Biogases Geospatial Resource Assessment Model

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Biogases supply potential estimates

The Biogases Geospatial Resource Assessment Model (Bio-GRAM) estimates the supply potential for biogases within the framework of the IEA's Global Energy and Climate Model (GEC). It is a geospatial model, which uses disaggregated data on 0.125° per 0.125° cells. It assesses the sustainable amount of biomethane that can be produced from crop residues, animal manure and biowaste (including municipal solid waste and wastewater). Its primary output is a supply cost curve, built by identifying prospective locations for digesters near feedstock sources, accounting for proximity to infrastructure such as gas pipelines and roads, and computing the associated procurement and capital costs.

This note presents the methodology and some of its parameters.

Data sources

Geospatial feedstock quantities are the main input of Bio-GRAM. They are translated into biomethane potential using species-level conversion factors drawn from the literature. The model draws on the following main inputs:

Agricultural feedstocks — FAO geospatial data for crops (33 species) and livestock heads (6 species), representing the 2020 reference year. National totals are then scaled using the FAO-OECD Agricultural Outlook 2025–2034 to project forward.

Wastewater — The HydroWASTE dataset, covering predominantly municipal wastewater treatment plants.

Municipal solid waste (MSW) — National production volumes and availability rates from the World Bank's What a Waste 3.0 database, spatially disaggregated using the Global Human Settlement Layer and WorldPop datasets.

Global Energy Monitor – Global gas infrastructure tracker

Crop residues potential

The FAO provides geospatial data on dry crop production. Crop output is converted into dry above-ground residue potential using crop-specific residue-to-product ratios. To reflect sustainable removal limits, the model assumes that 60% of above-ground residues are left on the field to maintain soil quality. For maize, rice and sunflower, the share left on the field is increased to 50% .

For crops that generate multiple residue streams, such as maize, rice, sugar beet, sugar cane, sunflower and palm, each residue type is assessed separately to reflect differences in moisture content, ash content and methane yield. Below-ground residues, such as roots, are excluded from this analysis. Dry residues are converted to fresh-matter quantities by applying crop-specific moisture content assumptions. A share of recovered residues is assumed to be used locally as animal feed or bedding. Stable-housed animals are assumed to require residues for part of their lifetime — 40% for cattle and sheep, up to 80% for pigs and 90% for poultry — with residues meeting 30% of these needs on average. As a result, residue availability for anaerobic digestion varies spatially depending on local livestock density.

No chemical pre-treatment is assumed, although such treatment could increase methane yields. Residues generated during industrial processing, such as sugar beet bagasse, are assigned back to the original crop production cell, reflecting the proximity of processing facilities to production areas. Animal manure potential

The FAO provides spatial distribution of livestock population by species. Animal headcounts are converted into manure production using species-specific factors from the literature (from around 30 kg per head per year for poultry to about 10 000 kg per head per year for cattle). To reflect practical constraints on collection from grazing and dispersed animal, the model assumes that, on average, 65% of total manure production is technically recoverable for anaerobic digestion. No competing uses are deducted from this recoverable manure potential.

Municipal solid waste potential

Municipal solid waste (MSW) includes food waste, garden waste, paper and cardboard. National waste quantities are sourced from the World Bank and spatially allocated using a proxy based on both population and housing density, with each grid cell assigned a share of waste proportional to the square root of the product of these two variables. This approach captures population distribution and the concentration of urban activity. To avoid overestimating waste potential in dense urban centres, where large-scale waste treatment facilities are rarely located, a portion of the waste is redistributed to surrounding areas.

The quantity of MSW available for biogas production is then estimated by applying country-specific collection rates, differentiated between urban and rural areas where data allows. Waste streams directed to recycling, incineration or composting are excluded using World Bank assumptions. The remaining collected organic fraction is assumed to be available feedstock for anaerobic digestion.

Wastewater potential

Wastewater data are drawn from HydroWASTE, which reports the annual volume of treated wastewater discharged by wastewater treatment plants around the world. Treated wastewater is converted into sewage sludge potential using two sludge streams, each with different physicochemical characteristics. Primary sludge is the solid material that settles during the first physical treatment stage, before most biological treatment takes place. Secondary sludge, also called biological or waste activated sludge, is the excess microbial biomass produced during biological treatment of the remaining organic matter in wastewater.

In the model, dry primary sludge production is assumed to be 150 kg per megalitre of treated wastewater, while dry secondary sludge production is assumed to be 70 kg per megalitre. The two sludge streams are combined to estimate the total dry sewage sludge available for anaerobic digestion. Methane yields are based on values reported by IEA Bioenergy Task 37. No competing uses of sewage sludge are considered.

Main conversion parameters, averaged by feedstock group

Feedstock group	Dry residue per dry product (Mt/Mt)	Moisture content of the residue	Ash content of the residue	Availability after other uses			Methane yield (Nm^3/t VS)
	World	World	World	ADV	World	EMDE	World
Wheat	1.3	14%	15%	50%	46%	43%	180
Maize	1.0	10%	*7%*	37%	44%	50%	247
Rice	1.4	15%	15%	24%	32%	40%	199
Other coarse grains	0.6	63%	8%	63%	49%	37%	207
Sugar crops	0.3	54%	11%	24%	28%	32%	191
Soybean	1.5	13%	10%	23%	29%	34%	240
Pulses	1.5	12%	10%	95%	97%	100%	280
Other oil seeds	0.9	23%	8%	53%	57%	60%	214
Roots and tubers	0.3	74%	9%	100%	100%	100%	249
Wastewater	0.00023	n/a	20%	100%	100%	100%	272
Municipal solid waste	1	42%	8%	54%	59%	63%	253
Cattle and buffalo	n/a	95%	9%	100%	100%	100%	257
Poultry	n/a	68%	25%	100%	100%	100%	185
Sheep and goat	n/a	80%	16%	100%	100%	100%	180
Pig	n/a	90%	15%	100%	100%	100%	491

Notes: Methane yields are expressed per tonne of volatile solid. The product-to-residue ratio represents the conversion from the edible fraction reported by the FAO to the corresponding residue fraction. For wastewater, it corresponds to the dry sludge content in water discharge. Moisture content, ash content and methane yields per unit of volatile solid are held constant across all regions. Other uses include animal feed and bedding, as well as incineration, recycling and composting for municipal solid waste. Nm^3 = Normal cubic metre of methane, equivalent to 36 MJ. n/a = Not applicable. VS = volatile solids. ADV = advanced economies. EMDE = emerging market and developing economies.

Costs estimations

Allocated potential and costs

In the second stage of modelling, feedstock datapoints are spatially clustered. Collection radii vary by feedstock type: manure clusters have a 10 km radius, smaller than those for crop residues (40 km) and municipal solid waste (150 km). Wastewater volumes are reported by treatment facilities and therefore do not require clustering. Within each cluster, a knapsack algorithm selects the combination of digesters that maximises the utilisable potential across a range of plant sizes and technologies. These standard digester configurations are derived from a database of biomethane projects compiled by the IEA. The selected plant configuration determines the nameplate capacity, capital cost, operating cost and annual biomethane output assigned to each cluster. Feedstock bundles that do not meet a minimum viability threshold are excluded. This represents close to 9% of the gross technical potential and corresponds to resources that are too dispersed to support a viable biomethane plant.

Plant-gate biogas costs are derived from the weighted-average capital cost of the allocated digesters and feedstock procurement costs. A uniform upgrading cost equivalent to around USD 3/GJ is then added to convert biogas to biomethane. The table below shows capital and operational costs, encompassing the complete anaerobic digestion system, including feedstock pre-treatment equipment, digester tanks, gas handling systems, and basic control systems. Manure, MSW and crop residues can be allocated to biodigesters whereas sewage sludge is treated separately within wastewater treatment (WWT) plants.

Feedstock procurement costs (gate fee) are set at around USD 30 per tonne of dry matter for crop residues and USD 5/t for manure. Wastewater and MSW are assumed to have no procurement cost, reflecting the fact that treatment and transport costs are often offset by negative gate fees. A 20-year technical lifetime and a construction time of 1.5 years are applied.

Other costs

Downstream processes are excluded from the analysis. Therefore, investments required to transform biogas into electricity or heat as well as grid connection costs are not included. These investments can be substantial; for example, adding a co-generation unit, including grid connection and heat recovery distribution, increases total project costs by 40-70%.

Similarly, gas grid connection costs are excluded. Average connection costs are estimated at around USD 1/GJ, although costs can differ significantly depending on plants' sizes, topography and local regulatory frameworks.

Operating costs incorporate the energy required for plant operation. Parasitic energy demand is around 15% for biogas, and up to 20% for biomethane plants given the additional energy required for upgrading and compression. Larger plants can achieve lower parasitic demand per unit of output through economies of scale, enhanced heat recovery, optimised membranes or better insulation. This analysis assumes that all energy requirements are met through grid electricity, and that heat pumps maintain mesophilic digester temperatures. This results in electricity consumption of 0.20-0.37 kWh/Nm^3, with an additional 0.10 kWh/Nm3 for upgrading. In practice, many biogas plants use a combined heat and power (CHP) unit, reducing external energy needs.

Digestate management is included as a separate cost of around USD 3-5/t depending on the region. Digestate volumes are estimated using a mass balance between the wet feedstock inputs and biogas output.

For larger biodigesters, feedstocks are collected from a wider area and transport costs of USD 0.03-0.12 per tonne-kilometre of fresh feedstock are added, proportional to the distance between agricultural resource locations and the cluster centre, covering fuel and labour requirements.

Standard biodigester configurations used in the allocation algorithm, 2025

Technology	Nameplate capacity (Nm³/h)	Targeted capacity factor			CAPEX (USD / (Nm³/h))			OPEX (USD / Nm³)			WACC		
	World	EMDE	World	ADV	EMDE	World	ADV	EMDE	World	ADV	EMDE	World	ADV
AD Size 1	2 500	81%	85%	90%	12300	13900	15600	0.08	0.09	0.09	10%	8%	6%
AD Size 2	1 500	81%	85%	90%	13400	15100	17000	0.09	0.09	0.10	10%	8%	6%
AD Size 3	750	71%	75%	80%	14600	16500	18500	0.10	0.11	0.12	10%	8%	6%
AD Size 4	375	71%	75%	80%	15900	17900	20100	0.11	0.12	0.13	10%	8%	6%
AD Size 5	175	61%	65%	70%	17300	19500	21900	0.14	0.14	0.15	10%	8%	6%
AD Size 6	75	70%	65%	61%	23800	21200	18800	0.17	0.16	0.16	12%	10%	7%
AD Size 7	37.5	61%	65%	70%	20500	23100	26000	0.17	0.18	0.19	14%	11%	8%
WWT plant	1 000	90%	90%	90%	19300	20800	22300	0.11	0.11	0.12	14%	11%	8%
Upgrading	1 000	78%	79%	80%	6800	7400	8000	0.03	0.03	0.03	10%	8%	6%

Notes: Costs are expressed in USD (2025, market exchange rate). OPEX includes fixed and variable operating costs associated with plant operation, excluding own use energy. Feedstock procurement and transport costs are assessed separately and do not vary with plant size. AD = anaerobic digester. ADV = advanced economies. EMDE = emerging market and developing economies. WACC = weighted-average cost of capital. OPEX = operating cost. CAPEX = capital cost.

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