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AI library to explore current trends and follow up topics for the Green Molecules Collective

What insight can we generate on state of affairs biogas research in NL?

By Emma Beroske

Introduction

On June 19th at the New Energy Forum, an AI session was held by members of the Green Molecules Collective (GMC). The aim of the session was to sum up existing research that has been conducted on the various forms of green molecules amongst the organisations and universities of applied sciences of the collective and beyond. Based on the scientific reports, project descriptions and other documents uploaded to an AI tool (Co-pilot), we could ask to synthesize the findings and research trends, answer questions from the audience and help identify the follow up questions that can be explored. The AI was surprisingly accurate with its answers although they should always be taken with a grain of salt as AI can sometimes give misleading answers. Continue reading to find out what were the key research findings identified with AI, the trends in innovation, the major breakthroughs and failures as well as the policy recommendations for the scale up of green molecules.

Part 1: Key Research Findings

Together with participants, we have first asked the AI to elaborate on green molecules and their role in the different societal transition. Based on the literature, it is evident that green molecules play a crucial role in replacing fossil feedstocks and accelerating the circularity transition. When asked “What are the topics and key research findings based on the reports I have uploaded?”, the AI generated the topics and key findings as summarised below.

Topic	*Key research findings*
Green Molecules as Infrastructure-Compatible Climate Solutions	• Biomethane and e-methane offer “drop-in” alternatives to fossil gas, crucial for heat, transport, and industry. • E-methane enables CO_2 recycling and hydrogen valorisation with fewer infrastructure upgrades than pure H_2 use. • Bio-based monomers (e.g. FDCA) and circular methanol represent scalable alternatives in chemical value chains.
Smart Biogas & AI-Driven Process Optimization	• Machine learning models (ANN, RF, PCA) are enhancing yield and system stability in anaerobic digestion. • Projects like *RHEA*, *TroCo*, and *Mest met een Pluim* show high-performance pilots incorporating waste heat, nitrogen stripping, and fertilizer recovery.
Transitioning to Circular Carbon Feedstocks	• The move toward CO_2-, biomass-, and waste-derived feedstocks is accelerating with increasing amount of strategies and vision being developed (e.g. *TNO/SmartPort*, Chemistry4Climate, *VNCI*). • Coordination between chemical, fuel, and agricultural sectors is essential to match circular inputs to molecule outputs.
Infrastructure and Policy Bottlenecks	• Slow permitting, grid congestion, and uncertain CO_2 logistics delay deployment. • Market uptake for sustainable molecules remains weak without standards, mandates, or price incentives.
Emerging Policy and Market Instruments	• ETS 2 and RED III raise carbon price floors and introduce binding mandates for renewable fuels, including Renewable Fuels of non-Biological Origins like e-methane. • Dutch instruments like SDE++, bijmengverplichting, and the Nationaal Programma Circulaire Economie offer partial alignment but require cohesion.

What do we think of the answers?

Interestingly, these topics and key findings are aligned with the ones we have heard from members of the collective and identified in previous events. We also see that the AI is able to make references to specific projects that were uploaded. Nevertheless, the elements identified remain on a rather high level. A deeper dive into the reports would be needed to get more insights on what the findings truly imply. It is also worth noting that the list of topics is not exhaustive. Yet it still provides a good understanding and overview of the main topics that have been researched and their findings.

Part 2: Innovation Trends Shaping the Sector

In a second part of the session, we explored with the help of AI the trends in the topics that have been have researched through the years by asking “What are the trends in research based on the reports I have uploaded?”. The topics and what they involve were generated and are summarised below.

Trend	*What It Involves*
Circular Carbon Transition	Replacing fossil feedstocks with bio-based, recycled, or CO_2-derived molecules
Smart Biogas via AI & Monitoring	Use of machine learning (ANN, RF, PCA, etc.) for forecasting, fault detection, and efficiency in anaerobic digestion
Regional Green Gas Pilots	DEI+-backed (Demonstration project Energy and Innovation) projects testing modular technology at farm and cluster level
Green Molecule Value Chains	Development and scale-up of sustainable molecules like biomethane, e-methane, FDCA, methanol. Focus on infrastructure and market creation.
Systems-Level Energy Integration	Aligning molecule production with surplus heat, renewable power, and CO_2 flows

Part 3: Major Breakthroughs & Failures

We asked AI to give us the biggest breakthroughs and failures in the development and scale up of green molecules production.

Breakthrough	*Systemic Failure*
There has been a systemic emergence of green molecules as a realistic, scalable bridge between today's fossil infrastructure and a circular future. Biomethane is already flowing in Dutch pipelines—backed by pilots, AI integration, and regulatory groundwork.	Despite technical readiness, deployment of green molecules lags due to misaligned permitting processes, weak market demand for sustainable products, and fragmented regulatory frameworks.

Part 4: Policy Recommendations

Lastly, to regulate the demand for green molecules and its supply to different end markets, we asked AI to come up with a number of policy recommendations. Co-pilot provided us with key areas to focus on.

Policy recommendations	*What it involves*
Anchor Demand with Binding Targets	• Expand and harmonize **blending obligations** across sectors (heating, transport, industry). ○ Require that new housing and building retrofits offer **dual-infrastructure** readiness (for both electrification and green gas uptake). • Introduce **minimum green content standards** for chemicals, packaging, and fuels.
Catalyze Production Through SDE++ and Sourcing Support	• Tailor SDE++ categories to **e-methane, co-digestion**, and **biogenic CO_2-to-fuel** projects. • Support **biomass logistics and CO_2 capture hubs** to unlock feedstock access.
Ensure Certification, Traceability & Trust	• Expand **Vertogas and other national registries** to cover all green molecules, aligned with EU's **RFNBO/RES-cert** frameworks. • Require **third-party verified lifecycle analysis (LCA)** to ensure credibility and avoid greenwashing.

	• Promote **mass-balance certification** for mixed-stream processing (especially in chemical clusters).
Build Market Confidence & Supply-Demand Visibility	• Develop a **national "Green Molecule Outlook"**, tracking demand projections and pipelines infrastructure per sector, similar to hydrogen roadmaps. • Establish a **Green Molecule Market Observatory** to publish pricing, emissions intensity, and uptake statistics across value chains.
Align Infrastructure & Spatial Policy	• Designate "**green molecule acceleration zones**" with fast-tracked permitting, access to waste/CO_2 streams, and grid connectivity. • Fund shared **CO_2 logistics and storage infrastructure** to enable large-scale e-molecule production. • Include **green molecule corridors** in national and EU TEN-E/TEN-T planning (e.g. the Delta Rhine Corridor).

Closing remarks

For this session, the AI library we created helped the Collective bring together a large body of literature that has been conducted on the topic of green molecules such as biogas. This AI library serves as a useful tool to synthesize insights from reports and other documents and generate new ideas by helping identify follow up questions. It is important to note that the answers the AI generates seem correct at first glance but when examined closer can appear to be misleading. This is known as hallucination when AI creates a response that contains false information. In order not to be misled, it is always good to take the answers with a grain of salt and look back at the original document to make sure that the information is right. Nevertheless, from the answers generated, we can already start identifying interesting questions and topics for future research with regards to infrastructure scale up, improving traceability and building market confidence.

If you are curious to read the insights the AI generated in more detail or want to keep the library up to date by uploading new literature and reports click here.

Background: Launch of the Green Molecules Collective at the New Energy Forum

The Green Molecules Collective (GMC) was launched at the New Energy Forum in Groningen on June 19th, 2025. This new initiative brings together Wageningen University of Research and Universities of Applied Sciences of Saxion, Avans and Hanze, as well as TNO, Investa, Platform Groen Gas and Platform Hernieuwbare Brandstoffen. Together we promote the role of green molecules in the sustainability transition, from molecules to end-product. Our mission is to accelerate the energy and raw material transition by stimulating innovation and collaboration in the field of green molecules in the Netherlands.

Over the course of the New Energy Forum, the collective hosted three sessions all centred around the goal of the initiative, spreading the word on the role of green molecules in contributing to important societal issues. One of the sessions was designed to be interactive with the use of AI.