

BIOMETHANE FROM MUNICIPAL WASTE: ACEA PINEROLESE CASE STUDY AND FINANCIAL REPLICATION MODEL FOR ROMANIA

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Abstract. Based on the ACEA Pinerolese case study (Pinerolo, Italy), the research investigates the possibility of establishing a municipal biomethane hub in Romania. In order to generate technical-energy indicators and build a scenario-based financial model, the analysis includes operational and financial data for the year 2024, including biomethane 33 464 MWh, cogenerated electricity 18 938 MWh and treated wet waste 48 566 kt. The resulting energy intensity, which is used as a reference point in the scenarios for Romania, is approximately 0.69 MWh/tonne of derived organic waste, or 3.35 million Nm³/year (assuming a LHV $\approx$ 10 kWh/Nm³). The scenario matrix fluctuates the biomethane price (70/90/110 €/MWh), the capital expenditure (8/12/20 million €) and the aggregate operational expenditure (6-10% of the capital expenditure). The results show a profitable area at price combinations $\geq$ 90 €/MWh and capital expenditure $\leq$ 12 million € for a medium scale (50 kt/year) (e.g. $\sim$ 5.6 years at 12 million € and 90 €/MWh; $\sim$ 3.2 years at 8 million € and 90 €/MWh). The scale effect is visible, by diluting the fixed costs and using economies of scale in modernization/connection, the transition from 30 to 80 kt/year reduces the payback time of the investment from about 13.3 to 3.0 years. The following are best practices: pursuing dual sampling (grid injection + CNG/biomethane for captive fleets), securing feedstock through functional separate collection and impurity control, arranging grid connection in advance, adopting hub integration with heat recovery and transparent internal transfers. Future research will focus on explicit quantification of support systems, Monte Carlo sensitivity and LCA/ESG analysis. Limitations include the use of internal transfer prices as proxies, LHV-based conversions and a single year data set. Municipal projects become bankable at sizes larger than tens of kt/year when integrated design reduces operational expenses and predictability of average market prices.

Keywords: Biomethane, Sustainability, Municipal waste (OFMSW), ACEA Pinerolese, Scenario financial model, Romania

How to cite: NEDELCU, A.-S., DOBRE - DOROFTEI, L. -. A., MILITARU, G. ., & FLEACĂ, E. . Biomethane from Municipal Waste: ACEA PINEROLESE Case Study and Financial Replication Model for Romania. *International Conference of Management and Industrial Engineering*, 12. Retrieved from <https://www.icmie.ro/index.php/icmie/article/view/188>

Introduction

Biomethane, or biogas upgraded to grid quality, is the main tool for decarbonising the gas segment and captive urban fleets. The move to a circular economy has led to a shift in focus from simple waste disposal schemes to integrated systems where the biodegradable fraction becomes an energy and agricultural resource. To anchor the increase in production capacity in the short and medium term, the European Union's REPowerEU Plan explicitly sets a target of 35 billion m³/year of biomethane by 2030, with anticipated investment needs in the order of tens of billions of dollars [1], [2].

Pretreatment and anaerobic digestion of biowaste (OFMSW = Organic Fraction of Municipal Solid Waste), cogeneration, transformation into biomethane with injection into the gas network and use as CNG (Compressed Natural Gas) or biomethane for transport, composting and creation of added value in the secondary stream are all connected to ACEA Pinerolese (Pinerolo, Italy). Initiated in September 2020, the transformation component was intended to manage up to approximately 1 500 Sm³/h of biogas, which would be used both for the CNG stations in the territory and for the distribution network [3], [4].

A solid reference point for modeling is provided by examining the company's official statistics for 2024, which validate the municipal-regional dimension of the operations, on the mass side, 48 566 390 kg were treated on the Wet/Digestion line and 22 689 020 kg on the Secco line, along with 19 960 258 kg in the composting plant and the sale of 6 052 tons of compost. At the same time, the energy input flows for valorization included 47 832 MWh biogas equivalent from anaerobic digestion, respectively marginal inputs from the landfill and treatment. 33 464 MWh of biomethane were produced and the cogeneration units produced 18 938 MWh of electricity. These figures provide an empirical basis for determining the technical-economic indicators of the study and measure the current performance of the center [5].

Documenting the operational performance of ACEA Pinerolese in 2024 and creating a parameterizable financial model to replicate a comparable facility in Romania are the two main objectives of this project. The model generates the investment recovery rate, net present value (NPV) and internal rate of return (IRR) for investment evaluation and examines prices, raw material availability and CapEx/OpEx (Capital Expenditure/Operating Expenditure) scenarios. The ACEA 2024 energy and waste tables serve as the basis for the benchmark and findings.

Using the 2024 performance of the ACEA Pinerolese integrated hub (anaerobic digestion of municipal biowaste, upgrading to biomethane with grid injection and related applications), a parameterizable financial model is built for a municipal facility in Romania. Then, using the official ACEA figures for 2024 (energy production, input flows, treated masses, financial indicators), the market and operational parameters that make the project bankable are assessed, including favorable depreciation, net present value (NPV) and internal rate of return (IRR).

In addition to translating the technical-economic performance of the ACEA Pinerolese in 2024 (biomethane and electricity output, energy input flows, waste treated) into a parameterizable financial model for a municipal facility in Romania, the study identifies the operational and market conditions that make the project bankable (investment recovery, NPV, RIR). The research is based on ACEA statistics in 2024 and is supported by the REPowerEU impetus for biomethane.

Based on the literature and the European framework, two working hypotheses are proposed, simple enough to be further tested using a scenario matrix: H1 (price - bankability) states that, under unchanged operating conditions, an increase in the biomethane valorization price (€/MWh) results in a higher NPV/RIR ratio and a shorter payback period due to the increase in specific revenues and H2 (scale - profitability) by reducing fixed costs and economies of scale in the modernization and connection sector, increasing the processed volume increases profitability indicators for realistic ranges of the annual amount of biowaste treated at municipal level. Indicators obtained from ACEA 2024 data and a financial model based on the scenarios provided in the Methodology will be used to evaluate these hypotheses.

Literature review

From a technical point of view, the bio-waste recovery chain usually runs as follows: separate collection → pretreatment → anaerobic digestion → biogas to biomethane → grid injection/light modifications for CNG → digestate management/composting. By combining these steps in a single facility, energy synergies (heat recovery, biogenic CO₂ capture/utilization) and logistics (short internal flows, minimal losses) are significantly increased. These pathways are documented in the literature and in the IEA Bioenergy Network technical guides, which also demonstrate the maturity of industrial conversion technologies (such as membranes, water/amine scrubbing and PSA (Pressure Swing Adsorption)). Pinerolo is an example of a grid-scale biogas to biomethane transition [6].

Regarding the indicators and conversions used in energy calculations, the standard relationship is adopted, which states that 1 Nm³ of biomethane ≈ 10 kWh (the reference value commonly used in technical reports). The gas network regulatory literature indicates a typical value of ~ 11 kWh/Nm³ for biomethane for higher calorific value (HCV) corrections, which is useful in checks and sensitivity analyses. When both standards are used simultaneously, the balance sheet and monetization calculations guarantee consistent reporting of energy (kWh/MWh) and volumetric (Nm³) quantities [6], [7].

According to market studies, the retrofit unit is usually the main driver of investment, with notable economies of scale as capacity increases. The total costs of the biomethane economy include biogas production costs (collection, pretreatment, digestion) as well as retrofit and connection costs (compressors, scrubbers/absorbers, instrumentation, injection stations). However, IEA analyses highlight that, compared to other energy technologies, biogas/biomethane projects can have relatively high operating expenses (OPEX), as they include energy and consumables for operating the equipment, as well as logistical costs of raw materials that vary depending on the local density of sources. These results

support the use of ranges by the financial model for pricing and capital expenditure/OPEX, followed by sensitivity studies [8], [9], [10].

The acceleration of projects is facilitated by political and regulatory issues. For example, the amendment to the Waste Framework Directive at European level requires that bio-waste be collected separately or recycled at source by 31 December 2023. This is a requirement for the stability of the input mix for digestion and, implicitly, for the financial viability of form derived biomethane projects. This obligation puts more pressure on the development of digestion/upgrading capacities and the installation of collection systems at municipal-regional level, when combined with the REPowerEU target of 35 billion cubic meters [11], [12], [1].

Using official ACEA Pinerolese data from 2024 to anchor operational indicators and create a scenario-based financial model for a city in Romania. The economic and policy interpretation focuses on minimum profitability thresholds and scaling needs, while the empirical basis is formed by energy/biomethane tables taken from the 2024 reports.

Case study: ACEA Pinerolese

With separate financial reporting in accordance with the MEF Directive (Separate Annual Accounts), Acea Pinerolese Industriale S.p.A. (API) manages an integrated hub for the management of municipal bio-waste in Bacino 12 (province of Turin). This hub includes the wet-anaerobic digestion line (OFMSW), the dry/transfer line, composting, biogas recovery and related utilities (cogeneration, thermal). Through internal transactions valued at market prices between compartments, this integration allows the monetization of secondary flows, in addition to energy recovery (biomethane, electricity) [5], [13].

Table 1: Energy production (outputs), 2024 - ACEA Pinerolese

Indicator	Value [MWh]
Biomethane produced	33 464
Electricity produced by cogeneration (CHP)	18 938
Photovoltaic production	101
Green electricity supplied to the grid	10 930
Electricity supplied to ACEA facilities	8 142

Source: [5], [13]

The contribution of anaerobic digestion to the biogas plant feed and the supporting function of natural gas for cogeneration and thermal energy are confirmed by the input energy flows: 47 832 MWh of biogas from digestion, 128 MWh from landfills, 1 242 MWh from treatment, 2 184 MWh from natural gas for boilers and 48 761 MWh from cogenerators [5], [13].

Table 2: Energy inputs to recovery

Description	Value [MWh]
Biogas from anaerobic digestion	47 832
Biogas from landfill	128
Biogas from wastewater treatment plant	1 242
Natural gas from the network - boilers	2 184
Natural gas from the network - cogeneration	48 761

Source: [5], [13]

In 2024, the composting facility processed 19 960 258 kg and 6 052 tons of compost were sold. The umid-digestion line processed 48 566 390 kg, while the secco/transfer line treated 22 689 020 kg. These volumes place the center in a position to continuously produce biogas and transform it into biomethane on a municipal-regional scale [13].

Table 3: Waste processed

Flow	Quantity
Wet Line - Anaerobic Digestion	48 566 390 kg
Dry Line - Transfer	22 689 020 kg
Composting - total inputs	19 960 258 kg
Compost sold	6 052 t

Source: [5], [13]

Internal transactions between compartments (electricity, heat, sludge and biogas) valued at market prices are explained in the documentation. As an internal indicator in the analysis, the examples of quantity $\times$ value for biogas (6 302 MWh $\rightarrow$ 213 058 €, 41 653 MWh $\rightarrow$ 1 410 247 €, 1 242 MWh $\rightarrow$ 42 137 €) suggest an average price of around 33-34 €/MWh [14].

Table 4: Internal biogas transactions (transfer prices)

Internal destination	Quantity [MWh]	Value [€]	Average price [€/MWh]
IA - Mercato	6 302	213 058	33.81
SII - Protetta	41 653	1 410 247	33.86
SII - Protetta (second stream)	1 242	42 137	33.93
Total biogas (internal purchases)	49 197	1 665 442	33.85

Source: [14]

An energy intensity of approximately 0.69 MWh biomethane/tonne of organic waste derived from stainless steel (OFMSW) is obtained by comparing the mass processed on the umid-digestion line (48 566.39 t) with the annual biomethane production (33 464 MWh). Depending on the annual operating hours (8 760 vs. 8 000 h), the energy to volume conversion (industry convention: 1 Nm³ biomethane $\approx$ 10 kWh) involves approximately 3.35 million Nm³/year, or an average flow rate of approximately 380 to 420 Nm³/h. The intensity is calculated using the information in Tables 1 and 3, and the energy to volume conversion uses the industry standard relationship. These key performance indicators (KPIs) are used in the scenario calibration methodology.

Table 5: Operational KPIs (derived from 2024 data)

KPI	Value	Observation
Biomethane energy intensity	$\sim$ 0.69 MWh/t	33 464 MWh / 48 566.39 t
Biomethane volume (estimate)	$\sim$ 3 346 400 Nm ³ /year	33 464 MWh $\times$ 1 000 / 10 kWh/ Nm ³
Average flow rate (8 760 h)	$\sim$ 382 Nm ³ /h	volume/year / 8 760 h
Average flow rate (8 000 h)	$\sim$ 418 Nm ³ /h	volume/year / 8 000 h

Source: Authors' calculations from Table 1 (energy) and Table 3 (mass)

In 2024, sales and service revenues at the parent company level (API) were EUR 60 849 907, with a net result of EUR 484 999, at the consolidated level, revenues were EUR 67 615 705, with a consolidated net result of EUR 1 792 833. These figures support a stable operational profile and a favorable result at the group level in a capital-intensive environment with notable impairments [5], [13].

Table 6: Financial benchmarks - 2024

Indicator	API (parent company) [€]	Group (consolidated) [€]
Sales and service revenues	60 849 907	67 615 705
Net result	484 999	1 792 833

Source: [5], [13]

Methodology

A parameterizable financial model for a municipal facility in Romania is created by initially calibrating a minimal set of technical-energy indicators observed at the ACEA Pinerolese center in 2024. Both the standard energy-volume conversion relationship for biomethane, where 1 Nm³ biomethane $\approx$ 10 kWh (lower value=LHV) and $\sim$ 11 kWh/Nm³ for the upper value (HHV), and the energy intensity derived from the case data (MWh biomethane per ton of biowaste treated), are used in the calibration step. The choice between LHV and HHV is consistent throughout the article and is used only for order of magnitude checks [6], [7].

After converting it into volume (Nm³/year) using the conversion relationship indicated above, the model calculates the annual energy production as the product of the annual mass of biowaste managed in the wet digestion line and the energy intensity calibrated for the ACEA case. A coefficient α applied to the CAPEX (approximating, in a single term, the recurring energy costs for modernization/compression, maintenance and consumables) represents the operational costs, while the annual revenue is determined by multiplying the annual energy (MWh/year) by the biomethane valorization price (€/MWh). The operating cash flow is the difference between revenue and operating expenses (OPEX), the basic depreciation is the ratio of capital expenditures (CAPEX) to this cash flow, and, if desired, the NPV and IRR can be

calculated over a 10 to 15 year horizon (with a fixed discount rate). This approach allows for sensitivity studies for decision variables (price, scale, CAPEX and OPEX) and preserves traceability from empirical data to financial indicators.

Three categories are used to group the parameters used in the scenarios. The project size (tons of bio-waste per year) and the calibrated energy intensity in the case of ACEA are the first categories. We use this as a reference value and test with a sensitivity of ± 10 -15% to take into account the impact of the operating regime and the quality of the raw material. The physical-energy parameters (hours/year, LHV/HHV conversion factors) that are recorded in the technical materials and specialized literature of the gas network fall into the second group.

The third element is economic and encompasses a variety of costs, as well as the recovery price (€/MWh). Using recent estimates from the International Energy Agency and the Biomethane Industry Partnership syntheses to support the plausibility of the price range and specific costs. These estimates show that, for Europe, average biomethane costs range between ~ 36 and 108 USD/MWh (IEA 2025 synthesis) and ~ 55 and 100 €/MWh (EBA/BIP, excluding connection costs), with variations depending on the size of the plant, the cost of the feedstock and the retrofit technology. Without claiming to be a regulated tariff, these benchmarks support the selection of a price range of 70 - 110 €/MWh for decision tests [15], [16], [17].

The formulas used are presented in the body of the text for clarity. The energy production is denoted $E_{annually} = Q_{OFMSW} \times y$, where Q_{OFMSW} is the mass of bio-waste treated (t/year), and y is the energy intensity (MWh/t). The energy-volume conversion is $V_{Nm^3} = \frac{E_{kWh}}{h}$, or, equivalently, $V_{Nm^3} = \frac{E_{MWh} \times 1000}{k}$, with $k = 10 \text{ kWh/Nm}^3$ (LHV) or $\sim 11 \text{ kWh/Nm}^3$ (HHV). The annual revenue is $V_{en} = E_{annually} \times p$, where p is the price (€/MWh). The aggregate operational cost is expressed as $OPEX = \alpha \times CAPEX$, with $\alpha \in [0.06, 0.10]$ and the operational cash flow is $CF = V_{en} - OPEX$. The simple payback indicator is $PB = \frac{CAPEX}{CF}$, and NPV and IRR are calculated in the next section, “Results”, where relevant, for the same sets of assumptions.

Table 7 provides a summary of the parameters and their sources for ease of reading and verification. The scenario matrix and associated figures (revenue, OPEX, CF, depreciation) for the price, CAPEX and project size combinations specified here are presented in Table 8 in the next section (“Results”).

Table 7: Model parameters and reference sources

Parameter	Symbol / unit	Reference value (sensitivity)	Justification / Source
Mass of bio-waste treated	Q_{OFMSW} [t/year]	30 000, 50 000, 80 000	Typical municipal/regional range, scale tested to capture the effect of economies of scale (scenario design).
Biomethane energy intensity	y [MWh/t]	0.69 (± 10 - 15%)	Calibrated on the ACEA 2024 case, variation for feedstock quality/operating regime. (from tables in the “Case study: ACEA Pinerolese” section - own data).
Operating hours	h [h/year]	8 760 (test: 8 000)	Annual regime vs. conservative industrial regime.
Energy to volume conversion (LHV)	k [kWh/Nm ³]	10 (LHV)	Standard relationship used in industry/IEA Bioenergy [6].
Alternative conversion (HHV)	k_{HHV} [kWh/Nm ³]	~ 11 (HHV)	Typical values for biomethane in ENTSG/JRC documents [7].
Biomethane price	p (€/MWh)	70, 90, 110	Plausible band for decision analysis, anchored in IEA (36-108 USD/MWh) and BIP/EBA (55-100 €/MWh) assessments [15], [16], [17].
Total investment	CAPEX [€]	8, 12, 20 [mil.]	Three steps for small-medium integrated hubs, range used as scenario assumption (consistent with specific costs from IEA/BIP sources when combined with α) [15], [17].
Operating costs	α [-]	0.06; 0.08; 0.10	Aggregate coefficient for upgrading/compression energy, maintenance and consumables, frequently used in TEA modelling at screening level (methodological justification, typical upgrading electricity consumption 0.2-0.3 kWh/Nm ³) [18].

Source: Author’s own contribution

Recent assessments for Europe served as a basis for selecting the range and price band, the decision analysis justifies testing the thresholds of 70, 90, 110 €/MWh, the values obtained are interpreted in light of the empirical indicators in section “Case study: ACEA Pinerolese” and the policy objective of 35 billion m³ of biomethane/year by 2030 set by REPowerEU. The IEA reports average biomethane costs in the range of ~ 36 - 108 USD/MWh globally, while the BIP/EBA indicates ~ 55 - 100 €/MWh (excluding connection costs) [1], [15], [16], [17], [19].

Results and further discussions

The operational indicators derived from 2024 data are consistent with an integrated municipal-regional plant, as validated by the calibration on the ACEA example. Input flows include 47 832 MWh equivalent of biogas from digestion, slightly supplemented by biogas from landfill (128 MWh) and treatment (1 242 MWh), natural gas inputs for boilers (2 184 MWh) and cogeneration (48 761 MWh). The reported annual biomethane production is 33 464 MWh, and the electricity generated in cogeneration is 18 938 MWh. In terms of material, 6 052 tons of compost were sold after 48 566 390 kg were treated by the umid-digestie line, 22 689 020 kg by the secco line and 19 960 258 kg by the composting plant. The energy intensity of approximately 0.69 MWh/t, used as a reference in the scenarios for Romania, is produced by the ratio between biomethane production and wet mass treated [5], [13].

For clarity, we emphasize that in the numerical replication of the ACEA case (with annual energy fixed at 33 464 MWh and $\alpha = 8\%$ of CAPEX for OPEX), a project with CAPEX between 8 and 20 million euros would have a simple payback period of approximately 2.6 to 9.6 years (longer towards the upper limit of CAPEX and at a price of 70 €/MWh) at prices of 70/90/110 €/MWh. With all other factors constant, this verification demonstrates the direction of the connections H1-H2 in the introduction, the payback decreases at higher prices and/or lower specific investments.

The following two tables present the results for the Romanian scenarios. The average project scale (50 000 t/year, intensity 0.69 MWh/t or 34 500 MWh/year) and OPEX ($\alpha = 8\%$ of CAPEX) are set out in Table 8. The capitalisation price (70/90/110 €/MWh) and CAPEX (8/12/20 million €) are varied. The matrix illustrates how these two variables affect the movement of revenues, CF and depreciation. The impact of scale is then demonstrated for three annual masses (30, 50 and 80 kt) under average economic conditions (price 90 €/MWh, CAPEX 12 million €, $\alpha = 8\%$) in Table 9.

Table 8: Scenarios Romania - CAPEX $\times$ price (average scale, 50 000 t/year; $y = 0.69$ MWh/t; $\alpha = 8\%$)

CAPEX [€]	Price [€/MWh]	Energy [MWh/year]	Revenue/year [€]	OPEX ~8% CAPEX/year [€]	Operational CF [€]	Payback [years]
8 000 000	70	34 500	2 415 000	640 000	1 775 000	4.5
	90		3 105 000	640 000	2 465 000	3.2
	110		3 795 000	640 000	3 155 000	2.5
12 000 000	70		2 415 000	960 000	1 455 000	8.2
	90		3 105 000	960 000	2 145 000	5.6
	110		3 795 000	960 000	2 835 000	4.2
20 000 000	70		2 415 000	1 600 000	815 000	24.5
	90		3 105 000	1 600 000	1 505 000	13.3
	110		3 795 000	1 600 000	2 195 000	9.1

Note: Authors' calculations based on the relationships in the previous section, energy intensity is from ACEA 2024 data.

Source: Author's own contribution

The interpretation of the matrix shows a financial zone where the payback period of the medium-scale investment (50 kt/year) falls below about 6 years for combinations of capital expenditure < 12 million euro and price ≥ 90 €/MWh. The same reasoning is valid for capital expenditure of 8 million euro, where the payback period is much more attractive, at 90 - 110 €/MWh (2.5 - 3.2 years). Reducing capital expenditure has a similar effect by decreasing operational expenditure (related to $\alpha \times \text{CAPEX}$) and increasing the operational risk factor, supporting the expectations of H2. Increasing the price systematically reduces the payback period of the investment (H1), keeping the physical parameters constant.

Table 9: Scenarios Romania - CAPEX $\times$ price (average scale, 50 000 t/year; $y = 0.69$ MWh/t; $\alpha = 8\%$)

OFMSW Mass [t/year]	Energy [MWh/year]	Price [€/MWh]	CAPEX [€]	OPEX ~8% CAPEX/year [€]	Revenue/year [€]	Operational CF [€]	Payback [years]
30 000	20 700	90	12 000 000	960 000	1 863 000	903 000	13.3
50 000	34 500			960 000	3 105 000	2 145 000	5.6
80 000	55 200			960 000	4 968 000	4 008 000	3.0

Note: Authors' calculations, $E = Q \times 0.69 \text{ MWh/t}$, with Q in tons/year and intensity comes from the ACEA 2024 case.

Source: Author's own contribution

The results in Table 9 demonstrate the significant impact of scale, at the same economic parameters, the move from 30 kt/year to 80 kt/year shortens the payback period of the investment from approximately 13.3 to 3.0 years. This contrasts with the proportional increase in revenues and the dilution of fixed costs (CAPEX/OPEX) per unit of energy produced. This implies that, from a decision-making perspective, securing bio-waste volumes (inter-UAT contracts, separate collection of enterprises) is as crucial a requirement as negotiating the recovery price or maximizing CAPEX.

A quick note on OPEX sensitivity is as follows, if α increases from 8% to 10% in Table 8 (middle row, 50 kt/year, CAPEX 12 million €), OPEX increases from 960 000 € to 1 200 000 €, CF decreases from 2 145 000 € to 1 905 000 €, and depreciation decreases from ~ 5.6 to ~ 6.3 years ($\approx +12\text{-}13\%$). This flexibility demonstrates that, similar to H2, hub integration (thermal recoveries / internal flows) and operational efficiency (modernization / compression consumption, maintenance) have a direct impact on bankability.

The findings show that bankability depends largely on the biomethane recovery price and the scale of the project, with operational efficiency (OPEX) ranking second and third, respectively, at the municipal-regional scale (≈ 50 kt/year of biowaste) and an energy intensity calibrated according to the ACEA example. The implementation of local initiatives that reduce market risk and improve “feedstock security” is justified by this finding, which is consistent with the technical-economic literature and the European political momentum targeting 35 billion m^3 /year of biomethane by 2030 (REPowerEU) [1].

The EU mandate for separate collection of bio-waste by 31 December 2023 strengthens compliance and ensures higher quality of feedstock. In particular, from an operational point of view, ensuring annual quantities through efficient separate collection, inter-UAT contracts and impurity control matters more than price discussions, as unstable feedstock with high volume elasticity lowers yields and increases retrofitting losses [11], [12]. From a commercial point of view, a dual valorisation approach (grid injection with CNG/biomethane for captive fleets) covers price risk and adds short-term flexibility, while national/local support schemes and recognition of origin assurances can shorten the payback period. Early involvement of the grid operator (pre-connection feasibility) reduces the risk of re-design and lock-in, as required by regulations; in Romania, new project guarantees and capacity allocation guidelines provide a realistic planning window [20], [21].

Ensuring the quality of raw materials through separate collection with key performance indicators (KPIs) of impurities ($< 10\text{-}12\%$ m/m), quarterly audits and contractual clauses with UATs are effective and immediately applicable strategies [12]. Also designing an integrated hub (digestion + retrofitting + composting + cogeneration/heat recovery) for heat/ CO_2 reuse and reducing operational expenses to prevent bottlenecks as collection increases [8], [15]. Establishing a double levy to protect against price risk (PPA/MWh to the grid plus CNG/biomethane for captive fleets), initiating feasibility studies for grid connection, complying with capacity allocation regulations and elucidating metering, odorization and compression fees, establishing clear internal transfer tariffs (€/MWh) in situations where the operator oversees multiple utilities [20], [21].

The use of public cost benchmarks (IEA 2025, BIP 2023) to discipline CAPEX/OPEX, testing conservative price bands (70/90/110 €/MWh) and robustness to $\pm = 6\text{-}10\%$ OPEX and $\pm = 10\text{-}15\%$ (MWh/t) yield [15], [16]. The use of mixed financing (investment grants/state aid for biomethane) to keep depreciation within targets are some ways to capitalize on digestate through fertilizer certification (traceability, analyses and agronomic plan) [19], [22]. Also the integration of ESG/LCA indicators from the design stage to support eligibility and reporting under REPowerEU type programs. European practice highlights three factors that facilitate project governance, at least a sales contract or letter of intent to provide price visibility and unlock bank financing, early authorization/sign-on processes that work concurrently, and signed agreements on raw materials before detailed design [1].

Conclusion

According to the study, ACEA Pinerolese is a reliable standard for planning and cost analysis of a municipal biomethane plant in Romania, as it is an integrated center. The relationship between technical-energy performance and bankability is quantified through a clear, scenario-based model that provides not only a description but also “go/no-go” criteria. This model is explicit in terms of prices, CAPEX/OPEX, operating hours and bio-waste tonnage.

The results support the theories, higher biomethane prices shorten the payback and increase NPV/RIR at constant operations (H1 - price - bankability), the shift from small to medium-large scale (tens of kt/year) drastically reduces payback through economies of scale and dilution of fixed costs (H2). While the OPEX sensitivity indicates that a higher α (consumption/maintenance) significantly extends the payback, the matrix provides a realistic bankable area (moderate

CAPEX, normal market prices). In practice, dual valorization (grid injection with CNG/biomethane for captive fleets), feedstock assurance (functional separate collection, inter-UAT agreements, impurity control), hub integration (heat recovery, transparent internal transfers) and early planning of grid connection are crucial.

Limitations include one-year data, domestic transfer prices used as proxies, and LHV-based conversions. Future research should quantify support contracts and schemes (PPA, GoO), conduct Monte Carlo sensitivity tests, and incorporate LCA/ESG at the project level. A stable mid-market price, a scale $\geq$ tens of kt/year, and an integrated design that reduces specific operational expenses are the three requirements that must be met for bankability, if not met, specific financial or contractual support is needed.

References

- [1] European Commission, "Biomethane," 28 September 2022. [Online]. Available: https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomethane_en. [Accessed 2025-09-10].
- [2] European Commission, "REPowerEU-3 years on," 16 May 2025. [Online]. Available: https://energy.ec.europa.eu/topics/markets-and-consumers/actions-and-measures-energy-prices/repowereu-3-years_en. [Accessed 2025-09-10].
- [3] HysyTech, "Inauguration of the new biomethane plant from the collaboration between HYSYTECH and ACEA," 28 September 2020. [Online]. Available: <https://www.hysytech.com/News/nuovo-impianto-biometano-acea-hysytech-2020-eng>. [Accessed 2025-09-10].
- [4] SHREC, "Biomethane from municipal organic waste," 05 July 2021. [Online]. Available: <https://www.interregeurope.eu/good-practices/biomethane-from-municipal-organic-waste>. [Accessed 2025-09-10].
- [5] ACEA PINEROLESE INDUSTRIALE S.p.A., "BILANCIO D'ESERCIZIO ANNO 2024," PINEROLO, TO, 2024.
- [6] International Energy Agency (IEA), "Biomethane" September 2014. [Online]. Available: <https://www.iea-biogas.net/files/daten-redaktion/download/Technical%20Brochures/biomethane-status-2014.pdf>. [Accessed 2025-09-10].
- [7] A. Münther, "Cost-efficient handling of oxygen from bio-methane in the European gas grid," August 2022. [Online]. Available: <https://www.entsog.eu/sites/default/files/2022-11/1.2%20Additional%20material%20-%20Cost%20efficient%20handling%20of%20Oxygen%20from%20biomethane%20in%20EU%20gas%20grid>. [Accessed 2025-09-10].
- [8] Biomethane Industrial Partnership, "Insights into the current cost of biomethane production from realk industry data," October 2023. [Online]. Available: <https://bip-europe.eu/wp-content/uploads/2023/10/>. [Accessed 2025-09-10].
- [9] International Energy Agency (IEA), "Sustainable supply potential and costs," 2020. [Online]. Available: <https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth>. [Accessed 2025-09-10].
- [10] International Energy Agency (IEA), "Assessing the sustainable potential and cost of feedstocks for biogas and biomethane" May 2024. [Online]. Available: <https://www.iea.org/reports/outlook-for-biogas-and-biomethane/assessing-the-sustainable-potential-and-cost-of-feedstocks-for-biogas-and-biomethane>. [Accessed 2025-09-10].
- [11] Official Journal of the European Union, "Directive (EU) 2018/851 of the european parliament and of the council" 30 May 2018. [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri>. [Accessed 2025-09-11].
- [12] European Union, "EU waste management law," 18 February 2024. [Online]. Available: <https://eur-lex.europa.eu/EN/legal-content/summary/eu-waste-management-law.html>. [Accessed 2025-09-11].
- [13] ACEA PINEROLESE INDUSTRIALE S.p.A., "BILANCIO CONSOLIDATO ANNO 2024," Pinerolo, 2024.
- [14] Acea Pinerolese Industriale S.p.A., "Conti Annuali Separati" 2024.
- [15] International Energy Agency, "Outlook for Biogas and Biomethane. A global geospatial assessment," May 2025. [Online]. Available: <https://iea.blob.core.windows.net/assets/5b757571-c8d0-464f-baad>. [Accessed 2025-09-12].
- [16] World Biogas Association, "IEA's 2025 Outlook for Biogas and Biomethane," 2025. [Online]. Available: <https://www.worldbiogasassociation.org/ieas-2025-outlook-for-biogas-and-biomethane/>. [Accessed 2025-09-12].
- [17] Biomethane Industrial Partnership, "A vision on how to accelerate biomethane project development," October 2023. [Online]. Available: https://bip-europe.eu/wp-content/uploads/2023/10/BIP_Task-Force-2_A-vision-report_Oct2023.pdf. [Accessed 2025-09-12].
- [18] J. G. Ammenberg, et al., "Perspectives on biomethane as a transport fuel within a circular economy, energy, and environmental system," December 2021. [Online]. Available: https://task37.ieabioenergy.com/wp-content/uploads/sites/32/2022/02/IEA_transport_T37_END_HIGH.pdf. [Accessed 2025-09-12].
- [19] European Union, "REPowerEU: Joint European action for more affordable, secure and sustainable energy," March

2022. [Online]. Available: <https://ec.europa.eu/commission/presscorner/api/files/attachment/871871/Factsheet%20-%20REPowerEU.pdf>. [Accessed 2025-09-12].
- [20] D. Vlasceanu, "Structural Changes to Romania's Grid Capacity Allocation Rules," 06 August 2024. [Online]. Available: <https://energyindustryreview.com/opinion/structural-changes-to-romanias-grid>. [Accessed 2025-09-12].
- [21] I. Apostolescu, "Romania: ANRE Order No. 53/2024 – Regulations on Grid Capacity Allocation and Guarantee Obligations," 27 February 2025. [Online]. Available: <https://bnt.eu/legal-news/romania-anre-order-no-53-2024-regulations-on-grid-capacity-allocation-and-guarantee-obligations>. [Accessed 2025-09-12].
- [22] Biomethane Industrial Partnership, "Biomethane. Facts & Figures," 2022. [Online]. Available: <https://bip-europe.eu/wp-content/uploads/2023/10/BIP-Biomethane-Factsheet-Oct2023.pdf>. [Accessed 2025-09-12].