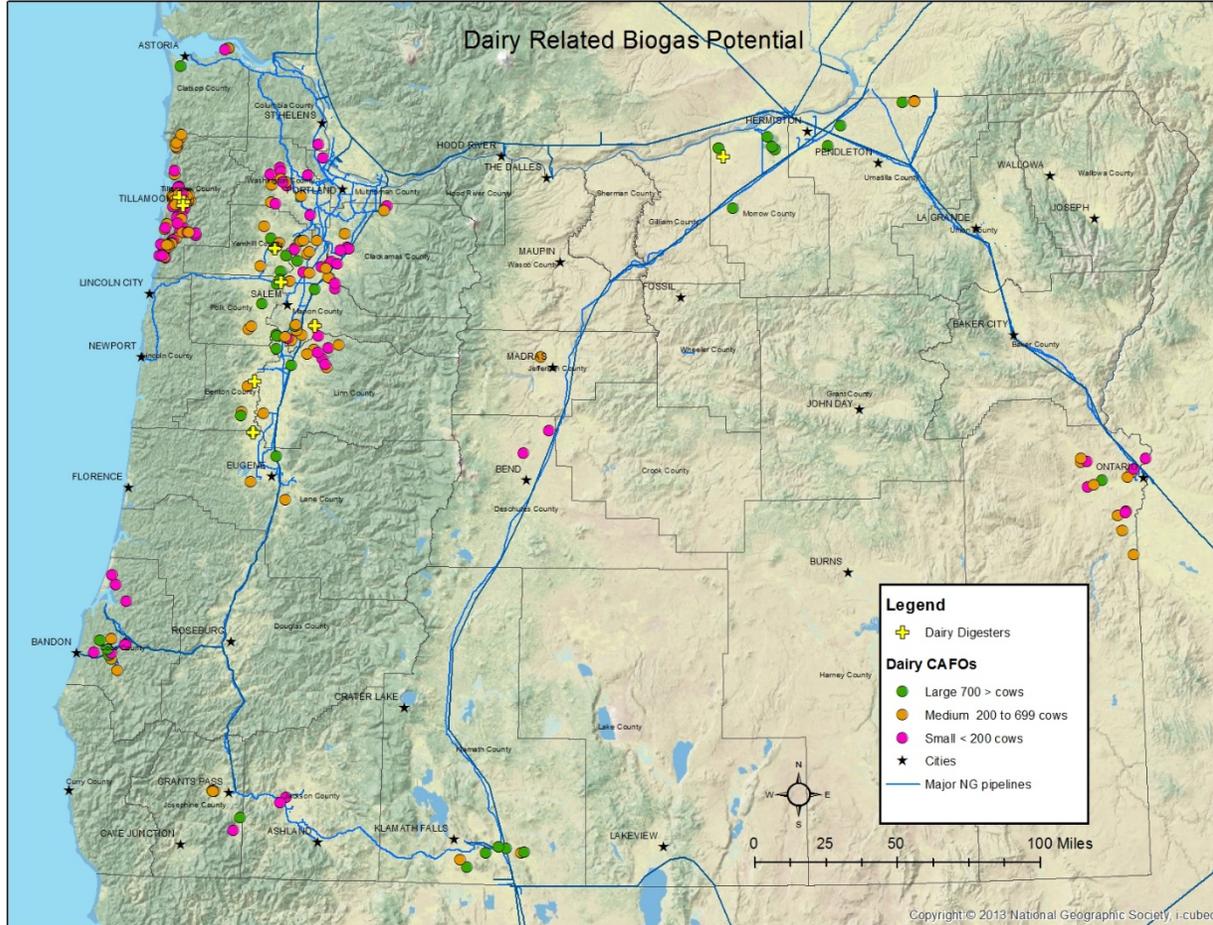
AD Pathway: Landfill



ODEQ Materials Management Program Data		ODOE Landfill Operator Survey Data	
Annual Cubic Feet of Modelled Methane Collected	Annual Cubic Feet of Reported Methane Collected	Annual Cubic Feet of Methane at 50% Methane Content	Annual Cubic Feet of Methane at 55% Methane Content
891,581,363.62	288,804,727.66	525,600,000	578,160,000
1,526,004,295.01	445,316,612.52	1,681,920,000	1,850,112,000
-	66,399,284.76	N/A	N/A
757,038,848.65	93,530,996.66	451,945,000	497,139,500
382,689,204.86	102,758,665.57	Unknown	Unknown
304,764,113.89	-	252,288,000	277,516,800
146,489,192.32	67,083,332.84	210,765,600	231,842,160
961,658,108.59	256,546,737.90	762,120,000	838,332,000
255,772,748.86	180,862,626.58	9,900,000	10,890,000
-	50,651,165.32	Closed	Closed
515,355,662.50	222,391,219.33	6,250,000	6,875,000
54,886,805.40	2,731,977.90	42,213,600	46,434,960
161,613,317.25	87,230,221.17	12,500,000	13,750,000
-	147,510,475.98	Unknown	Unknown
5,957,853,661 in cubic feet of annual methane	2,011,818,044 in cubic feet of annual methane	3,955,502,200 in cubic feet of annual methane	4,351,052,420 in cubic feet of annual methane

Total Potential Annual CH₄ = 4.4 billion scf

AD Pathway: Agricultural Dairy Manure



County	Manure		Volatile Solids		Methane Potential	
	Gross Manure Produced (lbs/yr)	Capturable Manure Produced (lbs/yr)	Gross Volatile Solid Produced (lbs/AU/day)	Capturable Volatile Solid Produced (lbs/AU/day)	Annual Cubic Feet of Methane Potential from Gross Volatile Solids	Annual Cubic Feet of Methane Potential from Capturable Volatile Solids
BAKER	-	-	-	-	-	-
BENTON	87,962,242	80,283,028	10,198,983	9,222,969	39,164,096	35,416,202
CLACKAMAS	91,783,032	60,380,837	11,155,878	6,988,244	42,838,572	26,834,859
CLATSOP	77,698,056	28,349,626	9,440,570	3,349,573	36,251,788	12,862,361
COLUMBIA	8,956,959	3,855,845	1,101,315	462,641	4,229,048	1,776,540
COOS	195,588,602	97,579,704	23,851,690	11,478,224	91,590,488	44,076,380
CROOK	1,665,872	245,581	198,722	28,833	763,094	110,719
CURRY	-	-	-	-	-	-
DESCHUTES	17,242,144	9,734,625	1,907,125	1,044,959	7,323,360	4,012,642
DOUGLAS	-	-	-	-	-	-
GILLIAM	-	-	-	-	-	-
GRANT	-	-	-	-	-	-
HARNEY	-	-	-	-	-	-
HOOD RIVER	-	-	-	-	-	-
JACKSON	9,530,439	5,621,186	1,120,506	638,371	4,302,744	2,451,346
JEFFERSON	12,533,124	4,355,240	1,488,361	462,084	5,715,304	1,774,402
JOSEPHINE	88,264,820	56,470,578	10,788,004	6,827,734	41,425,935	26,218,499
KLAMATH	361,005,183	309,681,371	44,938,670	37,510,529	172,564,494	144,040,430
LAKE	-	-	-	-	-	-
LANE	140,923,890	133,644,583	16,638,060	15,659,804	63,890,149	60,133,647
LINCOLN	-	-	-	-	-	-
LINN	164,627,857	115,568,991	20,429,725	14,527,676	78,450,145	55,786,277
MALHEUR	193,806,731	178,410,747	23,918,339	21,817,613	91,846,421	83,779,634
MARION	689,274,450	600,225,612	84,568,547	73,089,849	324,743,221	280,665,019
MORROW	2,193,859,287	2,193,859,287	253,509,870	253,509,870	973,477,902	973,477,902
MULTNOMAH	1,361,222	857,756	150,563	94,875	578,160	364,320
POLK	258,192,012	253,176,449	31,472,079	30,854,104	120,852,785	118,479,757
SHERMAN	-	-	-	-	-	-
TILLAMOOK	1,449,499,134	1,021,469,148	172,390,469	119,191,135	661,979,401	457,693,960
UMATILLA	136,336,107	99,815,765	16,282,050	11,944,147	62,523,070	45,865,523
UNION	-	-	-	-	-	-
WALLOWA	-	-	-	-	-	-
WASCO	-	-	-	-	-	-
WASHINGTON	121,083,205	105,404,730	14,504,770	12,414,338	55,698,316	47,671,057
WHEELER	-	-	-	-	-	-
YAMHILL	404,675,664	290,686,782	47,138,409	33,851,276	181,011,489	129,988,899
TOTAL	6,705,870,032	5,649,677,471	797,192,704	664,968,848	3,061,219,983	2,553,480,375

Results begin on page 12 in the report, appendix B for tech details

Total Potential Annual CH₄ = 2.6 billion scf

AD Pathway: Ag Manure, Feedlot Beef & Chicken

Feedlot Beef Cattle Methane Potential

County	Manure lb/yr	VS lb/yr	CH ₄ -cf ³ /yr
CLACKAMAS	7,041,580	465,828	2,464,228
JACKSON	2,856,490	188,968	999,640
LANE	1,660,750	109,865	581,186
LINN	62,244,910	4,117,740	21,782,846
MARION	42,780,920	2,830,122	14,971,347
POLK	20,759,375	1,373,313	7,264,823
WASHINGTON	5,447,260	360,357	1,906,290
YAMHILL	145,016,690	9,593,412	50,749,148
COOS	13,950,300	922,866	4,881,961
TILLAMOOK	51,748,970	3,423,393	18,109,751
BAKER	178,530,625	11,810,488	62,477,479
CROOK	79,250,990	5,242,758	27,734,189
GILLIAM	14,049,945	929,458	4,916,832
HARNEY	830,375	54,933	290,593
JEFFERSON	63,473,865	4,199,040	22,212,923
KLAMATH	61,447,750	4,065,005	21,503,876
LAKE	141,761,620	9,378,076	49,610,024
MORROW	1,612,621,465	106,681,112	564,343,084
MALHEUR	1,497,265,770	99,051,014	523,979,862
UMATILLA	886,906,930	58,672,305	310,376,491
WALLOWA	42,481,985	2,810,347	14,866,734
totals	4,932,128,565	326,280,399	1,726,023,309



Broiler Chicken Methane Potential

County	Manure - lbs	VS - lbs	CH ₄ - cf ³
CLACKAMAS	37,152,228	7,177,135	34,522,019
LANE	8,698,577	1,680,407	8,082,757
LINN	92,601,906	17,889,005	86,046,112
MARION	30,610,074	5,913,310	28,443,020
POLK	39,270,068	7,586,263	36,489,925
YAMHILL	27,694,829	5,350,137	25,734,161
total	236,027,682	45,596,257	219,317,995



Laying Chicken Potential Methane Production

County	Manure - lb	VS - lb	CH ₄ - cf ³
CLACKAMAS	87,981,994	16,978,981	92,535,448
LANE	13,144,474	2,536,653	13,824,758
MARION	57,217,828	11,042,037	60,179,101
total	158,344,296	30,557,671	166,539,308

Total Potential Annual CH₄ = 2.1 billion scf

AD Pathway: Waste Food

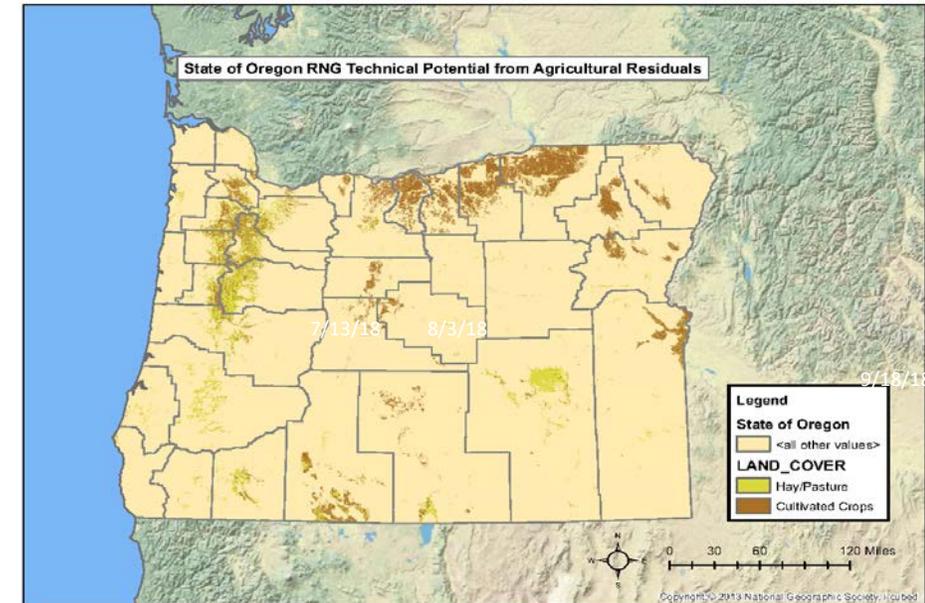
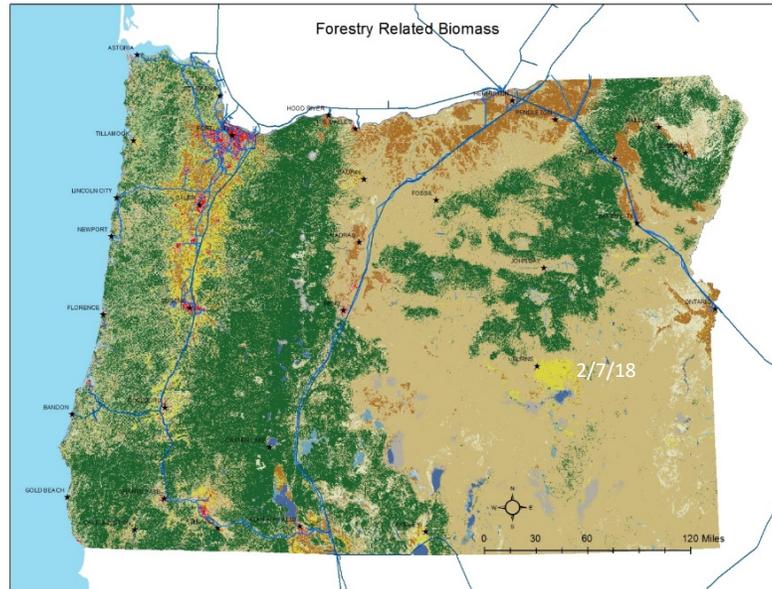


	Food Waste (tons)			CH ₄ (cubic feet)		
	Disposed	Recovered	Generated	Disposed	Recovered	Generated
Washed						
Baker	1,776	2	1,778	5,861,009	5,422	5,866,431
Benton	9,402	459	9,861	31,027,024	1,515,410	32,542,433
Clatsop	4,932	32	4,963	16,274,510	104,511	16,379,021
Columbia	4,006	11	4,016	13,218,901	35,218	13,254,118
Coos	6,494	71	6,566	21,430,630	235,877	21,666,507
Crook	2,591	0	2,591	8,550,726	0	8,550,726
Curry	2,622	0	2,622	8,652,223	0	8,652,223
Deschutes	22,086	790	22,876	72,883,023	2,606,974	75,489,997
Douglas	11,411	11	11,422	37,656,693	36,211	37,692,904
Gilliam	300	0	300	989,051	0	989,051
Grant	584	0	584	1,926,852	0	1,926,852
Harney	596	1	597	1,966,060	2,435	1,968,496
Hood River	2,852	62	2,914	9,413,098	203,481	9,616,579
Jackson	25,146	679	25,825	82,982,795	2,240,799	85,223,594
Jefferson	1,900	2	1,902	6,270,063	7,356	6,277,419
Josephine	9,525	191	9,716	31,432,444	629,072	32,061,516
Klamath	8,103	0	8,103	26,740,854	0	26,740,854
Lake	909	1	910	2,998,161	3,686	3,001,847
Lane	42,953	3,231	46,184	141,746,256	10,661,039	152,407,295
Lincoln	6,699	90	6,789	22,106,793	295,667	22,402,460
Linn	14,079	220	14,298	46,460,103	724,934	47,185,037
Malheur	3,213	177	3,390	10,601,791	583,721	11,185,512
Marion	37,812	2,959	40,772	124,780,981	9,766,129	134,547,110
Metro	175,087	32,071	207,158	577,787,227	105,833,208	683,620,435
Milton-Freewater	650	13	663	2,146,178	41,293	2,187,471
Morrow	2,554	0	2,554	8,428,659	0	8,428,659
Polk	6,551	495	7,046	21,619,174	1,632,814	23,251,987
Sherman	204	0	204	672,972	0	672,972
Tillamook	3,546	3	3,548	11,701,338	8,451	11,709,790
Umatilla	10,942	242	11,184	36,107,642	798,824	36,906,467
Union	3,110	157	3,267	10,263,953	517,618	10,781,571
Wallowa	595	1	596	1,963,569	2,327	1,965,895
Wasco	2,687	3	2,690	8,867,078	8,676	8,875,754
Wheeler	64	0	64	211,468	0	211,468
Yamhill	11,789	21	11,810	38,903,514	70,505	38,974,019
				0	0	0
OR. TOTALS	437,771	41,991	479,762	1,444,642,814	138,571,656	1,583,214,471

Total Potential Annual CH₄ = 138.6 million scf

Thermal Gasification: Forest and Ag Residuals

Forestry and Agriculture Related Biomass



Source – Thermal Gasification	Annual CH ₄ production scf ³
Forest Harvest Residuals	16,998,108,771
Agricultural Harvest Residuals	22,686,775,137

Total Potential Annual CH₄ = 39.7 billion scf

Annual Potential Production of CH₄ – Summary

Source – Anaerobic Digestion	Annual CH ₄ Production scf ³
Agricultural Manure	4,639,626,825
Waste Water	1,225,228,606
Landfill	4,351,052,420
Waste Food	138,571,656
Subtotal	10,354,479,507

Source – Thermal Gasification	Annual CH ₄ Production scf ³
Forest Harvest Residuals	16,998,108,771
Agricultural Harvest Residuals	22,686,775,137
Subtotal	39,684,883,908

Context: In 2016, Oregon consumed ~226,978,752,000 cf of methane.

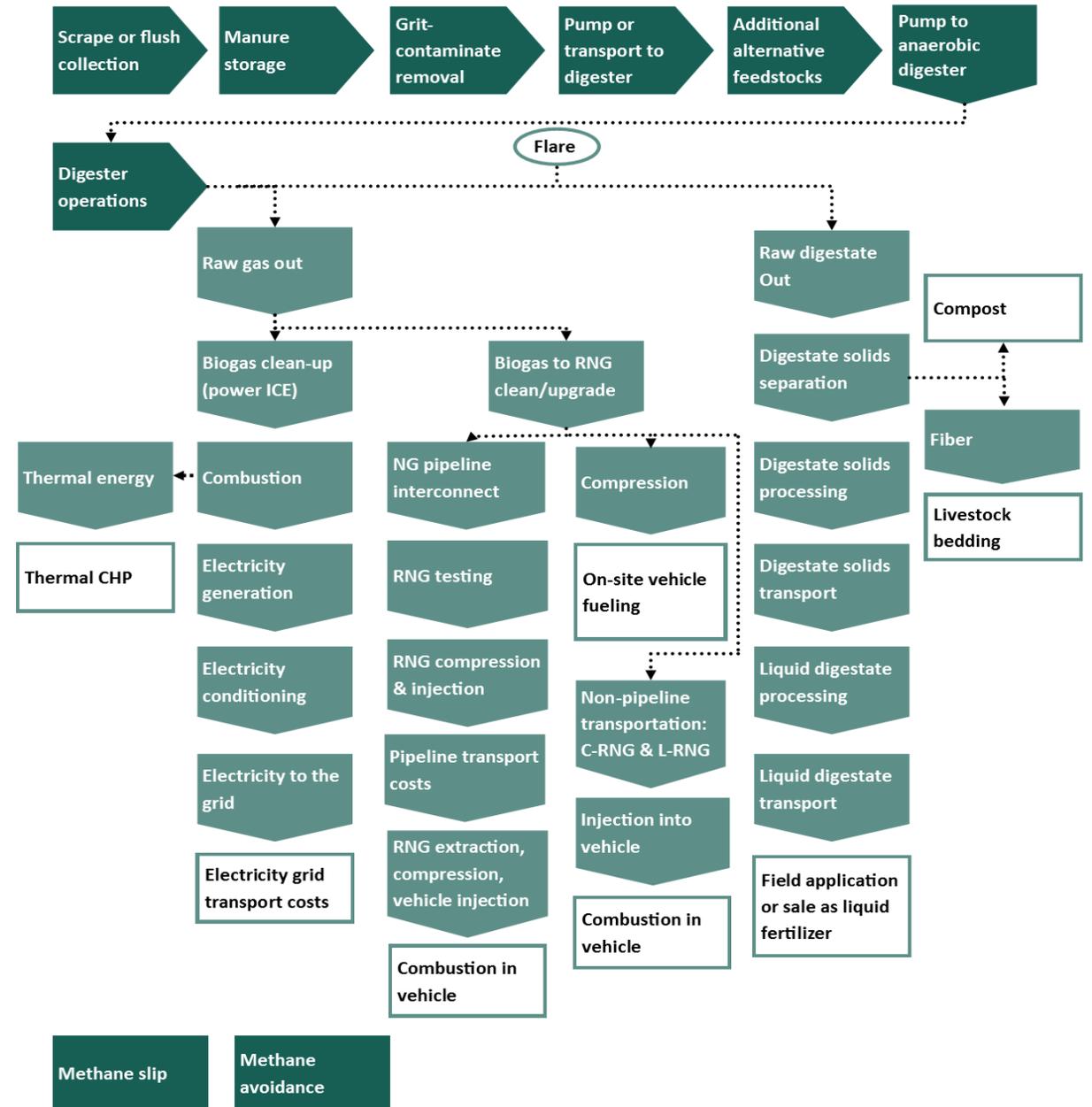
Estimated technical potential for RNG is 22% of Oregon's natural gas consumption (4.5% AD, 17.5 TG).

Supply Chains – Anaerobic Digestion: Agricultural Manure

- ODOE has mapped out supply chain models for each feedstock.
- The next phase is to add economic costs and carbon intensity values at each step.

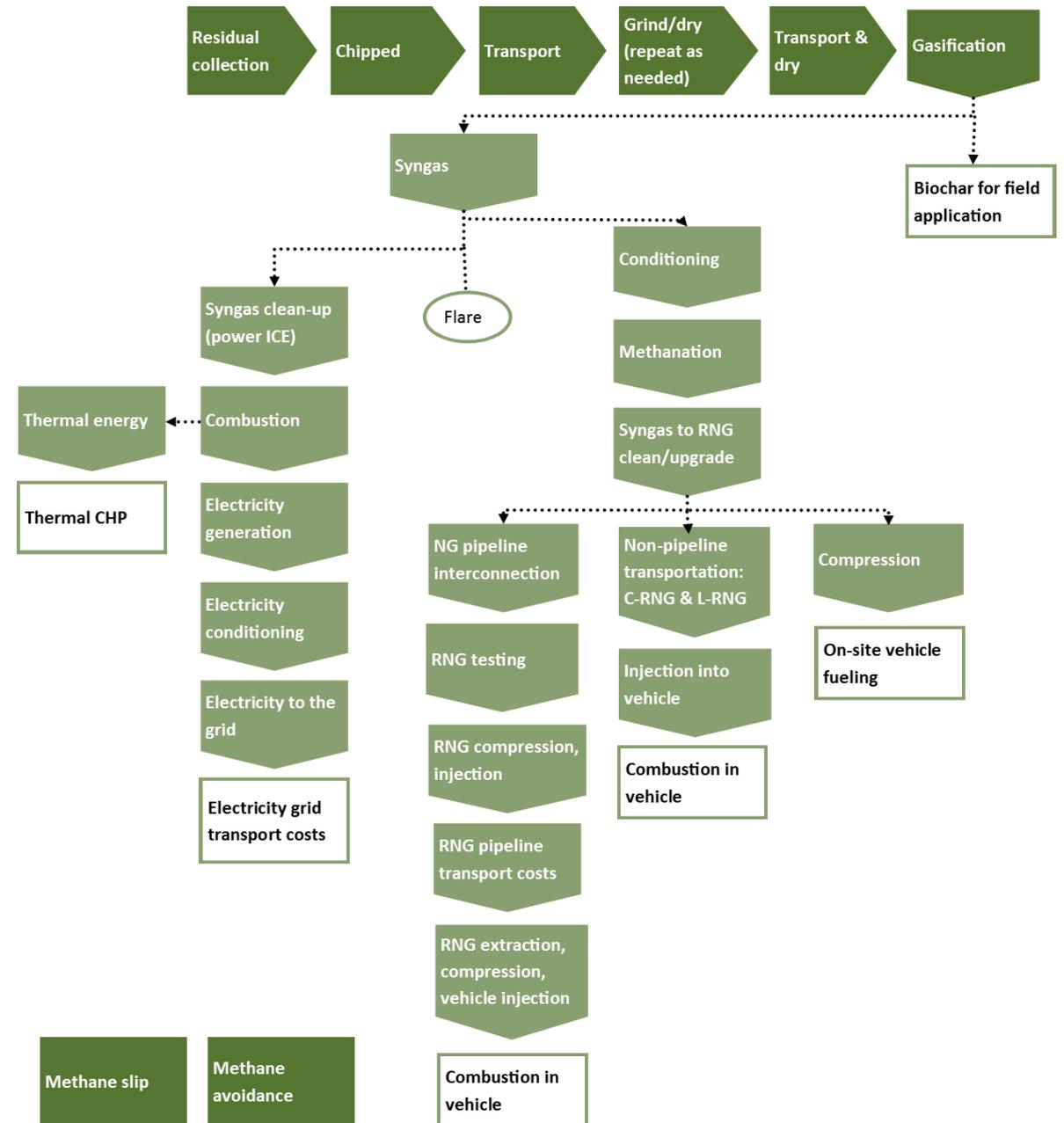
Supply chains begin on page 27 in the report

Carbon Intensity: The average Carbon Intensity (in gCO₂e/MJ) for this pathway is -264.



Supply Chains – Thermal Gasification: Forest and Agricultural Harvest Residuals

Carbon Intensity: The average Carbon Intensity (in gCO₂e/MJ) for this pathway is undetermined.



GHGs and Air Pollution

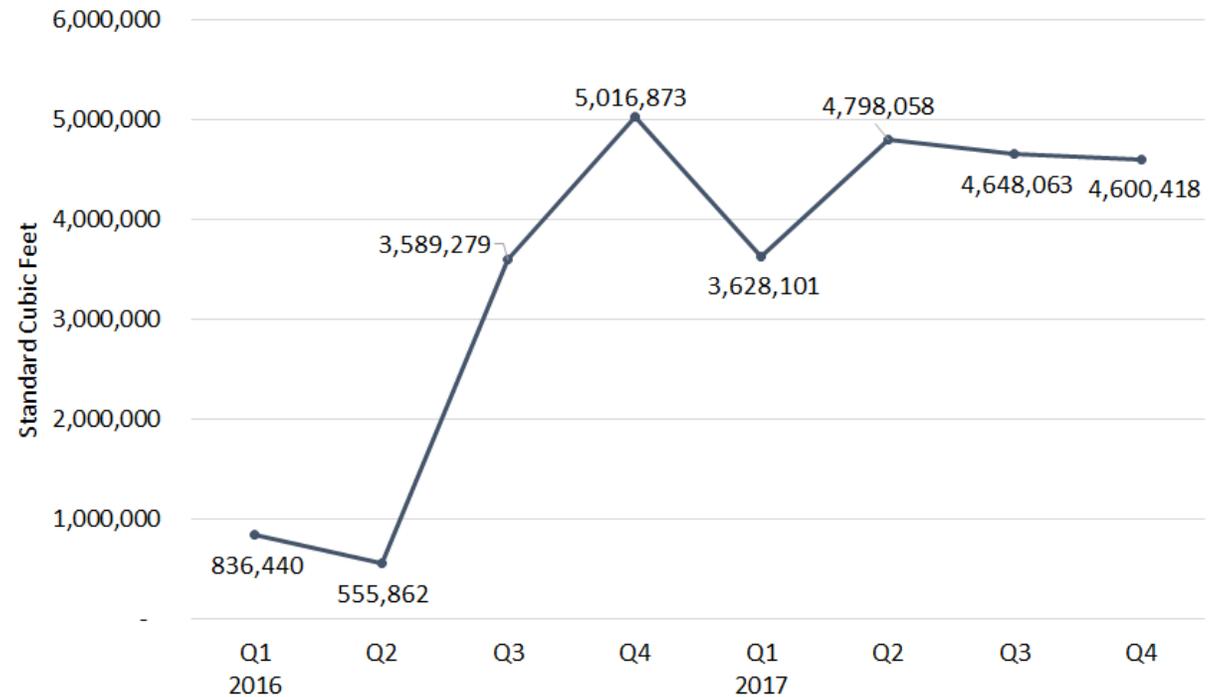
RNG as an Alternative Stationary Fuel: RNG production prevents methane from sources like landfills and animal waste from being directly emitted to the atmosphere. The combustion of captured gas results primarily in carbon dioxide, a GHG that is at least 25 times less potent in the atmosphere than methane. Approximately **2 million metric tons** of fossil fuel-based carbon dioxide could be prevented from entering the atmosphere if the potential RNG volume in Oregon could be captured and used to displace fossil fuel natural gas.

RNG as an Alternative Transportation Fuel: RNG used as an alternative to diesel fuel can produce significant reductions in air pollutants. The analysis shows **reductions of 20 percent or more** for GHGs, CO₂, fine particulate matter (PM_{2.5} and PM₁₀), **and greater than 30 percent decrease** in the amount of organic carbon emissions. When used as an alternative for an equivalent amount of diesel fuel, the state's total RNG production potential from anaerobic digestion alone would reduce net GHG emissions by **2.3 million MTCO₂e**.

Markets: Transportation & Stationary

- The current driver in the RNG market is its use as a transportation fuel.
- Once in the pipeline, RNG can be traded in multiple markets around the US.
- As a traded commodity, its value is multiplied by various state and federal market credits.

See chapter 5, page 37 in the report



Oregon Department of Environmental Quality Clean Fuels Program Quarterly Data Summary. 2016-2017.

Potential Barriers

Finance Barriers

- Access to financing
- Gas upgrading costs to remove impurities, and increase heat content of biogas
- Interconnection costs, testing, verification, and pipeline construction costs

Information Barriers

- The perception of risk due to unfamiliarity with biomass technologies and fuel supply chains

Market Barriers

- Lack of natural gas vehicles, fleets, and fueling infrastructure

Policy/Regulatory Barriers

- Existing policy prevents Oregon utilities from making ratepayer-funded capital investments in RNG infrastructure, such as extension of pipelines or connection points for RNG producers, as well as the requirement for utilities to purchase the least-cost resource
- Lack of policy encouraging or mandating the source separation of wastes (such as food wastes)
- Lack of financial incentives for natural gas fueling infrastructure

Recommendations

1. Allow natural gas companies to buy and sell RNG to and for their customers.
2. Allow local gas distribution companies to recover pipeline interconnection costs through their rates.
3. Study how best to expand natural gas transportation fueling infrastructure.
4. Explore development of voluntary gas quality standards for injection of RNG into the natural gas pipeline.
5. Explore financial incentives to help drive the nascent industry forward.
6. Coordinate with RNG stakeholders and state agencies to develop a tracking and accounting protocol for production and use of RNG.

See chapter 6, page 43 in the report

Proposed Next Steps

1. Practical Statewide RNG Potential
2. Lifecycle Economic Analysis of RNG Production Pathways
3. Tracking and Accounting for RNG in Transportation & Stationary Fuel Use
4. Detailed Analysis of Market Economics & Drivers
5. More Comprehensive Feedstock Inventory and Other Biogas Production Pathways

See chapter 8, page 48 in the report