Journal of Metallurgical Engineering and Processing Technology, Vol, No.
February, 2025
P-ISSN: , E-ISSN: 27, page -
DOI: https://doi.org/10.31315/jmept

Green Metal from Thin Air: Electrowinning Iron Using Direct Air Capture CO_2 as Reductant in a Solar-Powered Reactor

Grev Williem Manurung[1]
[1]Department of Metallurgical Engineering, Institut Teknologi Del, Laguboti, Indonesia
Corresponding author: tms23036@students.del.ac.id

Received: 06 October 2025; Revised: —— 2025; Published: —— 2025

Abstract

This paper presents a study on the development of a carbon-negative steelmaking process that utilizes captured CO_2 as a reducing agent in an electrometallurgical system. The main objective is to demonstrate a low-emission pathway for converting Fe^{2+} into solid iron while simultaneously sequestering atmospheric CO_2. The methodology includes the design and operation of a 1 L tubular electrochemical reactor equipped with a 3D-printed porous titanium cathode, operating at 60 °C and 200 A m^{-2}, powered entirely by a 5 kWp solar panel. The results show that the process produces 99.7% pure iron with an energy consumption of 3.8 MWh per ton, representing a 35% reduction compared to the conventional blast furnace route, while capturing 0.4 tonnes of CO_2 per ton of iron produced as a calcium carbonate by-product. This research is expected to contribute to decarbonizing the steel industry, promoting sustainable metallurgy, and advancing green technologies aligned with CBAM and US-IRA initiatives.

Keywords: ***electrowinning iron, CO_2 utilization, carbon-negative steel, solar reactor, urban mining***