



POLITECNICO
MILANO 1863

The impact of geography and carbon source on the competitiveness of e-chemicals production

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FutureCHEM Europe 2026
1-2 October 2026

KEY FACTORS FOR COMPETITIVE E-CHEMICALS

1. Low-carbon and low-cost electricity
2. Technologies and infrastructure to manage renewables variability
3. Sustainable, low-cost carbon



Low-carbon and low-cost electricity

I&EC
research

Industrial & Engineering Chemistry Research

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Article

Utilization or Sequestration for Captured CO₂ from Cement Plants?

Published as part of Industrial & Engineering Chemistry Research *special issue* "Marco Mazzotti Festschrift".

Syed Ali Zaryab, Federico d'Amore, Paolo Colbertaldo, and Matteo C. Romano*

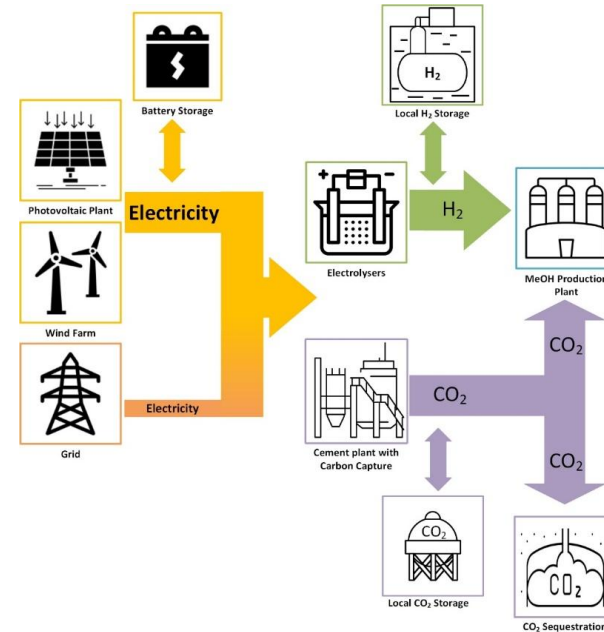


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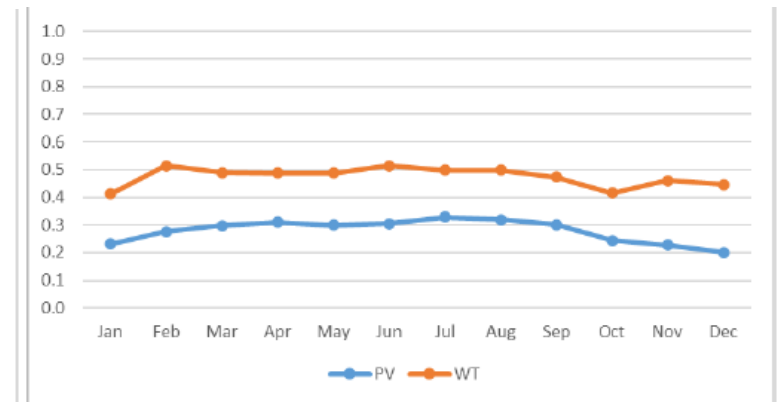
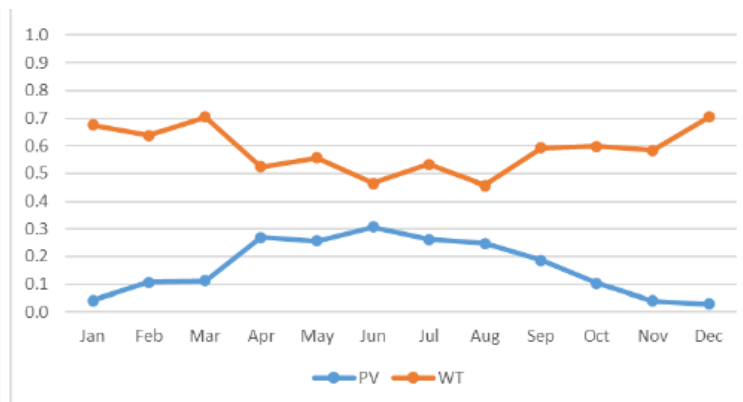
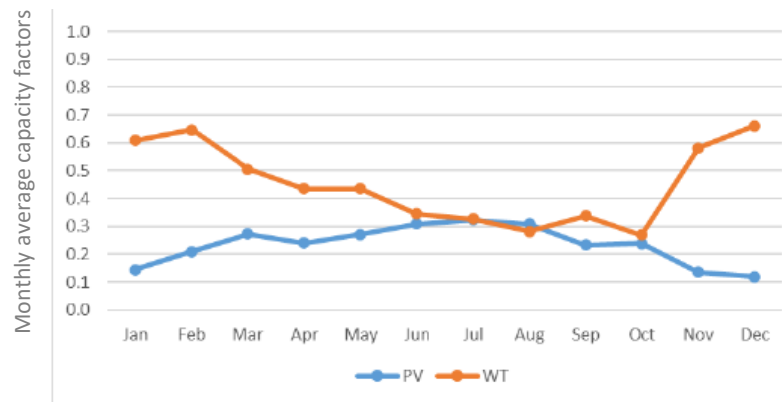
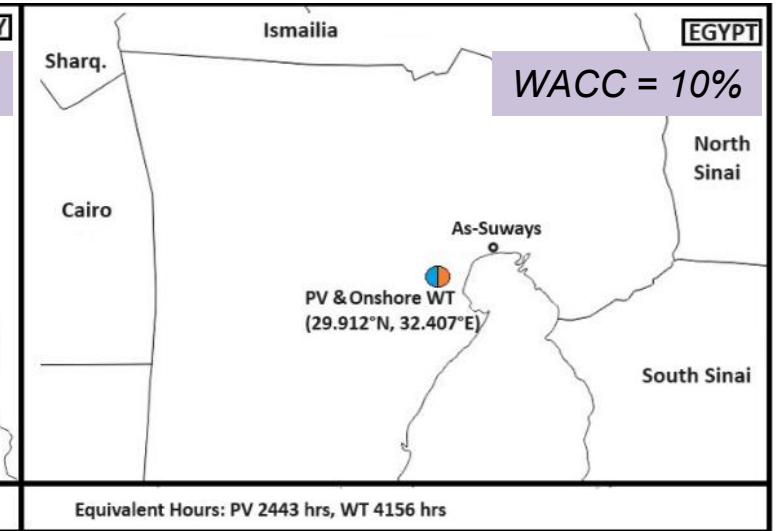
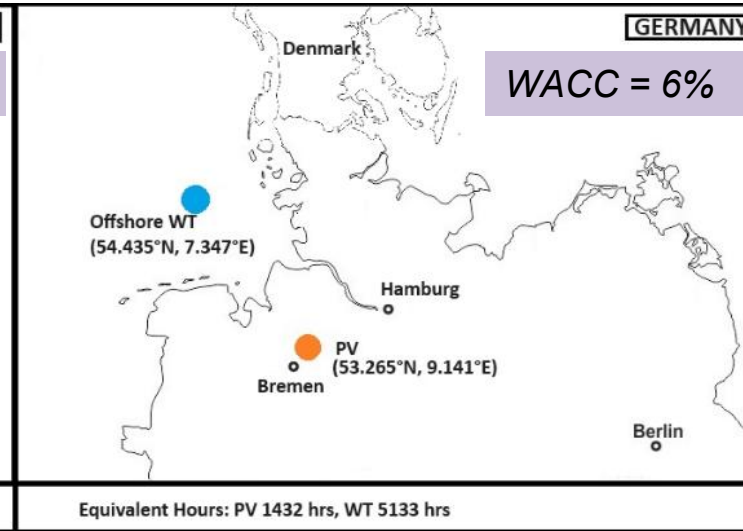
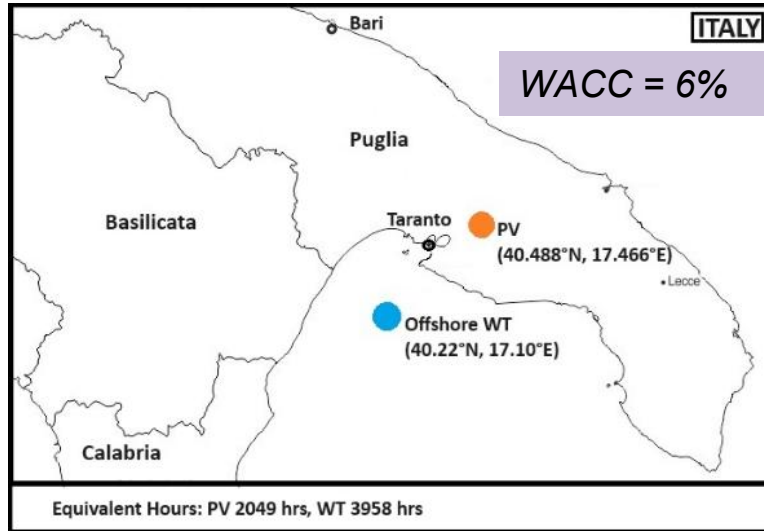


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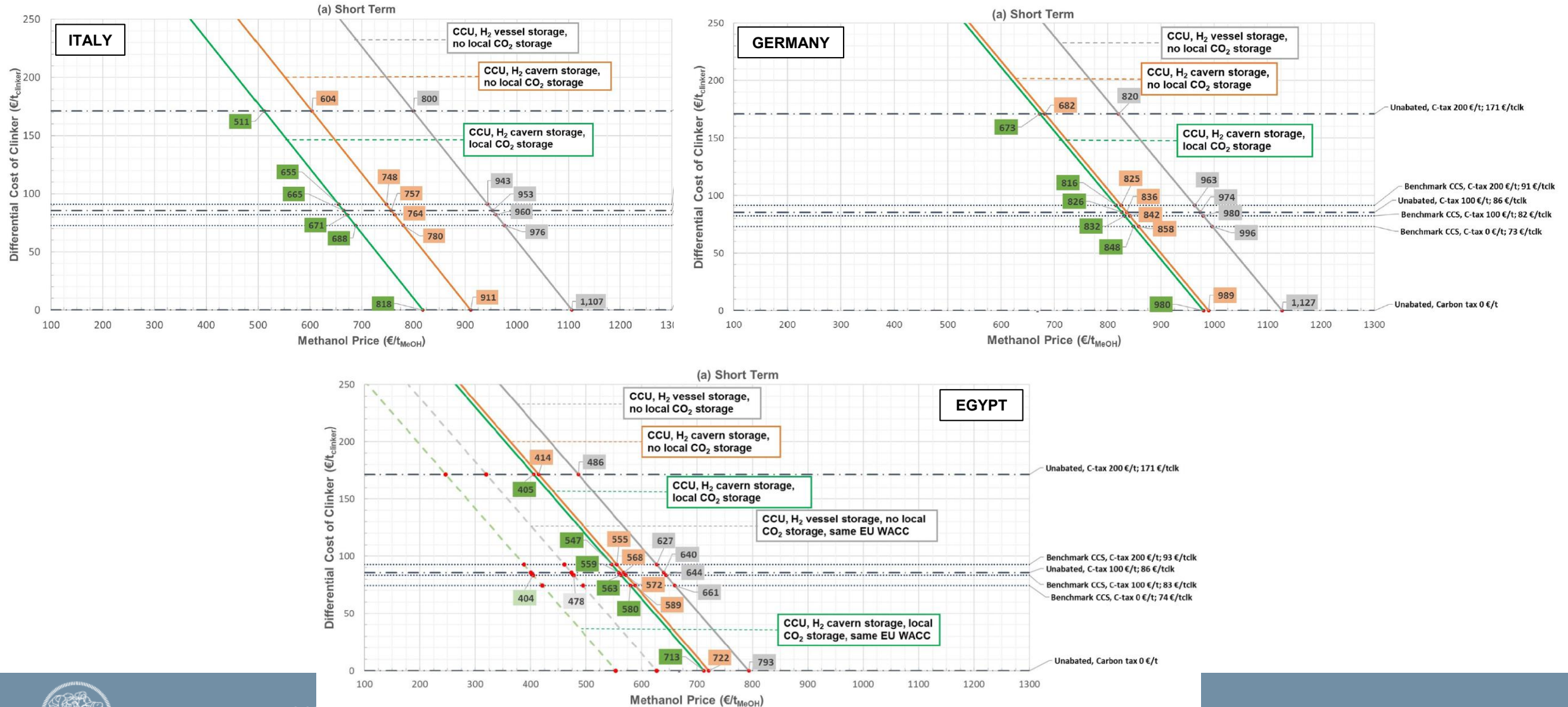
- Three locations: Southern Italy | Northern Germany | Egypt
- Two cost scenarios: short-term | long-term
- Different constraints on infrastructure availability:
 - No constraints (flexible e-methanol plant, low-cost H₂ storage available, local CO₂ storage available)
 - No low-cost H₂ storage in caverns (only high-cost storage in pressure vessels)
 - No local CO₂ storage (i.e. inflexible e-methanol plant, for a continuous CO₂ supply)



Low-carbon and low-cost electricity

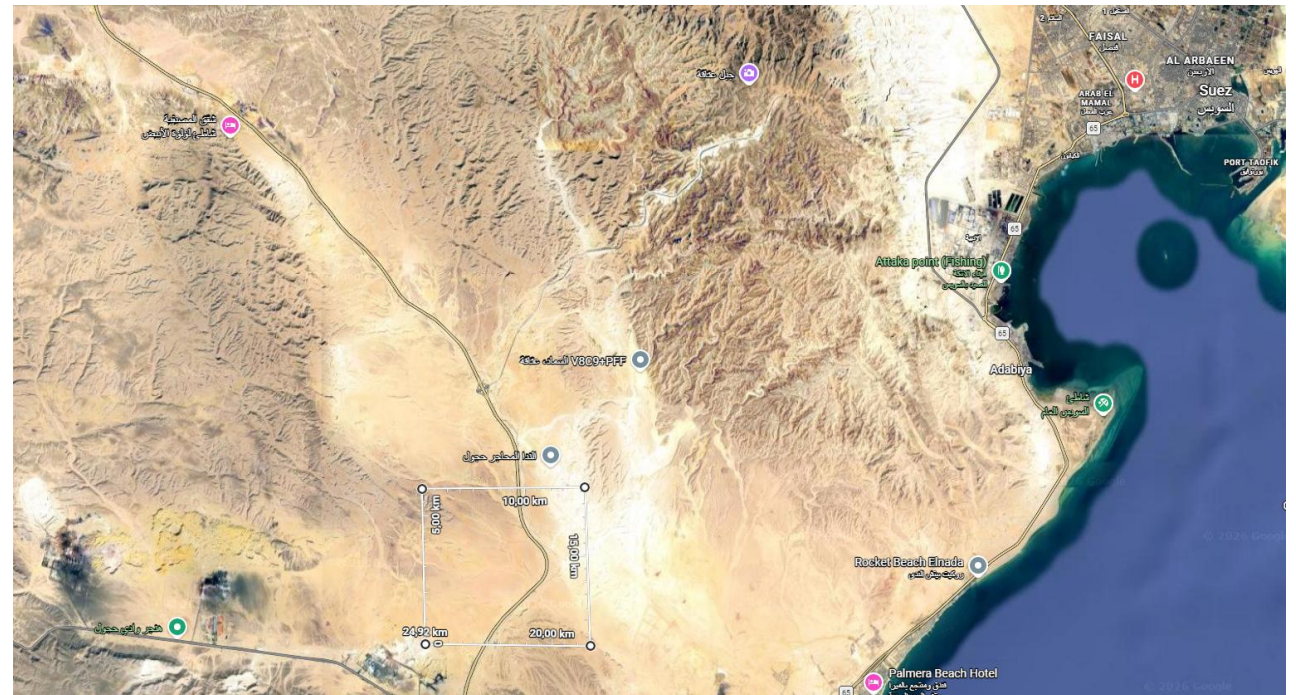


Low-carbon and low-cost electricity



Low-carbon and low-cost electricity

It's not just a matter of technical renewable energy potential.
Land availability, population density and social acceptance matter too.

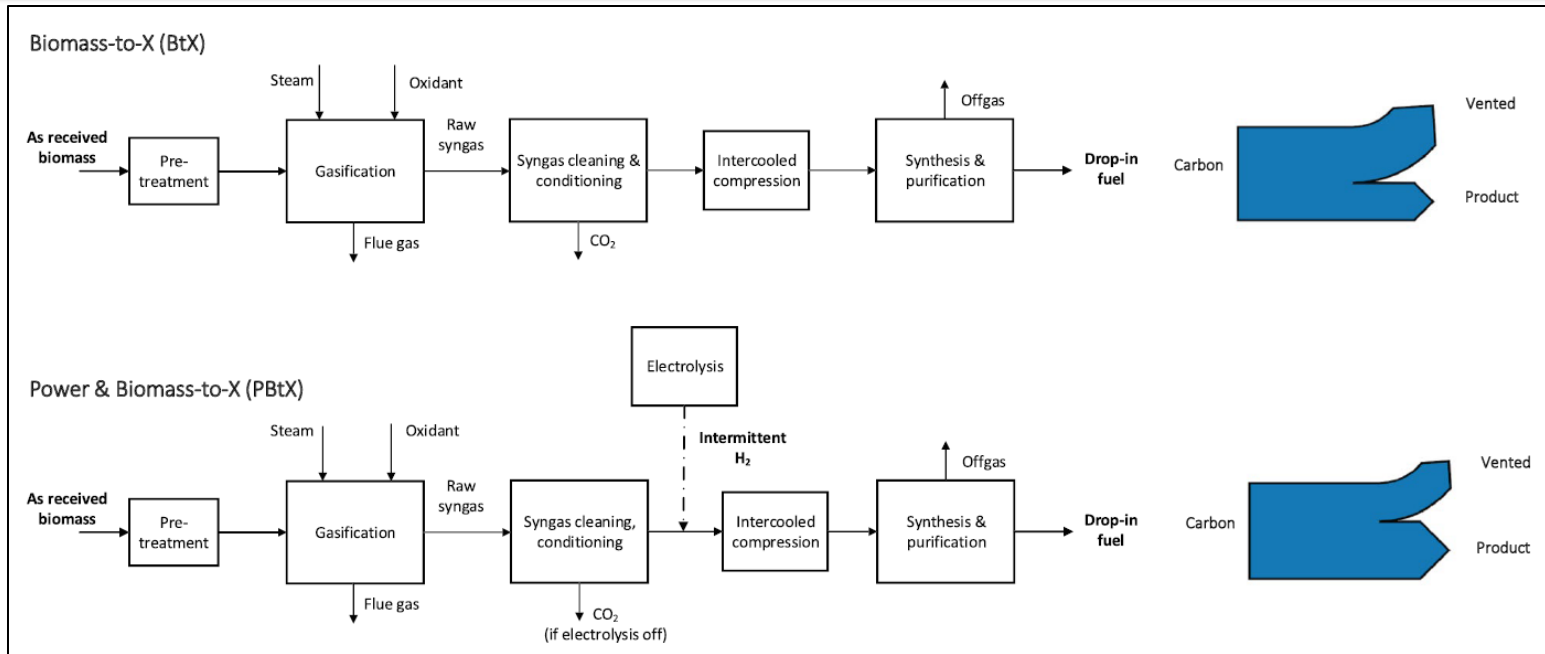


SUSTAINABLE, LOW-COST CARBON

- Carbon cost matters:
 - from a concentrated source: $150 \text{ €/t}_{\text{CO}_2} \rightarrow \approx 210 \text{ €/t}_{\text{MeOH}}$
 - from air: $500 \text{ €/t}_{\text{CO}_2} \rightarrow \approx 700 \text{ €/t}_{\text{MeOH}}$
- Carbon origin matters: climate-neutral carbon $\rightarrow$ premium price product
- Chemical energy matters: biomass supplies both renewable carbon and chemical energy



Bio-/e-chemicals



Current Sustainable/Renewable Energy Reports
<https://doi.org/10.1007/s40518-021-00191-7>

DEEP DECARBONIZATION: BECCS (P PATRIZIO AND N MAC DOWELL, SECTION EDITORS)

The Potential of Power and Biomass-to-X Systems in the Decarbonization Challenge: a Critical Review

Alessandro Poluzzi¹ · Giulio Guandalini¹ · Federico d'Amore¹ · Matteo C. Romano¹

Fuel 310 (2022) 122113

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Flexible Power & Biomass-to-Methanol plants: Design optimization and economic viability of the electrolysis integration

Alessandro Poluzzi^a, Giulio Guandalini^a, Simone Guffanti^a, Cristina Elsidio^a, Stefania Moiola^b, Patrick Huttenhuis^c, Glenn Rexwinkel^c, Emanuele Martelli^a, Gianpiero Groppi^a, Matteo C. Romano^{a,*}

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ORIGINAL RESEARCH
 published: 27 January 2022
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Flexible Power and Biomass-To-Methanol Plants With Different Gasification Technologies

A. Poluzzi¹, G. Guandalini¹, S. Guffanti¹, M. Martinelli¹, S. Moiola², P. Huttenhuis³, G. Rexwinkel³, J. Palonen⁴, E. Martelli¹, G. Groppi¹ and M. C. Romano^{1*}

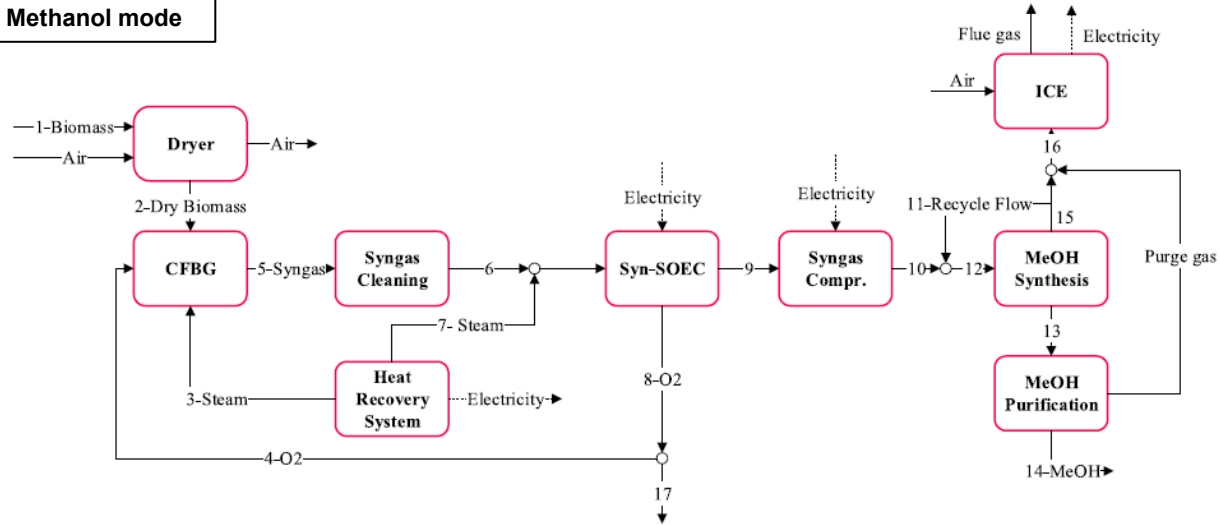
¹ Dipartimento di Energia, Politecnico di Milano, Milano, Italy, ² Dipartimento di Chimica, Materiali e Ingegneria Chimica "Giulio Natta", Politecnico di Milano, Milano, Italy, ³ Primes Renewable Energy Solutions BV, Alphen Aan Den Rijn, Netherlands, ⁴ Sumitomo SHI FW Energy Oy, Espoo, Finland



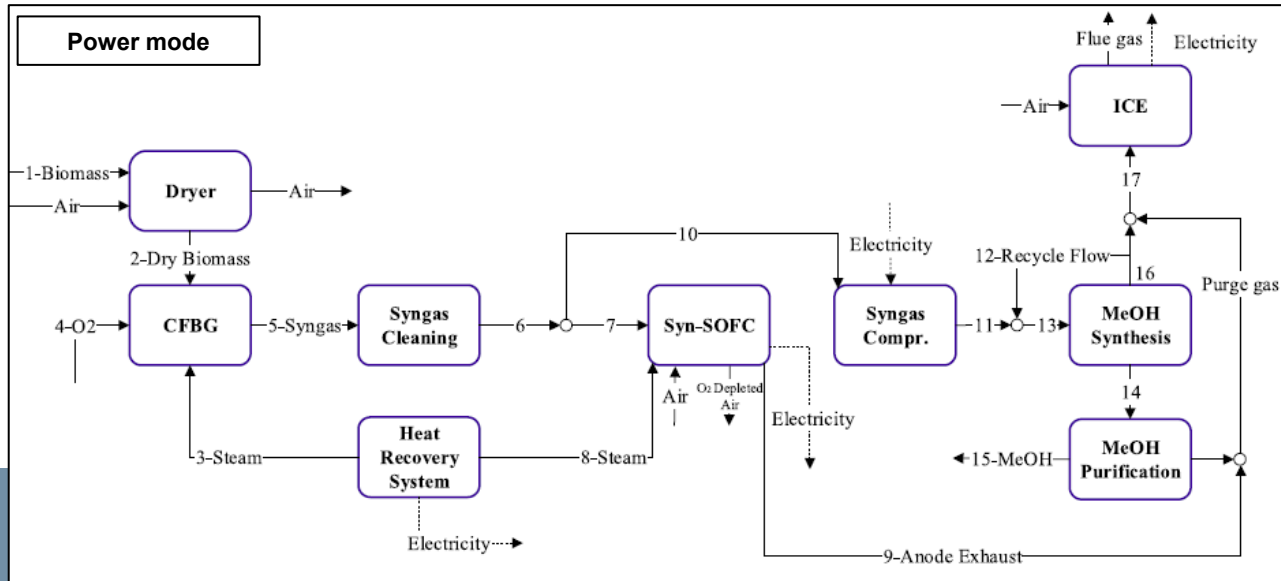
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Bio-/e-chemicals

Methanol mode



Power mode

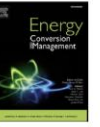


Energy Conversion and Management 301 (2024) 118009



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Techno-economic evaluation of biomass-to-methanol production via circulating fluidized bed gasifier and solid oxide electrolysis cells: A comparative study

Fatemeh Rajaei^{a,b}, Giulio Guandalini^b, Matteo C. Romano^{b,c,*}, Jouni Ritvanen^{a,*}

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Energy

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Flexible integrated gasification solid oxide cell (IGSOC) plant for bio-methanol and bio-power generation

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<https://www.bebop-project.eu/>

Bio-/e-chemicals

		Syngas electrolysis (BeBOP process)	Low-temperature electrolysis
		SyE	LT electrolysis
Inputs	Biomass input (MW)	100	100
	Electric Consumption (MW)		
	<i>Electrolysis</i>	96.29	129.04
	<i>Multi-Stage Compressors</i>	11.01	8.05
	<i>MeOH Loop Recycle Compressor</i>	0.84	0.90
	<i>Heat Pump</i>	1.79	–
	<i>Dryer</i>	0.65	0.65
	<i>Water and Scrubber Pump</i>	0.08	0.04
Outputs	O ₂ Consumption (kg/s)	1.82	2.45
	MeOH Production (kg/s)	7.08	6.99
	O ₂ Production (kg/s)	5.38	5.97
	District Heat Production (MW)	22.74	–
	Electric Production (MW)		
	<i>ICE</i>	3.53	4.44
	<i>Steam Turbine</i>	2.24	4.34
	CO/CO ₂ of the conditioned syngas	2.85	1.21
Performance Indicators	MeOH output (MW)	140.90	139.07
	Total Electricity Consumption (MW)	110.67	138.67
	Total Electricity Production (MW)	5.78	8.78
	Net Electricity Output (MW)	–104.89	–129.89
	Carbon Efficiency (%)	91.86	90.46
	Global Fuel Efficiency (%)	74.19	73.35
	Equivalent fuel efficiency (%)	35.25	28.85
	Total efficiency (%)	68.76	61.94
Total efficiency (%) (with DH)		79.86	–

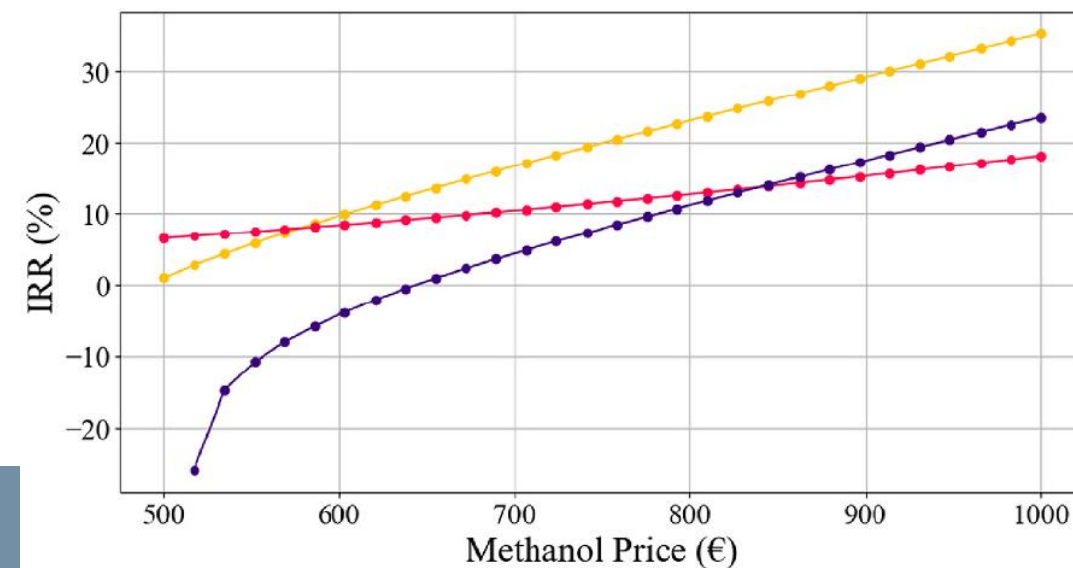
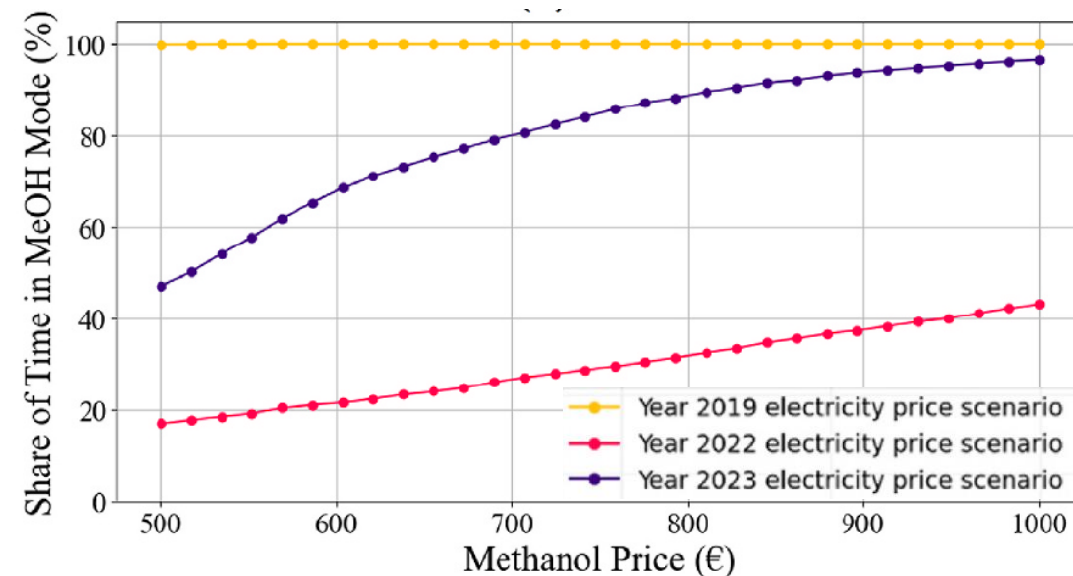
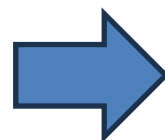
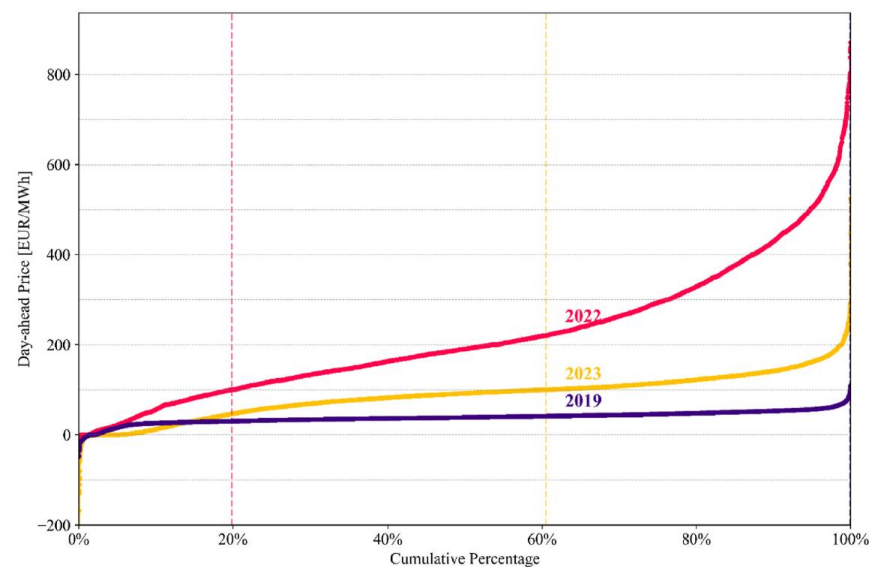
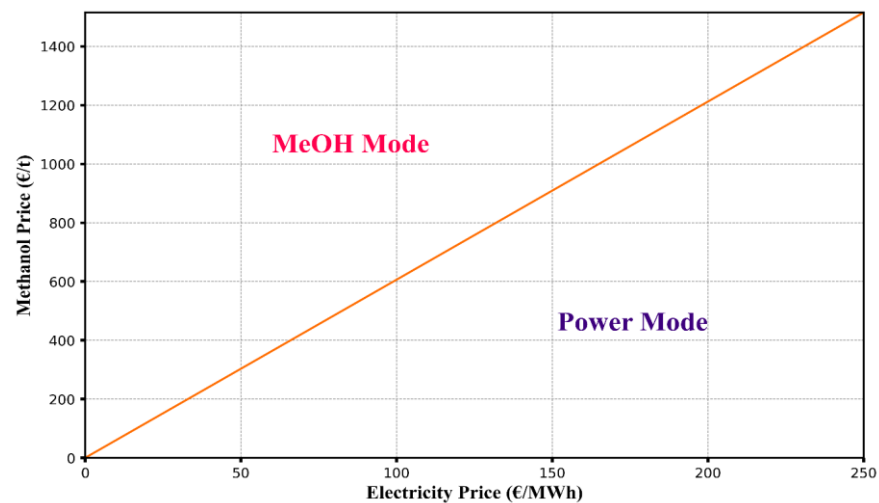


Bio-/e-chemicals

		Methanol mode	Power mode
Inputs	Biomass input (MW)	100	100
	Electric Consumption (MW)		
	<i>Electrolysis</i>	94.98	–
	<i>Syngas Compressors</i>	10.9	0.96
	<i>MeOH Loop Recycle Compressor</i>	0.67	0.14
	<i>Heat Pump</i>	2.19	0.11
	<i>Dryer</i>	0.65	0.65
	<i>Water and Scrubber Pump</i>	0.05	0.07
	O ₂ Consumption (kg/s)	–	1.73
Outputs	MeOH Production (kg/s)	7.03	0.29
	O ₂ Production (kg/s)	5.3	–
	District Heat (DH) Production (MW)	1.9	6.5
	O ₂ net production (kg/s)	3.57	–
	Electric Production (MW)		
	<i>ICE</i>	4.19	24.05
	<i>Steam Turbine</i>	2.07	0.18
	<i>SOFC</i>	–	21.64
	MeOH output (MW)	139.9	5.79
	Total Electricity Consumption (MW)	109.5	1.9
	Total Electricity Production (MW)	4.99	45.83
	Net Electricity Output (MW)	–104.48	43.92
	Carbon Efficiency (%)	91.19	3.76



Bio-/e-chemicals



TAKEAWAYS

- Geography matters in different ways (energy cost, carbon availability, carbon origin, WACC)
- Despite the scarcity of solar energy, Nordic countries are very well positioned for the production of (bio-)/e-chemicals
- Flexible bio-/e-fuel processes are valuable in the energy system
- Bio/e-fuel production and bio-CCS can compete for biogenic carbon



Kiitos



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