ENERGETICS

PNRR - Techno-economic and environmental analysis of the role of low-carbon fuels in the design of future energy systems

Funded By	MINISTERO DELL'UNIVERSITA' E DELLA RICERCA [P.iva/CF:97429780584] Politecnico di TORINO [P.iva/CF:00518460019]
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Context of the research activity	Hydrogen, e-fuels and biofuels will be crucial for the decarbonisation of the energy sector, especially for those applications where electrification is not economically viable or technically feasible. The supply chain for the production (from renewable sources), transport and use of hydrogen and low-carbon fuels currently includes low-temperature electrochemical technologies (mainly PEM and alkaline technologies). Low conversion efficiencies and the resulting high cost of the final product are trivial barriers to the widespread use of low-carbon fuels in the various energy sectors (industry, transport, power generation). Progetto finanziato nell'ambito del PNRR - PNRR M4C2, Investimento 1.3 - Avviso n. 341 del 15/03/2022 - PE0000021 Network 4 Energy Sustainable Transition (NEST) - CUP E13C22001890001
	In this context, this PhD path aims to analyse the role of high-temperature electrochemical technologies (SOC, MCC, PCC) in the low-carbon fuels supply chain for the decarbonisation of different end-uses (power generation, mobility, hard-to-abate industry, etc.). High-temperature fuel cells and electrolysers indeed have higher conversion efficiencies, flexibility in terms of fuels (in fuel cell mode) and electrolysis pathways (co-electrolysis in electrolyser mode), and the possibility of energy integration (heat) in many industrial sectors. On the contrary, some limitations might occur due to the lower dynamic behaviour, while investment costs are decreasing thanks to automated production and improved durability. The aim of the PhD activity is to model and analyse different supply chains to understand when low-carbon fuels are needed for the decarbonisation of the

Objectives	final use and when high-temperature electrochemical systems are the best option. The work will start from the modelling of individual components and use a robust and validated modelling framework to assess the whole supply chain. Components will be modelled using Matlab/Aspen Plus software. Experimental test benches (SOFC/SOEC) will be available within the STEPS laboratory for validating the component models under different operating conditions (multi-fuels, ammonia feeding, co-electrolysis). The entire supply chain will be then modelled and evaluated, taking also advantage of specific optimisation tools (e.g., the MILP-based design optimisation tool) developed in the STEPS research group. The results will include both economic (cost analysis) and environmental indicators, to investigate the economic and environmental footprint of the analysed pathways (e.g through a LCA approach). The PhD activity will be carried out within the research group STEPS (Synergies of Thermo-chemical and Electro-chemical Power Systems, coordinator prof. Santarelli). The research activities that the PhD candidate will undertake are divided as follows: - Comprehensive literature review on the hydrogen and low-carbon fuels supply chain for selected end use applications (including both current and future pathways), performance and costs of individual components, modelling frameworks (optimisation methods) and environmental indicators. - Definition of supply chains to be analysed (e.g. power generation, hard-to-abate sectors, mobility) - Collection of techno-economic and environmental data on the technologies (from recent literature, ongoing EU and national projects or from the experimental activities in POLITO) and modelling of the individual components. - Definition of the supply chain modelling and optimisation tool. - Investigation of the selected supply chains with the aim of understanding the role of high-temperature electrochemical devices in fostering deep decarbonisation of energy systems. - Writing dissertations and scientific papers. The activity will be performed in cooperation with different international partners, e.g.: - University of Wisconsin-Madison (US), Prof. Luca Mastropasqua – Assistant Professor, director of the HERD Lab (Researching sustainable electrochemical energy and hydrogen-based systems for decarbonization). - University of California Irvine (UCI), Prof. Jack Brouwer, Professor of Mechanical and Aerospace Engineering and Director of the National Fuel Cell Research Center (NFCRC) and Advanced Power and Energy Program (APEP). - National University of Catamarca, Dr. Gabriel Correa Perelmute, Centro de Energía FACEN. The activity will also interact with ongoing national and international projects in the framework of the STEPS research group: - PNRR - NEST - Network 4 Energy Sustainable Transition - AMPS - Automated Mass Production of SOC Stacks (EU project 2023-2027) - ECCO-2050 - Smart Energy in Cities and Communities for 2050 (IT PRIN project, 2023-2025)

	- Activities with specific end-use stakeholders (hard-to-abate, heavy duty, aviation, maritime, biofuels, etc.). References: [1] Marocco, P., Gandiglio, M., Audisio, D., Santarelli, M. (2023). Assessment of the role of hydrogen to produce high-temperature heat in the steel industry. Journal of Cleaner Production, 388, 135969. https://doi.org/10.1016/J.JCLEPRO.2023.135969 [2] Marocco, P., Ferrero, D., Lanzini, A., Santarelli, M. (2022). The role of hydrogen in the optimal design of off-grid hybrid renewable energy systems. Journal of Energy Storage, 46, 103893. https://doi.org/10.1016/j.est.2021.103893 [3] Gandiglio, M., Marocco, P., Bianco, I., Lovera, D., Blengini, G. A., Santarelli, M. (2022). Life cycle assessment of a renewable energy system with hydrogen-battery storage for a remote off-grid community. International Journal of Hydrogen Energy, 47 (77), 32822–32834. https://doi.org/10.1016/J.IJHYDENE.2022.07.199 [4] Marocco, P., Gandiglio, M., Santarelli, M. (2022). When SOFC-based cogeneration systems become convenient? A cost-optimal analysis. Energy Reports, 8, 8709–8721. https://doi.org/10.1016/J.EGYR.2022.06.015 [5] Correa, G., Volpe, F., Marocco, P., Muñoz, P., Falagüerra, T., Santarelli, M. (2022). Evaluation of levelized cost of hydrogen produced by wind electrolysis: Argentine and Italian production scenarios. Journal of Energy Storage, 52. https://doi.org/10.1016/J.EST.2022.105014 [6] Massaro, M. C., Biga, R., Kolisnichenko, A., Marocco, P., Monteverde, A. H. A., Santarelli, M. (2023). Potential and technical challenges of on-board hydrogen storage technologies coupled with fuel cell systems for aircraft electrification. Journal of Power Sources, 555, 232397. https://doi.org/10.1016/J.JPOWSOUR.2022.232397

Skills and competencies for the development of the activity	- Expertise in modelling of hydrogen and electrochemical components (both for the production and end use). - Good knowledge of Matlab and/or Python environment with programming skills. - Willingness to have international exchange periods in other universities and research centres. - Good knowledge of the English language, both oral and written.