

THUNDER

**Innovation in
e-MeOH Production
by One-Pot Tandem
Process**

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Flexible Solutions for Industrial Energy and Chemical Use

THUNDER develops a modular and integrated technology for the production of carbon-neutral electro-methanol (e-MeOH) using renewable electricity and recycled carbon dioxide. The system is designed to address the high costs, energy demand and complexity of current benchmark e-MeOH production routes, while enabling flexible deployment across industrial and energy applications.

A core feature of THUNDER is the integration of multiple process steps into a single one-pot tandem system, combining CO₂ and H₂O vapour capture, co-electrolysis for the production of carbon monoxide and green hydrogen, and catalytic hydrogenation to synthesise e-MeOH. By operating these steps in a unified and optimised configuration, THUNDER significantly improves overall process efficiency and reduces system complexity.

The technology will be demonstrated under realistic and simulated flue-gas conditions, validating its performance at laboratory and pilot-relevant scale. These demonstrations focus on efficient e-MeOH production for use in fuel cells, supporting both low-carbon mobility and renewable electricity generation.

By advancing the technology from Technology Readiness Level 3 to 4, THUNDER establishes a robust foundation for further scale-up and industrial deployment.



Commitment to Efficiency, Safety and Sustainability

Beyond technological innovation, THUNDER places strong emphasis on safety, sustainability and system integration. The project evaluates environmental, economic and energy performance across the full process chain, ensuring alignment with European climate and energy policy objectives.

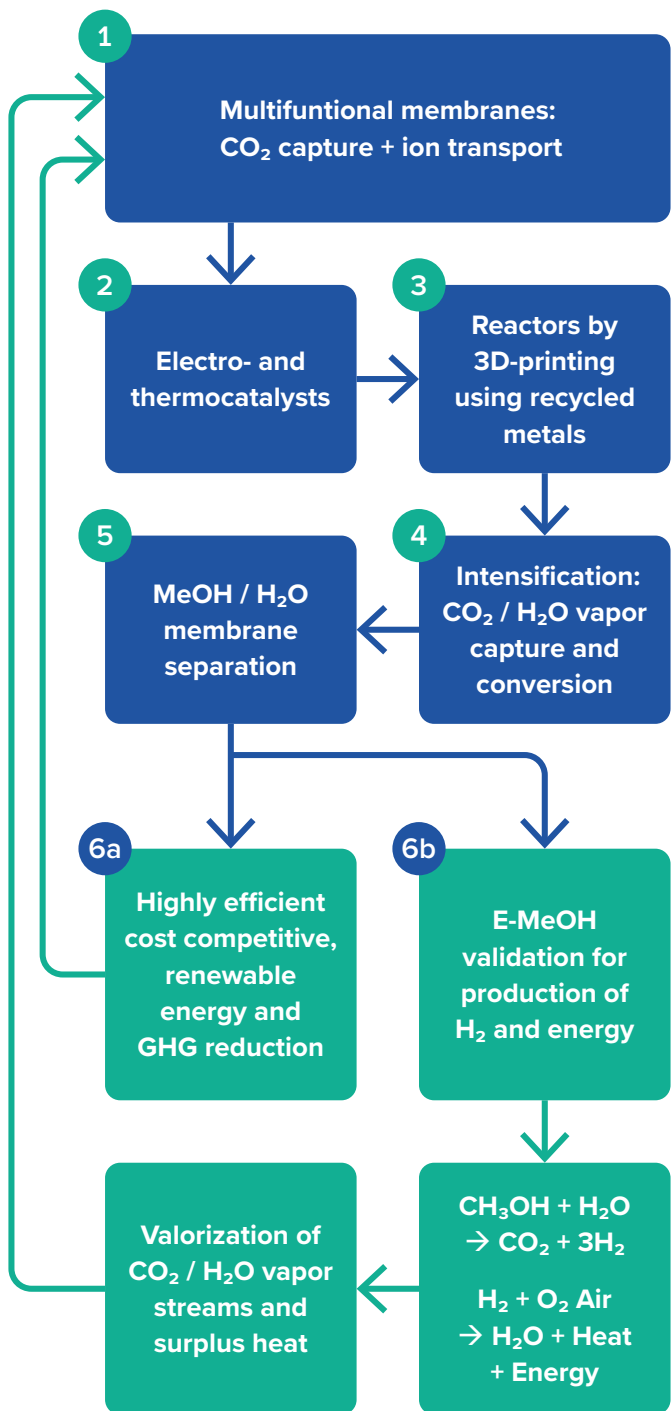
The integrated system operates using renewable electricity, recycles CO₂ and H₂O vapour, and recovers surplus heat from fuel cell operation. This approach results in substantially lower energy consumption compared with conventional e-MeOH production routes, while minimising infrastructure requirements and the use of critical raw materials.

THUNDER is expected to achieve up to a 75% reduction in greenhouse gas emissions, a 50–60% reduction in capital expenditure, and an 8–16% reduction in operational costs. The modular design enables safe operation under controlled conditions and supports flexible adaptation to different industrial environments.

By closing the carbon loop and supporting the production of sustainable fuels, THUNDER contributes directly to the European Union's transition towards a climate-neutral, circular energy and chemical economy.



Schematic Concept and Use Case



THUNDER Benefits

- Integrated capture and conversion of CO₂ and H₂O vapour for e-methanol production
- One-pot tandem process combining capture, co-electrolysis and methanol synthesis in a single system
- Significant energy efficiency gains through process integration and heat recovery
- Modular and scalable technology adaptable to diverse industrial and energy applications
- Validation under real and simulated flue-gas conditions at relevant laboratory and pilot scale
- Substantial reduction in greenhouse gas emissions (up to 75%)
- Reduced capital and operational expenditure compared with benchmark e-MeOH technologies
- Safe operation using renewable electricity and reduced use of critical raw materials

Engaging Stakeholders for Impact

THUNDER actively engages a broad range of stakeholders, including industrial technology providers, energy and fuel users, researchers, and policymakers. Through transparent communication, targeted dissemination and cross-sector collaboration, the project promotes awareness and understanding of integrated e-methanol production technologies.

This engagement approach supports informed decision-making, facilitates future industrial uptake and contributes to the alignment of technological innovation with European climate, energy and industrial policy objectives. By demonstrating a viable pathway towards carbon-neutral fuels, THUNDER strengthens the foundation for market integration and long-term system transformation.



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