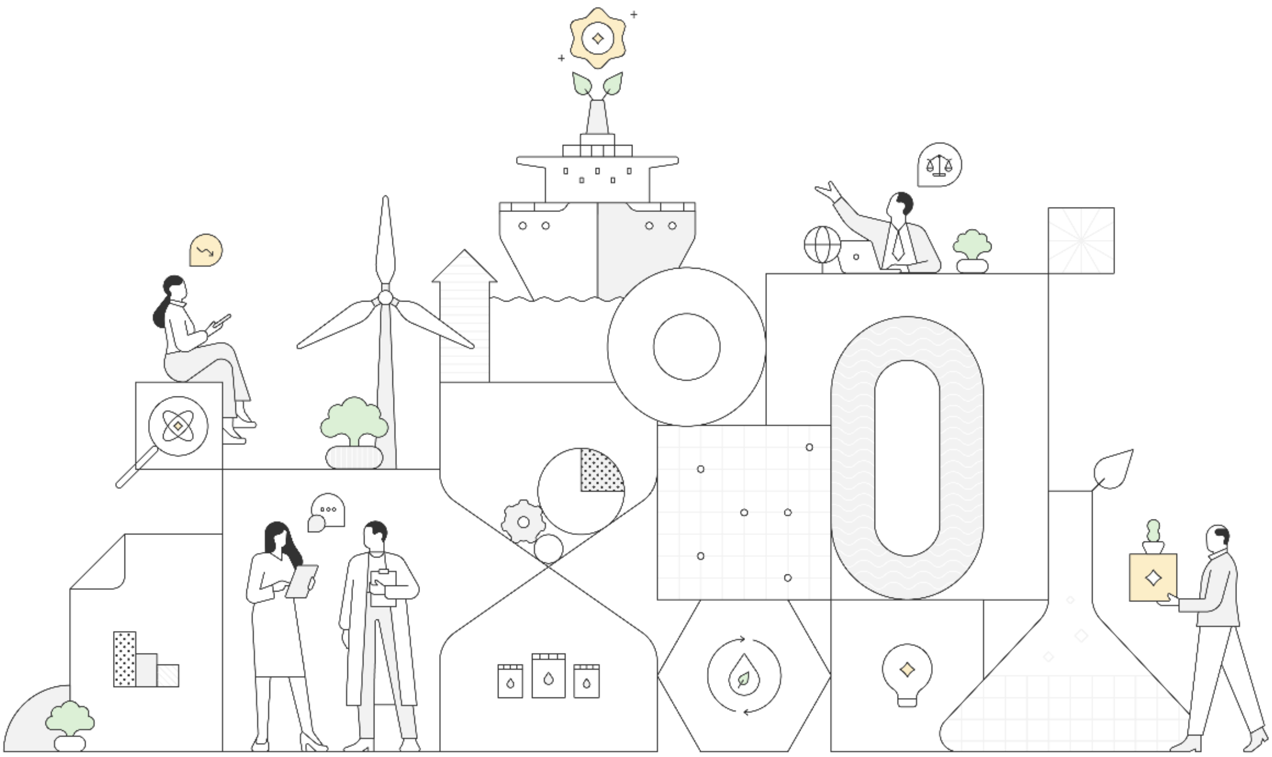
Appendices for Biomethane supply potential and its relevance for shipping by 2030



Mærsk Mc-Kinney Møller Center
for Zero Carbon Shipping

Appendix 1: 2030 biomethane production assessment

Each region's aggregate 2030 biomethane estimate is split by feedstock type. This is based on IEA regional feedstock shares, using feedstock-specific biogas potential estimates as shown in Table 3. This potential-based allocation is a simplifying assumption and does not necessarily reflect the realized commercial feedstock mix in 2030, which may tilt more strongly toward lower-cost feedstocks than technical potential alone would suggest.

Table 3: Share of feedstock potential per region.

	Crop residues	Manure	Biowaste	Woody biomass
Europe	35.0%	39.0%	18.0%	8.0%
India	56.0%	35.0%	9.0%	0.0%
China	23.1%	62.0%	14.8%	0.0%
North America	48.0%	11.0%	26.0%	15.0%
Southeast Asia	48.9%	25.7%	18.4%	6.7%
South America	53.0%	26.0%	9.0%	12.0%
Africa	54.0%	23.0%	14.0%	9.0%

Table 4: "Base" case - 2030 production (bcm) by feedstock.

	Crop residues	Manure	Biowaste	Woody biomass	Total
Europe	3.45	3.84	1.77	0.79	9.86
India	0.34	0.21	0.05	0.00	0.60
China	0.46	1.25	0.30	0.00	2.01
North America	3.86	0.88	2.09	1.21	8.05
Southeast Asia	0.00	0.00	0.00	0.00	0.00
South America	0.38	0.19	0.07	0.09	0.72
Africa	0.00	0.00	0.00	0.00	0.00
Total (bcm)	8.5	6.4	4.3	2.1	21.24

Table 5: "Max" case - 2030 production (bcm) split by feedstock.

	Crop residues	Manure	Biowaste	Woody biomass	Total
Europe	8.58	9.56	4.41	1.96	24.52
India	0.84	0.53	0.14	0.00	1.50
China	1.16	3.10	0.75	0.00	5.00
North America	9.61	2.20	5.21	3.00	20.02
Southeast Asia	0.00	0.00	0.00	0.00	0.00
South America	0.95	0.47	0.16	0.22	1.80
Africa	0.00	0.00	0.00	0.00	0.00
Total (bcm)	21.15	15.86	10.66	5.18	52.85

Appendix 2: Max case: policy-induced growth targets

In regions with strong policy support, notably the EU, higher growth rates relative to our base case are needed to achieve the announced targets. For instance, achieving the REPowerEU target[1] of 35 bcm by 2030 requires about 38% annual growth (CAGR) from 2024 onwards. Europe currently leads global biomethane deployment but faces structural constraints. For instance, the REPowerEU targets exceed biomethane potential with grid access within 20 km (30 bcm vs 35 bcm), requiring new grid connections or installing small liquefaction units at production sites. Table 9 in Appendix 7 quantifies biomethane potential with grid access within 20 km for all regions, including Europe.

China aims to reach 20 bcm of biomethane under its 14th Five-Year plan.[2] Similarly, India aims to targets 5% of renewables in total natural gas consumption by 2030.[3] Given India's projected gas demand of 105 bcm by 2030,[4] meeting this target would require about 5 bcm per year. These national policies require significantly higher annual growth rates of about 71% and 83% for India and China, respectively.

In 2024 Brazil adopted the Fuel of the Future Package,[5] which mandates annual replacement of 1% of fossil fuel gas consumption with renewable gas over the next ten years. This would require a renewable gas supply of approximately 2 bcm per year.

Table 6: Announced regional biomethane targets for 2030 and implied annual growth rates.

Region	Current production, bcm	Policy driven target by 2030 (bcm)	Growth rate required to meet policy target	Policies
Europe	4.9	35	38%	RePowerEU, Waste Framework Directive, RED II, national blending mandates
India	0.3	5.25	71%	Mandatory blending, GOBAR-Dhan scheme in India
China	1.0	20	83%	14th Five-Year plan target
North America	4	-	-	Renewable Fuel Standard, California Low Carbon Fuel Standard.
South America	0.36	1.6	29%	Fuel of the Future Package

Reaching many of these targets seems ambitious. Therefore, our max case biomethane scenario assumes that global biomethane production grows with the implicit EU policy target of 38% (CAGR). Assuming this global policy-driven growth rate of 38%, biomethane supply would reach 52.85 bcm (47.5 million tLSFOeq) by 2030, five times the current capacity.

[1] REPowerEU Plan, European Commission, 2022.
[2] Renewables 2023, International Energy Agency, 2024.
[3] India Gas Market Report. International Energy Agency, 2025.
[4] Gas 2025, International Energy Agency, 2025.
[5] Mapping Brazil's latest fuels policies, International Council on Clean Transportation, 2026.

Appendix 3: Emission factors and production cost estimates

Emission factors

We estimate well-to-wake emissions intensities as shown in Table 7. These emission factors suggest that biomethane can deliver substantial emissions reductions relative to fossil marine fuels, although the outcome varies by feedstock and region.

An important caveat is that some emissions from feedstock and fuel production may not be fully captured under the IMO LCA Guidelines, meaning the cost of addressing those emissions may also not be reflected in the production cost profile. This is particularly relevant for manure-based biomethane, where life cycle emissions depend strongly on how manure and digestate are managed. Our analysis reflects the assumed pathway embedded in the selected emission factors, including closed and effective digestion and digestate management. Actual emissions may be higher where methane losses occur outside that assumed configuration.

Production cost estimates

We base biomethane production costs on IEA regional estimates[6] by feedstock and add 7 USD/GJ for liquefaction at large-scale LNG terminals, consistent with a mass-balanced LBM pathway.

Table 7: WTW emissions estimates (gCO_2eq/MJ).

Region	Crop residues	Manure	Biowaste	Woody biomass
Europe	17.7	17.0	19.5	20.6
India	30.2	29.5	32.0	20.6
China	24.5	23.8	26.3	20.6
North America	20.3	19.5	22.0	20.6
Southeast Asia	25.7	25.0	27.5	20.6
Africa	29.8	29.1	31.6	20.6
South America	18.3	17.6	20.1	20.6

Table 8: Feedstock-specific biomethane production cost estimates (USD/GJ).

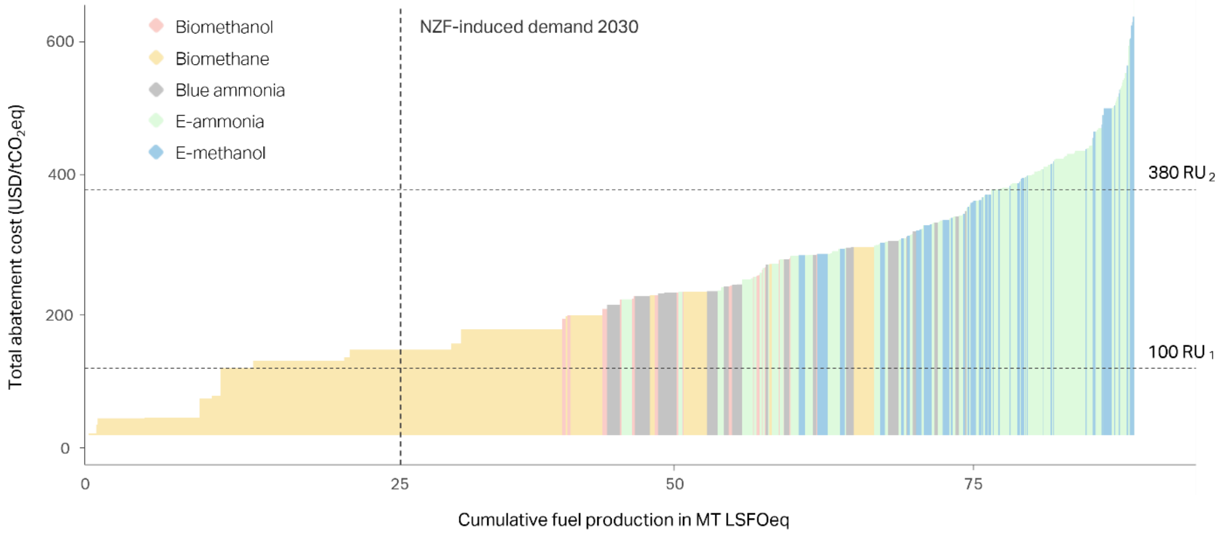
Region	Crop residues	Manure	Biowaste	Woody biomass
Europe	17	21	10	30
India	12	16	9	20
China	12	15	8	20
North America	14	18	10	23
Southeast Asia	18	25	10	22
Africa	19	25	22	28
South America	24	24	24	24

Notes: Using data from IEA (2025).

[6] Outlook for Biogas and Biomethane, International Energy Agency, 2025.

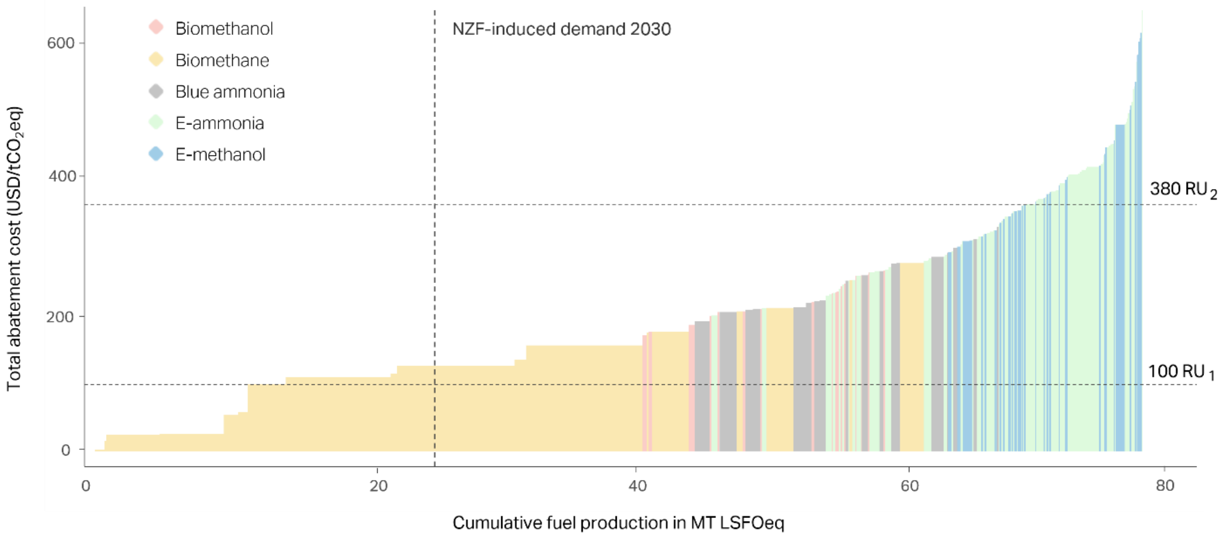
Appendix 4: Abatement cost curves under the max case scenario

Figure 3: Alternative fuel supply potential (max case, full pre-FID project pipeline).



Notes: Estimated potential supply for biomethanol, blue ammonia, e-ammonia, e-methanol and biomethane. Biomethane potential is based on the max case scenario. Each bar represents one fuel production project in pre-FID stages. Projects are ordered by abatement cost (bar height), with the bar width indicating the quantity of annual fuel production. Abatement cost, or cost per tonne of emissions reduced below LSFO, is shown across projects for five low-emissions marine fuels. The four pathways besides biomethane use full and non-risk weighted project-level data from Rystad Energy, which was combined with transport and storage costs but does not include rewards or Surplus Unit revenues from the IMO NZF. The projects included in this figure are taken from a broader dataset of projects filtered based on pre-FID status, with a start-up year or commercial operation date (COD) of 2030 or earlier, and production volume of over 100,000 tonnes LSFOeq per year.

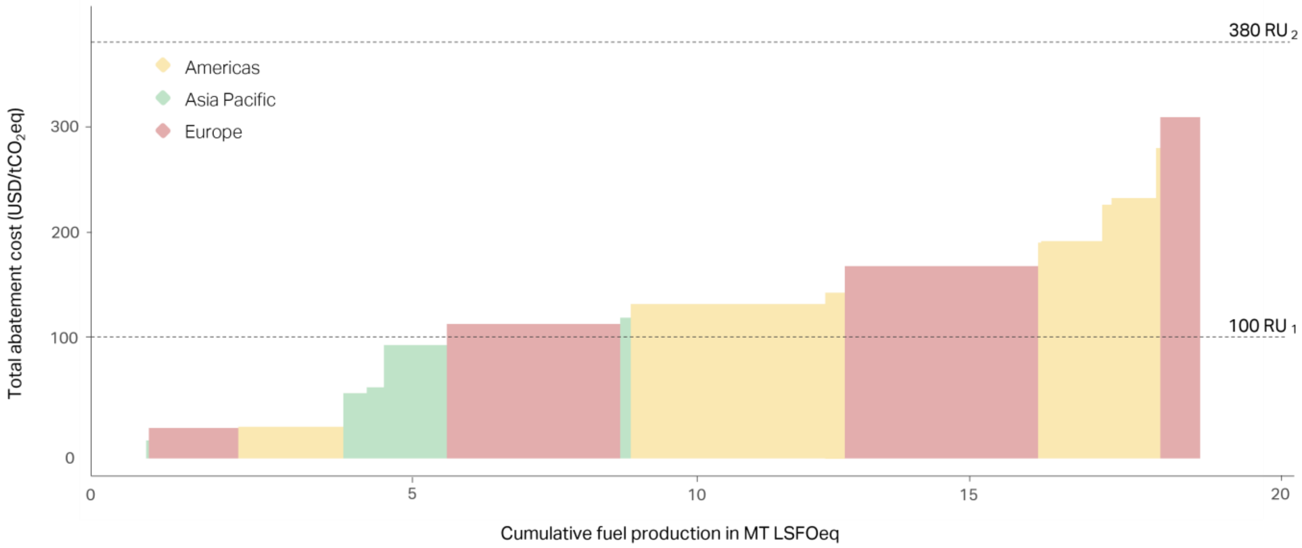
Figure 4: Alternative fuel supply potential (max case, pre-FID project pipeline excluding concept and announced phases).



Notes: Estimated potential supply for biomethanol, blue ammonia, e-ammonia, e-methanol and biomethane. Biomethane potential is based on the max case scenario. Each bar represents one fuel production project in pre-FID stages (excluding projects in the 'concept' or 'announced' phase). Projects are ordered by abatement cost (bar height), with the bar width indicating the quantity of annual fuel production. Abatement cost, or cost per tonne of emissions reduced below LSFO, is shown across projects for five low-emissions marine fuels. The four pathways besides biomethane use full and non-risk weighted project-level data from Rystad Energy, which was combined with transport and storage costs but does not include rewards or Surplus Unit revenues from the IMO NZF. The projects included in this figure are taken from a broader dataset of projects filtered based on pre-FID status, with a start-up year or commercial operation date (COD) of 2030 or earlier, and production volume of over 100,000 tonnes LSFOeq per year.

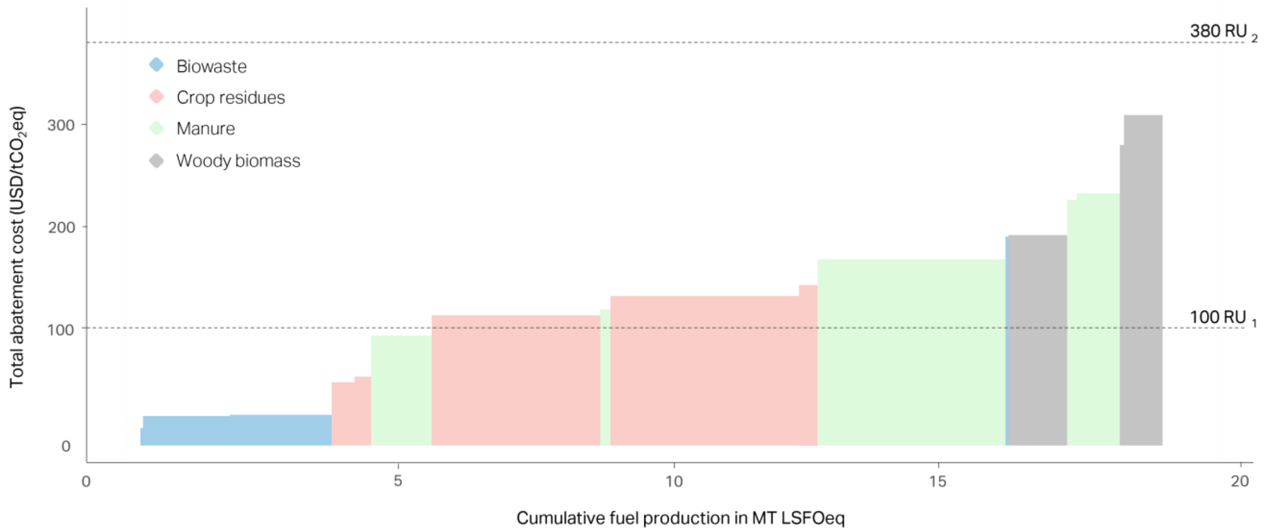
Appendix 5: Regional and feedstock-specific biomethane dynamics

Figure 5: Alternative fuel supply potential (base case, full pre-FID project pipeline).



Notes: This figure decomposes 2030 biomethane production under the base case scenario, split by region. Supply potential is ordered by abatement cost (bar height), with the bar width indicating the quantity of annual fuel production. Abatement cost, or cost per tonne of emissions reduced below LSFO, is shown. Cost estimates follow IEA (2025), as expressed in Appendix 3. Costs do not include rewards or surplus unit revenues from the IMO NZF.

Figure 6: Alternative fuel supply potential (base case, full-pre-FID project pipeline).

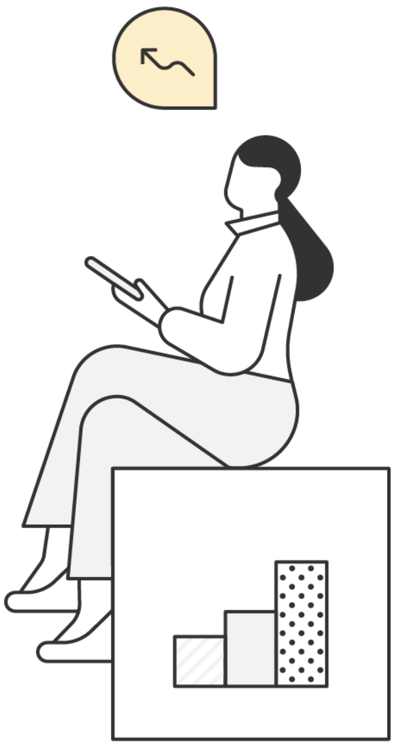


Notes: This figure decomposes 2030 biomethane production under the base case scenario, split by feedstock. Supply potential is ordered by abatement cost (bar height), with the bar width indicating the quantity of annual fuel production. Abatement cost, or cost per tonne of emissions reduced below LSFO, is shown. Cost estimates follow IEA (2025), as expressed in Appendix 3. Costs do not include rewards or surplus unit revenues from the IMO NZF.

Appendix 6: Methodology revisions for the abatement cost curve

This article uses an updated version of the abatement cost curve presented in our earlier newsletter.[7] The main methodological changes are:

- **Project pool updated:** The status and plans for each project have been reviewed and updated; new projects have been added, while projects that were discontinued, cancelled, or progressed from pre-FID to FID have been removed from the pool.
- **Production cost assumptions revised:** Minor updates to the CapEx and OpEx assumptions affect the estimated production costs of some pathways and therefore their relative abatement costs compared with the earlier published curve.
- **Electricity cost inputs updated:** In this article, 2030 LCOE estimates are derived from IRENA,[8] using 2024 country-level LCOE data as a starting point and applying assumptions on learning effects and risk factors. The earlier newsletter used a different LCOE assessment.



[7] Countdown: The potential fuel supply waiting for a market, Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping, 2026.
[8] Renewable Power Generation Costs, IRENA, 2025.

Appendix 7: Feedstock potential within natural gas grid proximity

In a mass-balancing framework, grid access determines which biomethane volumes can participate without requiring decentralized liquefaction. At the same time, grid access does not appear to be the binding constraint on our 2030 supply cases. According to the IEA,[6] around 30% of the total global biomethane potential (840 bcm) lies within 20 km of an existing natural gas grid. That implies roughly 251 bcm per year of near-term infrastructure-compatible potential (Table 9): still far above the supply volumes we project for 2030.

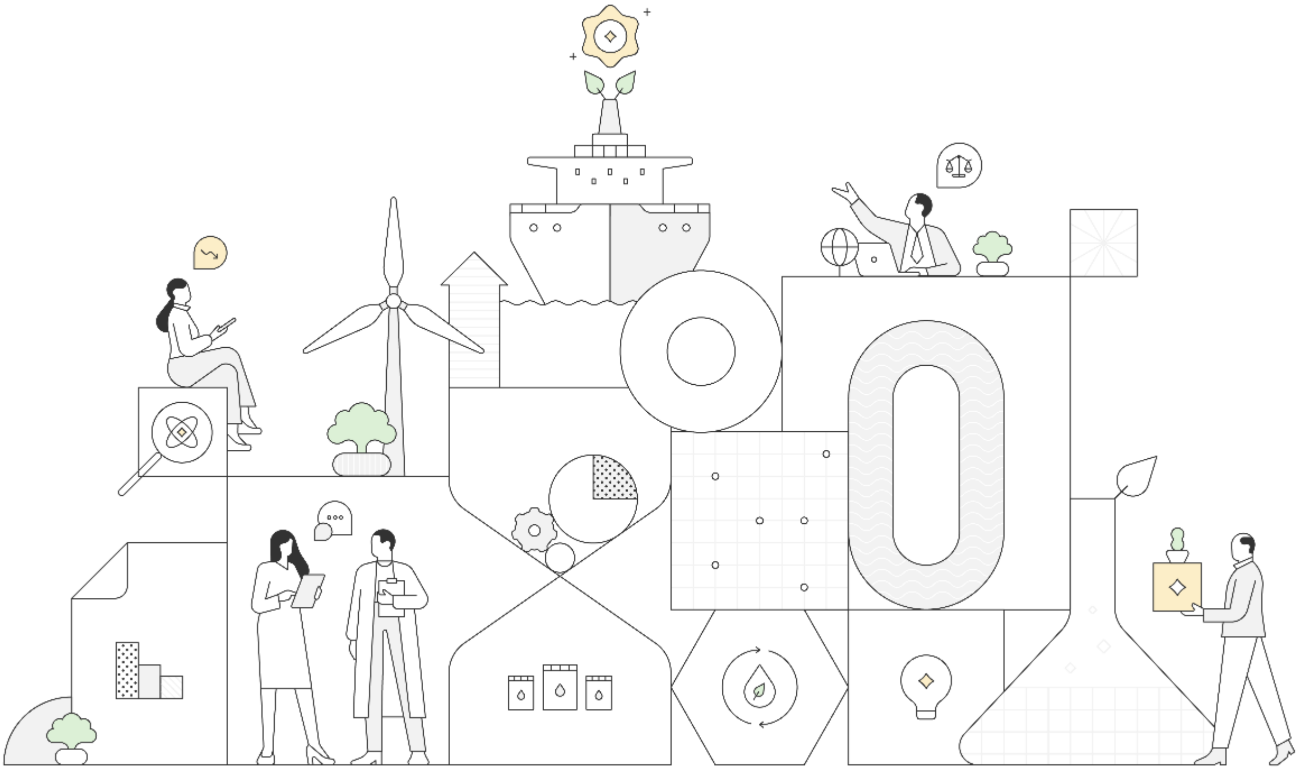
In other words, while grid connection is important in determining whether supply can flow efficiently into a mass-balanced system, the amount of feedstock close to the grid does not appear to constrain near-term biomethane deployment at the levels considered here.

Table 9: Feedstock potential less than 20 km away from a natural gas transmission grid.

Region	Crop residues	Manure	Biowaste	Woody biomass	Total potential within 20 km from gas grid
Europe	10.7	11.9	5.5	2.4	30.6 (60%)
India	16.1	10.0	2.5	0	28.7 (25%)
China	14.6	30.2	14.5	1.3	60.7 (50%)
North America	40.3	9.2	21.8	12.6	84.0 (60%)
Southeast Asia	7.8	4.1	3.0	1.1	16.1 (20%)
Africa	6.4	2.7	1.6	1.0	12.0 (10%)
South America	10.0	4.9	1.7	2.2	19.0 (10%)

Notes: Biomethane potential less than 20 km away from natural gas transmission grid, denoted in bcm. Parentheses in the last column represent how much this feedstock potential within natural gas grid proximity is as share of total regional feedstock potential. Data source: Outlook for Biogas and Biomethane, IEA, 2025.

[6] Outlook for Biogas and Biomethane, International Energy Agency, 2025.



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