ELECTRIFICATION OF CHEMICAL INDUSTRY: CO_2/H_2O ELECTRO-CONVERSION TO LIGHT OLEFINS IN CO-IONIC CERAMIC REACTORS

C. Athanasiou[1,2,*], A. Banti[2,3], K. Makridis[2,3], E.A. Nanaki[4,5], S. Kiartzis[4], K. Christoforidis[1,2], V. Kyriakou[6], M. Konsolakis[7], V. Binas[8], G.E. Marnellos[2,3]

[1]Department of Environmental Engineering, Democritus University of Thrace, Xanthi, Greece

[2]Chemical Process & Energy Resources Institute, CERTH, Thermi, Thessaloniki, Greece

[3]Department of Chemical Engineering, Aristotle University of Thessaloniki, Thessaloniki, Greece

[4]Dept. New Technologies and Alternative Energy Sources, HELLENiQ ENERGY, Athens, Greece

[5]University of Aarhus, Dept. of Business Development and Technology, Herning, Denmark

[6]Department of Chemical Engineering, Engineering and Technology Institute Groningen (ENTEG), University of Groningen, Groningen, The Netherlands

[7]Technical University of Crete, School of Production Engineering and Management, Chania, Greece

[8]Department of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece

(*kathan@env.duth.gr)

ABSTRACT

The chemical industry is a major global warming contributor, and its detach from oil or other fossil carbon sources is a unidirectional urgency towards sustainability. Light olefins ($C_{2-4}^{=}$) are among the top chemicals, in production volumes [1] and the key building blocks for a vast range of products. They are mainly produced by naphtha steam cracking, an energy intensive process that charges each $C_{2-4}^{=}$ ton with up to 11.5 tons of CO_2 emissions, depending on the production route and the energy sources (usually 2 – 5 tnCO_2, for oil and natural gas) [2]. The necessity to detach $C_{2-4}^{=}$s from oil has activated intense research efforts towards CO_2 hydrogenation by renewable H_2, a benchmark equilibrium limited reaction, conducted at 30 bars [3]. For the stoichiometric ethylene and propylene production, and 50 kWh/kgH_2 typical electrolysis consumption [4], $C_{2-4}^{=}$s specific electricity consumption is 7.1 MWh/tn$C_{2-4}^{=}$. For EU's ethylene and propylene production (20 and 15 Mtn/a, respectively [5]) this consumption amounts to 250 TWh/a, i.e. to ca. 7 % of the total EU's electricity balance. Moreover, the low $C_{2-4}^{=}$ yield of the thermochemical reaction (< 10 %), due to primarily CH_4, other hydrocarbons, CO and H_2O byproducts, results in a ten-fold increase of the electricity requirement, and complexes the estimation of the energy costs for electrified $C_{2-4}^{=}$s. ECOLEFINS project was granted to originally put forward a new paradigm for $C_{2-4}^{=}$ electrosynthesis in co-ionic (H^+ and O^{2-}) electrochemical membrane reactors (ci-EMRs). The concept promises to substantially suppress CO/H_2O byproducts, thus drastically increase $C_{2-4}^{=}$s yield and decrease specific electricity consumption and $C_{2-4}^{=}$s electricity costs. The present work describes the ECOLEFINS concept and examines the impacts of the ci-EMRs' targeted performance on the electricity requirements and the economics of electrified $C_{2-4}^{=}$s, with respect to $C_{2-4}^{=}$'s yields, ci-EMRs' specific resistance, electricity prices, carbon taxes and technology costs.

KEYWORDS: olefins electrification, electrochemical reactors, co-ionic electrolytes

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REFERENCES

[1] Ma Z, Porosoff M. (2019). *ACS Catalysis*, 9(3), 2639–2656.

[2] Schiffer Z, Manthiram, K. (2017). *Joule*, 1(1), 10–14.

[3] Ye R, Ding J, Gong W, Argyle M, Zhong Q, Wang Y, Russell C, Xu Z, Russell A, Li Q, Fan M, Yao Y. (2019) *Nature Communications*, 10, 5698.
[4] Hydrogen Europe, Strategic Research and Innovation Agenta. (2020).
[5] petrochemistry.eu/petrochemicals-facts-and-figures/european-market-overview/