OrgWaste2Fuel

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From organic residues to Fuel & Heat

Authors:

Stefan Klebingat[1], Jan Philipp Groß [2], Ralf Reuters[2], Romy Sommer[1], Johannes Gulden[1], Heralt Schöne[2]

[1] University of Applied Sciences Stralsund, Institute of Renewable Energy Systems
[2] Neubrandenburg University of Applied Sciences, Department of Agricultural Economics and Food Sciences

1.Introduction

Background: The transition from fossil-based energy systems towards a circular bioeconomy requires efficient pathways to convert organic residues into renewable fuels and heat. Biomethane and biomethanol are key low-carbon energy carriers, enabling the valorisation of agricultural residues, municipal green waste and other biogenic by-products while reducing greenhouse gas emissions and strengthening regional energy security (2–4). Biomethane is typically produced via anaerobic digestion followed by gas upgrading, whereas biomethanol among other can be synthesised from biogenic CO_2 and renewable hydrogen or via syngas-based conversion routes from residual biomass (4,5). The DVGW 'Zukunftsbild Biomethan 2025–2045' additionally underlines the relevance of biomethane for climate neutrality and regional resilience (6). Recent studies further indicate that centralized and decentralized biomethane pathways differ in transport distance, feedstock distribution and infrastructure demand, which affects regional deployment (7).

Fig. 1: OrgWaste2Fuel programme area, modified after (1)

The Interreg VI A project OrgWaste2Fuel (INT0400111) addresses these challenges within the cross-border Euroregion Pomerania (cf. Figure 1), including the German counties of Vorpommern-Rügen, Vorpommern-Greifswald, Mecklenburgische Seenplatte, Uckermark, Barnim and Märkisch-Oderland, and the Polish counties of Szczeciński, Koszaliński, Stargardzki and Szczecinecko-Pyrzycki. The project aims to identify underutilized organic residues and develop technically feasible, economically viable and sustainability-compliant biomethane and biomethanol pathways based on these residues (8). Regional biomass potential is assessed with regard to feedstock availability, conversion routes, logistics and integration options. Seasonal supply patterns and decentralised conversion concepts are evaluated in relation to local infrastructure and market conditions. Promising residue streams are identified, alternative process routes are compared and technical, economic and organisational barriers to deployment are analysed. Expected outputs include a regional biomass toolkit and a technological guideline, supporting municipalities, farmers, SMEs and public authorities in implementing climate-neutral biofuel pathways and strengthening regional energy security.

2.Methodology

Organic Residues: Data Analysis & Biomass Potential

Published statistical and authority data on organic residues from agriculture, municipalities and the food industry (cf. Figure 2) are assessed to identify biomass potentials for biomethane and biomethanol pathways.

Spatial Mapping & Logistics Calculations

GIS-based spatial mapping (cf. Figure 3) and on-site assessments are used to identify biomass clusters, transport infrastructure and suitable processing sites, with focus on biogas plants and renewable energy systems. A cost calculation tool will be developed to evaluate logistics scenarios.

Value Chain: Pathways to Biomethane & Biomethanol Production

Value chains for biomethane and biomethanol production are analysed regarding viable biomass utilisation pathways, conversion technologies, CO_2 integration and economic feasibility to identify sustainable regional implementation concepts (cf. Figure 4).

Knowledge Transfer & Cross border implementation

Cross-border pilot site visits, stakeholder exchange and training activities support knowledge transfer, technology evaluation and the development of transferable regional concepts for sustainable biomethane and biomethanol value chains..

Fig. 2: Exemplary organic residue streams across sectors (9-18)

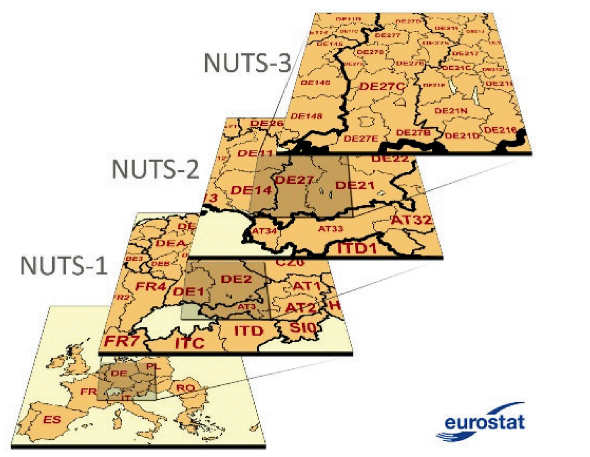

Fig. 3: Spatial mapping principle based on NUTS-Levels (19)

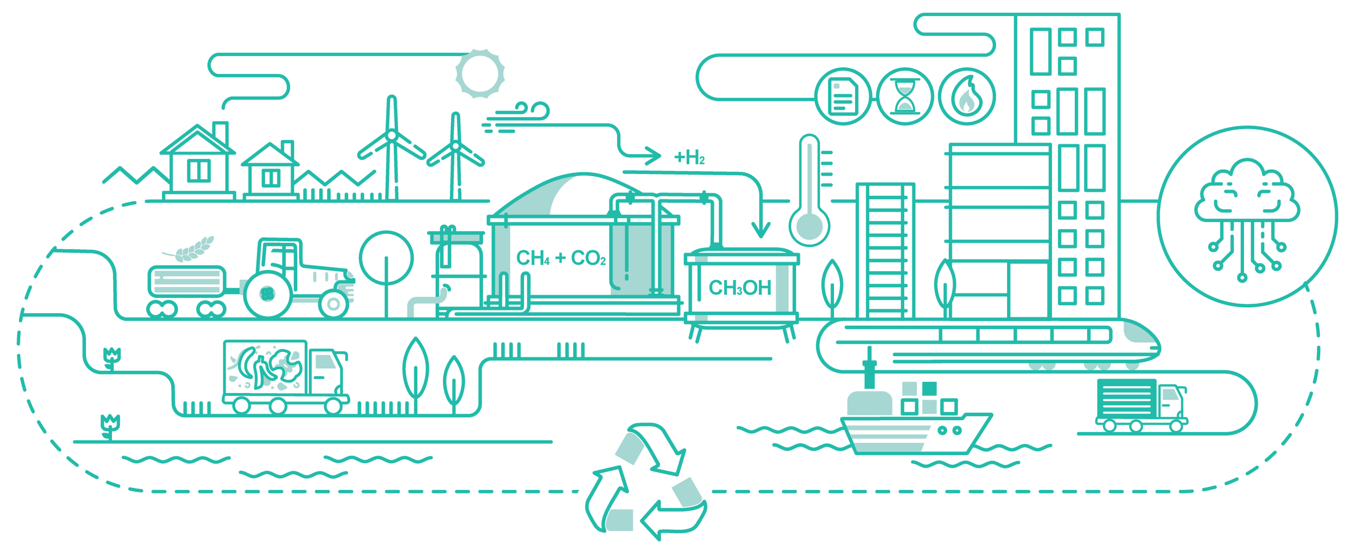

Fig 4: Orgwaste2Fuel Value Chain

3.First Results

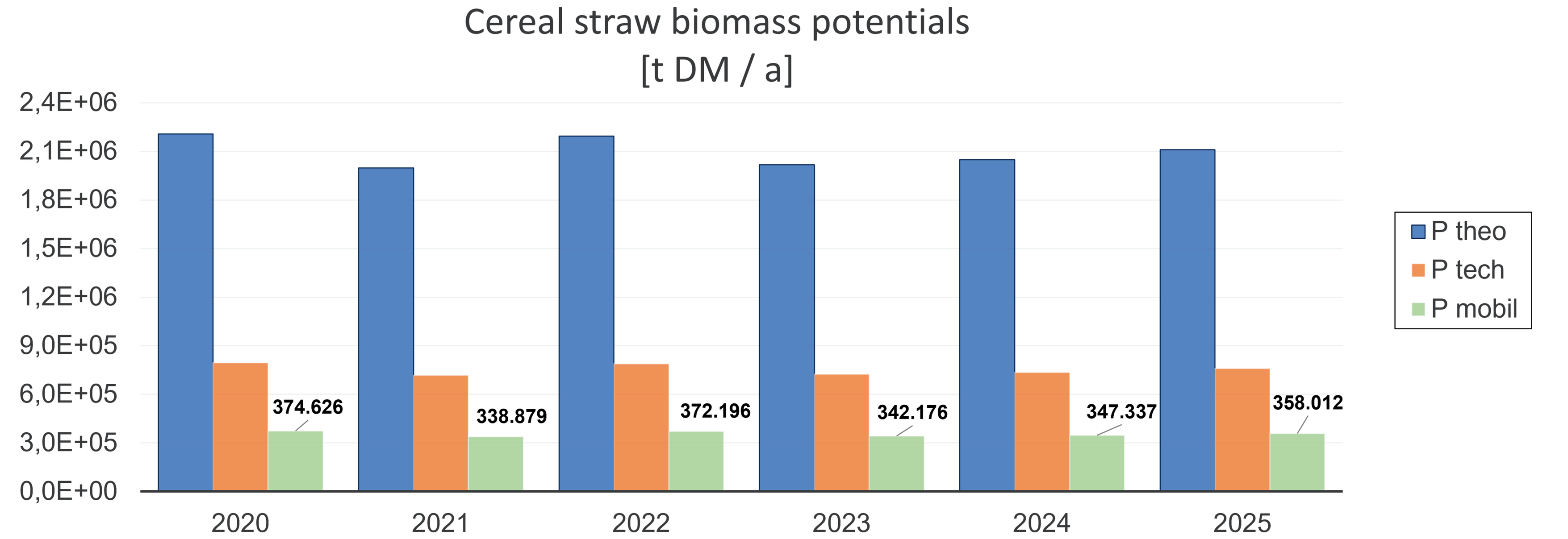

Fig. 5: Example of total cereal straw biomass potentials within the German project area part, including calculated theoretical potential (P theo), technical potential (P tech) and mobilizable technical potential (P mobil) 2020–2025 based on regional statistical data and cereal straw flowchart analysis (20)

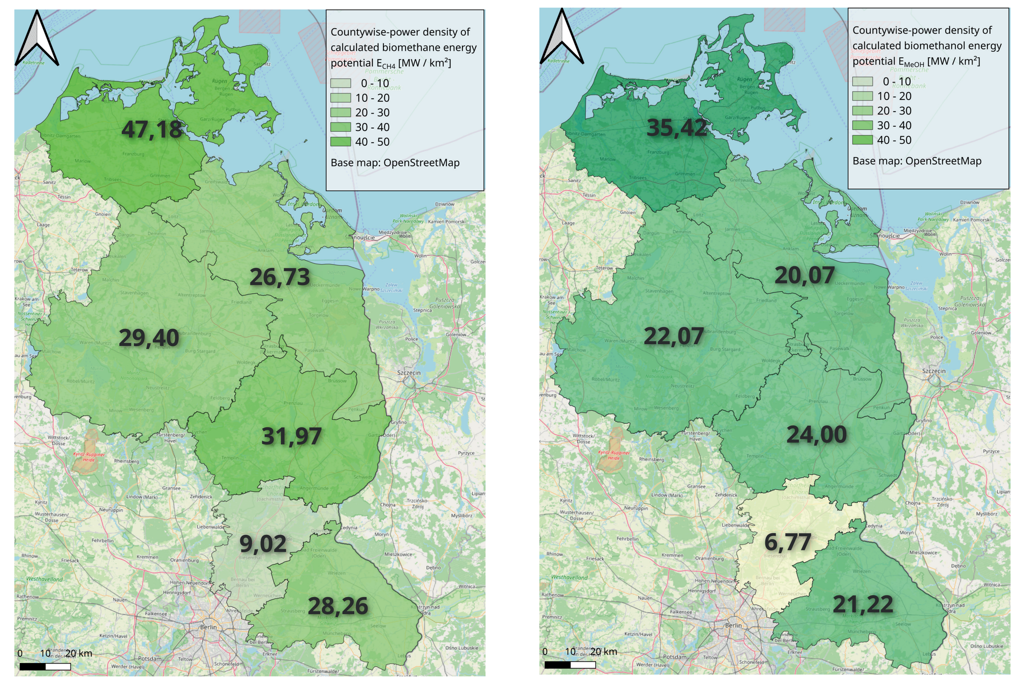

Fig. 6a/6b: Countywise-power density of calculated biomethane energy potential E_{CH4} [MW/km²] (6a, left) and biomethanol energy potential E_{MeOH} [MW/km²] (6b, right: assumed for further biogenic CO_2 and H_2 utilization) 2025 within the German project area part, based on calculated mobilizable technical biomass potential of cereal straw (20)

Tab. 1: Pre-Ranking: Technological pathways to regional biomethane & biomethanol production

Product	Technological pathways*	Exemplary feedstock / implementation fit	Pre-Ranking**	Selected references
Bio-CH_4	UASB	high-load industrial & municipal wastewater	+	(23, 24, 28)
Bio-CH_4	AHPD	liquid manure, organic industrial wastewater	+	(21-23)
Bio-CH_4	Pretreatment + AD	straw, paludiculture biomass, fibrous residues	+	(21, 26, 27)
Bio-CH_4	Multiphase AD	lignocellulosic biomass, fibrous residues	+	(21, 24, 25)
Bio-MeOH	Biological methanotroph-based methanol production	purified CH_4 / biogas CH_4	+	(30, 31, 32)
Bio-MeOH	RWGS + methanol synthesis	purified biogenic CO_2 + renewable H_2	+	(33, 34, 35)
Bio-CH_4	Dry AD (continuous)	strawy grass, structural plant residues	++	(21, 23, 37)
Bio-CH_4	Wet AD (thermophilic)	food waste, dairy by-products, manure mixtures	++	(21, 23, 29)
Bio-CH_4	Dry AD (batch)	green wastes, grass cuttings, straw	++	(21, 23, 36)
Bio-MeOH	Plasma/catalytic direct methanol synthesis	purified CH_4 or biogenic CO_2-derived syngas (stable gas quality)	++	(30, 38, 39)
Bio-MeOH	RDF gasification -> syngas -> methanol	RDF with biogenic fraction	++	(40-42)
Bio-MeOH	Biomethane -> reforming -> methanol	upgraded biomethane from AD pathways	++	(43-45)
Bio-MeOH	Wood gasification -> syngas -> methanol	forestry residues, sawmill residues, waste wood	++	(30, 45, 46)
Bio-CH_4	Plug-flow fermenter	manure, silage mixtures	+++	(23, 24, 47)
Bio-CH_4	Standard co-digestion	manure, food waste, bio-waste, silage mixtures	+++	(21, 24, 36)
Bio-CH_4	Wet AD (mesophilic)	manure, sewage sludge, food waste	+++	(21, 23, 29)
Bio-MeOH	Biogas-CO_2 + green H_2 -> e-methanol (PtX)	biogenic CO_2 from AD upgrading + green H_2	+++	(48-51)

LEGEND: Technological pathways UASB: upflow anaerobic sludge blanket; AHPD: autogenerative high-pressure digestion; AD: anaerobic digestion; MeOH: methanol; RWGS: reverse water-gas shift; RDF: refuse-derived fuel; PtX: power-to-X. Pre-Ranking** based on practical regional implementability, technical maturity, CAPEX/OPEX, feedstock flexibility, regional implementation fit and decarbonization potential. Symbols: + low, ++ medium, +++ high priority.*

4.Conclusion & Outlook

First calculations for the German project area show that cereal straw theoretical, technical and mobilisable technical biomass potentials fluctuate round about 5% around their mean, i.e. within an overall min-max range of roughly 10%, and thus remain almost constant over the years 2020–2025, while the technically mobilisable potential stays below 20% of the theoretical total biomass potential (normalised to 100%). Using the mobilisable cereal straw potential for 2025, the highest areal power densities of the exemplary biomethane and biomethanol potentials are obtained in the counties of Vorpommern-Rügen (Mecklenburg-Western Pomerania) and Uckermark (Brandenburg). Against this background, a first literature-based pre-ranking of suitable technological pathways from an implementability perspective highlights wet mesophilic anaerobic digestion, standard co-digestion and plug-flow fermenters as particularly well-established biomethane technologies for the German project region. In addition, further utilisation of the CO_2 contained in raw biogas, coupled with green hydrogen for decentralised biomethanol production via direct methanol synthesis, emerges as a key option for future regional demonstration and upscaling activities.

Contact: Dr. rer. nat. Stefan Klebingat

University of Applied Sciences Stralsund, Institute of Renewable Energy Systems
stefan.klebingat@hochschule-stralsund.de

References (1-51) via QR-CODE

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