https://doi.org/10.7250/CONECT.2026.027

MODELLING THE ECONOMIC VIABILITY OF AGGREGATED BUILDING RETROFITS IN CARBON MARKETS

Siti Shahada SHAMSHUDDIN[1], Ashwin THURAIRAJAH[2], Azlin MOHD AZMI[3*]

[1,3] *Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
[2] *GreenRE Sdn Bhd, Wisma REHDA, 47301 Petaling Jaya, Selangor, Malaysia*
[*] ***Corresponding author.*** *E-mail address: azlinazmi@uitm.edu.my*

Abstract – Building energy efficiency retrofits are a critical component of long-term energy transitions, yet their deployment at scale remains constrained by limited access to viable financing mechanisms. Carbon markets offer a potential revenue stream to support retrofit investments; however, individual building projects are often too small to absorb the high transaction, monitoring, and verification costs required for carbon credit issuance. This study develops a quantitative break-even modelling framework to assess the economic viability of building energy efficiency retrofits and to identify the conditions under which aggregation becomes necessary for market participation. Using empirical data from 11 GreenRE-certified commercial buildings in Malaysia, we estimate potential emission reductions associated with common retrofit measures. A cost-based model is constructed to estimate the total volume of verified carbon units (VCUs) required to recover project-related costs under alternative assumptions for carbon prices, verification frequencies, and crediting periods (7 and 10 years). The analysis evaluates the scale of emission reductions needed for cost recovery and uses this to infer the role of aggregation in enabling market entry. Results show that at a representative global voluntary carbon market price of USD 3 per tCO_2, individual building retrofit projects are economically unviable. Under optimized cost structures and biennial verification, break-even conditions require cumulative emission reductions in the range of approximately 40 000–200 000 tCO_2 over the studied crediting periods, indicating that aggregation across multiple buildings is essential. The model identifies a minimum carbon price threshold of at least USD 4 per tCO_2 for aggregated building retrofit projects to achieve economic viability. The findings highlight the importance of aggregation mechanisms, carbon price signals, and cost-efficient MRV designs in enabling building energy efficiency investments. This study provides policy-relevant insights for market designers and policymakers seeking to leverage carbon markets to support demand-side decarbonization in Malaysia and other emerging economies.

Keywords – Energy efficiency; emission reduction potential; measurement, reporting and verification (MRV); programmatic approaches; verified carbon unit (VCU); voluntary carbon market (VCM)