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Spatial Potential for Biomethane Production in Portugal: Policy Implications for Integrating Renewable Gas into the National Gas Network

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Executive summary

Biomethane supports decarbonisation and rural development but faces constraints from uneven resources, infrastructure limitations and market uncertainty. The BioRede project provides the first spatially explicit assessment at the municipal level of biomethane production potential in Portugal, focusing on the anaerobic co-digestion of agricultural and agro-industrial residues. By integrating geospatial analysis with techno-economic modelling and GHG assessment, the study quantifies the theoretical, technical, and implementation potential of biomethane, identifies priority regions for integration into the National Gas Network (NGN), and estimates associated GHG reductions and marginal abatement costs. The results presented in BioRede+ tool indicate that Portugal holds approximately 0.65 bcm·y^{-1} of theoretical biomethane potential. After accounting for technological efficiencies and feedstock recovery rates, the technical potential is estimated at around 0.28 bcm·y^{-1}, driven by livestock residues (38.7%) and cereal crop residues (35.6%), followed by prunings (17.2%) and agro-industrial residues (8.5%). When logistical, infrastructural and regulatory constraints are considered, the implementation potential decreases to approximately 0.11 bcm·y^{-1}, with only 19% of total municipalities (273) identified as implementable, concentrated in Centre-South regions. Marginal abatement costs range from cost-saving mitigation options to cases with no abatement benefit, with an average cost of 77 € per tCO_2e among municipalities where deployment is economic feasible. At this level of deployment, biomethane production could reduce emissions by approximately 183.34 $ktCO_2e \cdot y^{-1}$. However, a structural mismatch between biomass resource availability and the current coverage of the natural gas network constrain near-term deployment in several high-potential regions. Unlocking biomethane's contribution to Portugal's energy transition will therefore require spatially targeted policy instruments, strategic infrastructure planning, and stable economic incentives aligned with regional resource availability.

Recommendations

- Target support to high-potential municipalities identified by the BioRede+ tool, where feedstock density and infrastructure access enable cost-effective deployment of 0.11 bcm·y^{-1} implementation potential.
- Prioritise regional biomethane hubs over uniform infrastructure expansion, focusing on areas with the highest resource, which account for a disproportionate share of viable potential.
- Reduce logistics and grid connection costs, noting that municipalities within ~20 km of the gas network achieve lower average MAC (€67/tCO_2e-€115/tCO_2e).
- Ensure stable and predictable support mechanisms, targeting economically viable projects with average MAC of €77/tCO_2e (median €104/tCO_2e) and enabling deployment of cost-saving opportunities.
- Use municipal-scale decision-support tools (BioRede+) to guide spatially targeted deployment, maximising climate impact (183 $ktCO_2e$/year) while avoiding inefficient allocation of public support.

Recipient(s) of this policy brief

This policy brief targets key stakeholders including the Directorate-General for Energy and Geology (DGEG), the Portuguese Environment Agency (APA), the Agency for Climate, and regional and municipal authorities involved in energy transition strategies.

Addressing the Evidence Gap in Biomethane Spatial Planning

The decarbonisation of the European energy system increasingly relies on renewable gases as complementary solutions to electrification, particularly in sectors where electrification remains technically or economically challenging. Biomethane offers the advantage of compatibility with existing natural gas (NG) infrastructure while simultaneously promoting circular economy practices through the valorisation of agricultural and agro-industrial residues (IPCC, 2022; IEA 2025). At the European level, the REPowerEU strategy recognises biomethane as a key pillar for reducing dependence on imported NG and has set a target of producing 35 billion cubic metres (bcm) of biomethane annually by 2030 (EC 2022).

In Portugal, the *Plano de Ação para o Biometano* estimates that biomethane produced from organic residues could reach 2.7 TWh (0.24-0.27 bcm) by 2030, potentially replacing around 9% of projected NG consumption (GoP, 2024). Despite this potential, the development of a competitive biomethane sector faces major structural challenges, mainly:

- the uneven spatial distribution of biomass resources across the territory;
- the limited coverage and concentration of the National Gas Network (NGN) in coastal areas, leaving out of reach high potential municipalities in inland regions;
- uncertainty regarding the economic viability and climate effectiveness of large-scale deployment;
- regulatory and permitting complexity, including licensing, grid connection procedures and certification; and,
- competition for biomass resources that can be used in other applications;

Current policy frameworks identify biomethane as a strategic priority, yet lack spatially explicit evidence to guide infrastructure investment, regional targeting, and cost-effective support mechanisms. Without a robust territorial assessment, there is a risk of inefficient public investment, under utilisation of domestic biomass resources, and delayed progress toward climate and energy security objectives.

The BioRede project addresses this evidence gap by providing a municipal-scale spatial assessment of biomethane production potential in Portugal, based on the anaerobic co-digestion of agricultural and agro-industrial residues, namely livestock manure, cereal crop residues, pruning residues from vineyards and olive groves, and agro-industrial by-products (wine vinasse and olive pomace). It quantifies the theoretical, technical and implementation potential, identifies priority regions for production and grid integration, and evaluates the associated GHG mitigation potential and marginal abatement costs, providing an evidence base for targeted and cost-effective biomethane policies.

Portugal holds significant biomethane potential, but structural constraints limit immediate deployment

Resource availability is significant but geographically uneven

The analysis reveals substantial regional variation in the availability of agricultural and agro-industrial residues suitable for biomethane production across Portugal. These residues, particularly livestock manure, agricultural by-products, and agro-industrial effluents, are a key feedstock for biomethane production through anaerobic co-digestion.

The estimated theoretical biomethane amounts to approximately 0.65 bcm per year, but biomass resources are not evenly distributed across the territory. The highest theoretical resource concentrations are located in Norte (28%), Centro (26%), and Alentejo (21%), with Peninsula de Setúbal, Grande Lisboa and Algarve accounting for the lowest share.

These spatial patterns largely reflect the geographical distribution of livestock farming

systems and agricultural production activities. Regions characterised by intensive livestock production tend to generate the largest volumes of organic wet residues with theoretical potential for anaerobic digestion. The dominance of livestock and agricultural residues reinforces the role of farmers and agro-industrial actors in future biomethane value chains.

Not all available biomass can be mobilised

Based on the spatial assessment of biomass resources, the study estimated the technical and implementation potential for biomethane production at the municipal level. After accounting for sustainable residues collection rates, technological efficiencies, operational constraints and conversion losses associated with anaerobic co-digestion processes, the technical biomethane potential is 0.28 bcm per year (43% of the theoretical potential), driven by livestock residues (38.7%) and cereal crop residues (35.6%), followed by prunings (17.2%) and agro-industrial residues (8.5%), mainly concentrated in Norte and Alentejo regions. Top municipalities with highest concentration of biomethane potential include Barreiro, Espinho and Moita (Figure 1).

Further restrictions related to transport distances, plant scale requirements, regulatory conditions, infrastructure accessibility and project economics significantly reduce the achievable implementation potential to approximately 0.11 bcm per year (17% of the theoretical potential). Only 53 of the 278 municipalities analysed (19%) meet the breakeven conditions for biomethane production when comparing the cost of production with NG price (Figure 2). This indicates a strong economic feasibility threshold, where relatively small differences in resource density, infrastructure access or plant scale and configurations determine whether biomethane projects are viable.

Overall, results indicate that biomethane could represent a meaningful and competitive domestic renewable gas resource. The estimated implementation potential could substitute approximately 3% of Portugal's annual NG imports (3.9 bcm), thereby replacing the volume of NG currently imported from Russia (0.12 bcm) with domestically produced biomethane (DGEG, 2025). Biomethane potential is also highly concentrated, with a relatively small number of municipalities accounting for a disproportionate share of the national implementation potential, highlighting the importance of targeted deployment strategies.

Infrastructure proximity determines cost competitiveness

By combining data on biomass resource availability with infrastructure accessibility, the analysis identifies several priority regions for biomethane production and injection into the RNG.

Municipalities with the most favourable conditions typically combine:

- high concentrations of agricultural and livestock residues,
- proximity to existing gas infrastructure, and
- favourable logistics for biomass collection and transport.

At the same time, the analysis highlights a spatial mismatch between biomass resource availability and the current coverage of the NGN, particularly in inland regions of Alentejo. In these municipalities, limited infrastructure access may represent a key barrier to the economic viability of biomethane projects, as the production and use of biomethane would require trucking the gas to injection or consumption points, significantly increasing transport and operational costs. Addressing this infrastructure gap will be critical for unlocking the full potential of biomethane production in Mainland Portugal.

Climate benefits are significant but regionally differentiated

The biomethane production in the identified priority regions could deliver substantial reductions in GHG emissions. Based on the estimated implementation potential, biomethane deployment could replace emissions by approximately 183.34 $ktCO_2e$ per per year. These GHG emission reductions arise from several mechanisms:

- the displacement of fossil NG (70%);
- improved management of agricultural and manure residues (16%).
- the displacement of fossil N fertiliser (14%);

The results suggest that biomethane could make a meaningful contribution to Portugal's climate neutrality goal, particularly in sectors where electrification remains challenging, such as heavy industrial heat and gas-based energy systems.

Economic viability depends on scale and logistics

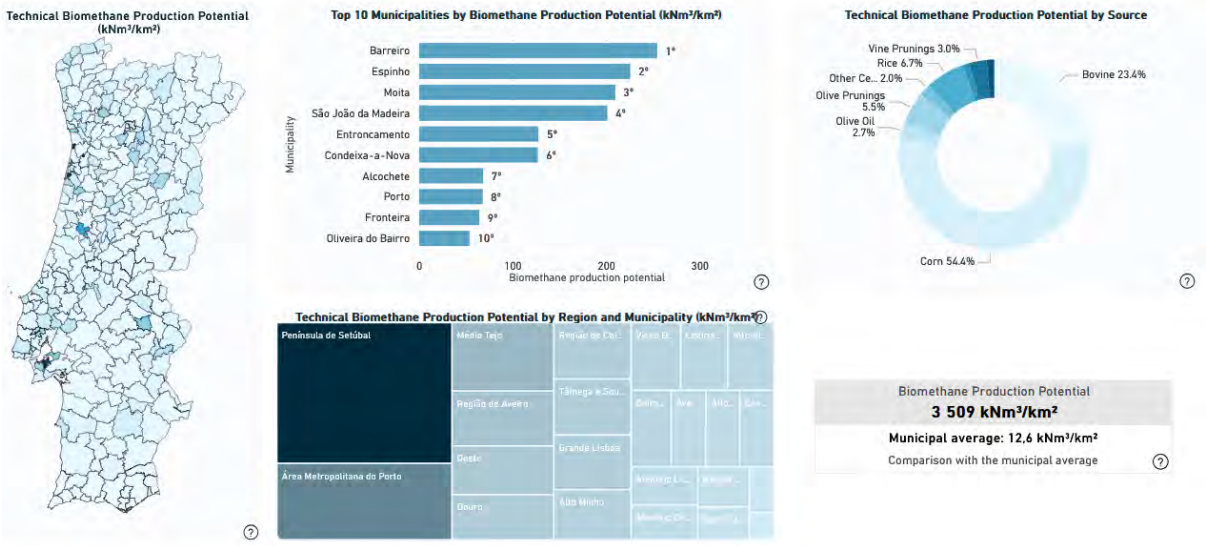
The estimated MAC ranges from cost-saving (negative-cost) mitigation options to cases with no net abatement benefit, depending on factors such as plant scale, technology configuration, feedstock type, biomass transport distance, and proximity to gas infrastructure. The lowest MAC were observed in municipalities where biomass resources are highly concentrated and located close to existing NGN (Figure 3).

In our analysis, implementable municipalities within ~20 km of the existing NGN had average MACs around €67 per tCO_2-e, whereas those further away averaged €115 per t CO_2-e. Proximity clearly helps, but the relationship is only moderate (correlation ≈0.15); high feedstock density and larger plant scale can partially offset distance effects, and some near-network sites still have high MAC when resources are limited, indicating that resource availability remains a critical constraint alongside infrastructure access.

Biomass transport and grid connection costs are the primary drivers for overall system costs, showing strong correlations with total system cost (≈0.84–0.88), highlighting logistics as a critical determinant of economic viability. In the 53 implementable municipalities, the MAC averages about €77 per t CO_2-e, with a median of €104 per t CO_2-e; several municipalities even achieve negative MAC values (i.e., cost savings), while the highest MACs remain below €263 per t CO_2-e.

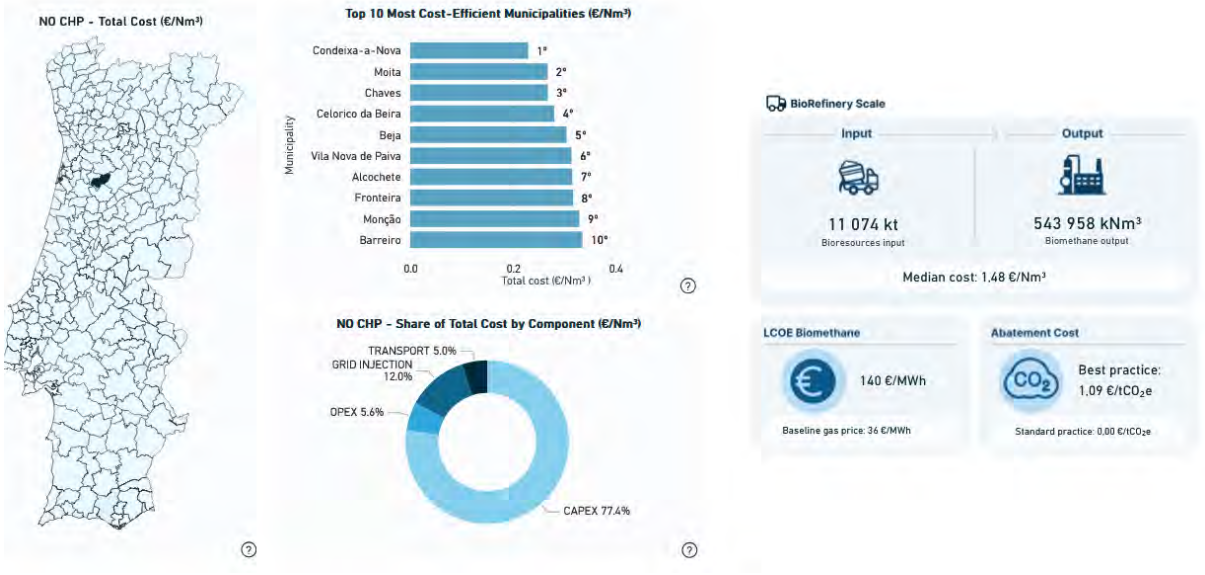
Overall, larger-scale projects in municipalities with high feedstock density consistently show lower MAC, confirming that economies of scale are a key driver of cost competitiveness. These results demonstrate that biomethane deployment costs are highly location-dependent, reinforcing the importance of spatially targeted policy support. Under favourable conditions, biomethane can represent a competitive decarbonisation option for the gas sector, particularly for applications in hard-to-electrify sectors such as industrial heat, heavy transport and gas-based energy systems.

Figure 1: Spatial distribution of biomethane production technical potential across Portuguese municipalities ($kNm^3 \cdot km^{-2}$).



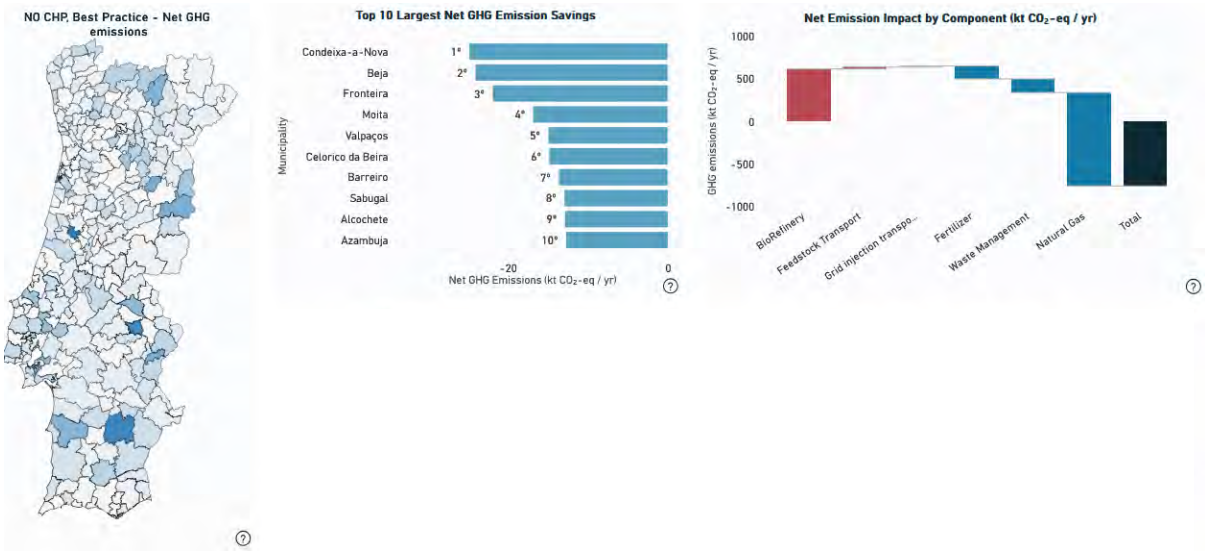
Souce: Zickmantel et al. 2026.

Figure 2: Spatial distribution of biomethane production implementable potential across Portuguese municipalities (€·kNm^3).



Souce: Zickmantel et al. 2026.

Figure 3: Spatial distribution of GHG emissions of biomethane production across Portuguese municipalities (ktCO$_2$e·y^{-1}).



Souce: Zickmantel et al. 2026.

Targeted policy interventions are required to unlock biomethane's contribution to the energy transition

The results of BioRede project suggests that mainland Portugal holds meaningful biomethane potential, but its deployment will depend on coordinated policy action addressing infrastructure constraints, investment risks, and planning capacity at local level. A coherent policy framework should combine territorial strategies, market support mechanisms and evidence-based planning tools. In the short-term, policy should prioritise deployment in high-potential municipalities with existing infrastructure access, while in the

medium-term focusing on regional hub development and targeted infrastructure adaptation.

Avoid uniform national approaches

Public policy should prioritise the development of biomethane projects in regions where favourable conditions already exist, particularly where biomass availability, infrastructure access and logistical conditions align.

Targeted regional strategies through Intermunicipal Communities (CIMs) could improve project feasibility and accelerate the deployment of biomethane production facilities. The municipalities with the highest implementable technical potential under best-practice assumptions are Batalha, Serpa, Constância, Góis, Montemor-o-Velho, Estremoz, Santarém, Belmonte, Alcácer do Sal and Celorico de Basto; together they account for over one-quarter of Portugal's implementable biomethane. Implementation feasibility is clustered in the Centre and Alentejo regions: more than half of the implementable municipalities belong to Centro and Alentejo NUTS II regions, with the Norte region showing moderate potential and Península de Setúbal and Algarve much lower.

Policymakers may consider:

- Promoting regional biomethane hubs, enabling local production and use in high-resource areas and strengthening circular bioeconomy value chains.
- Developing local demand clusters, linking biomethane production with nearby industrial users, heavy transport fleets, agricultural machinery, or district energy systems.
- Supporting alternative distribution solutions, such as compressed biomethane transport by road or small-scale storage and logistics systems.
- Developing demand-side instruments, such as public procurement, support for biomethane use in industry and heavy transport, and long-term offtake agreements to ensure stable demand.
- Encouraging cooperative or regional investment models, allowing municipalities, farmers, and local industries to jointly develop biomethane projects. Integrating biomethane planning with regional energy and rural development strategies, ensuring that projects contribute to both decarbonisation and territorial economic development.

Stable markets drive deployment

Despite its environmental and energy security benefits, biomethane production may face economic barriers due to high initial investment costs and uncertain market conditions. Without stable and predictable policy support, private investment in biomethane production is likely to remain limited.

Policy mechanisms that could support market development include:

- Feed-in tariffs or premium payments for biomethane injected into the NGN;
- Contracts for difference (CfDs) to reduce price volatility and provide long-term investment certainty for renewable gas producers;
- Capital grants, low-interest financing, or tax incentives for anaerobic digestion and biomethane upgrading facilities;
- Financial support for grid connection, upgrading, or alternative distribution solutions;
- Renewable blending mandates, requiring a minimum share of renewable gases properly certified with guarantees of origin;
- Long-term overarching policy, including clear deployment targets and regulatory frameworks for renewable gases.
- Streamlining permitting and licensing procedures for biomethane projects to reduce administrative delays and project development risks.

These measures would improve project bankability, reduce investment risk, and help mobilise private capital for biomethane production, accelerating the contribution of

renewable gases to Portugal's energy transition.

Evidence-based planning strengthens policy effectiveness

Biomethane potential, infrastructure availability, and economic feasibility vary significantly across regions, making territorial analysis essential for effective policy design. To strengthen policy design and planning capacity, policymakers should consider:

- Establishing an integrated decision-support platform, such as BioRede+ tool, to help identify priority investment locations and assess the economic competitiveness and climate benefits of biomethane projects at regional and municipal levels.
- Embedding spatial planning tools into national energy and climate policy frameworks, supporting evidence-based infrastructure planning and more efficient allocation of public support.
- Establishing transparent sustainability criteria and monitoring frameworks, ensuring that biomethane deployment delivers verifiable climate benefits and avoids negative impacts on land use or food systems.
- Promoting regional biomethane development clusters, where feedstock supply, processing infrastructure and end-use demand can be coordinated to improve project viability.
- Improving coordination between energy, agricultural, and regional planning authorities, ensuring that biomethane deployment strategies reflect local resource availability and development priorities, and are aligned with circular economy and waste management policies.
- Establishing coordination mechanisms between national and regional authorities to ensure alignment of energy, agricultural and infrastructure policies.

Strategic Insights

Biomethane represents a strategic opportunity for Portugal to simultaneously advance climate neutrality, strengthen energy security, and promote circular economy practices in rural territories. The spatially explicit evidence generated by the BioRede project demonstrates that meaningful volumes of renewable gas can be produced domestically, with measurable climate benefits and competitive abatement costs under favourable conditions.

However, the results also make clear that potential alone does not guarantee successful deployment. The uneven territorial distribution of biomass resources and the limited coverage of gas infrastructure create structural constraints that require coordinated policy intervention. Without spatially informed planning, there is a risk of fragmented investment, inefficient public support and delayed decarbonisation outcomes.

By aligning infrastructure planning, economic incentives and regional development strategies with evidence-based spatial analysis, Portugal can unlock the full value of biomethane as part of a resilient and low-carbon energy system. The decisions taken today will determine whether biomethane remains a theoretical opportunity or becomes a concrete pillar of the national energy transition in the near future.

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