WARUNG KARBON: Community-Based UCO Aggregation for Carbon Credits and Energy Resilience in Indonesia

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Abstract
Escalating geopolitical tensions, including Middle East and Russia-Ukraine conflicts, have disrupted global oil supply chains and pushed crude prices to five-year highs in 2026, severely straining Indonesia's fiscal capacity. As a net oil importer since 2003, consuming 1.5 million barrels per day against domestic production of 600,000 barrels, Indonesia's energy security is further eroded by Rupiah depreciation that amplifies import-denominated fuel costs. Domestically sourced renewable fuels are thus a strategic resilience imperative. Used Cooking Oil (UCO), widely discarded by UMKM causing soil and water contamination, offers a high-efficiency solution: life cycle analysis shows UCO biodiesel achieves a net energy ratio of 5.49, six times higher than fossil diesel (0.83) with a carbon footprint of only 0.22 kgCO2eq/kg. This paper proposes WARUNG KARBON, a community-based UCO aggregation model that addresses pollution, fossil fuel dependency, and Indonesia's carbon market supply shortage. UCO collected from UMKM at above-market prices is channeled to biodiesel and Sustainable Aviation Fuel (SAF) producers, supporting the government's B50 mandate effective July 2026, while avoided emissions are monetised as carbon credits on IDXCarbon under CDM AM0047, responding directly to the exchange's 98.5% trading volume decline in 2025. Using Business Model Canvas framework and CDM AM0047 carbon quantification, a pilot of 100 UMKM in Surakarta projects IDR 294-474 million annual revenue and 2,000-3,000 tCO2e carbon credits, requiring under IDR 40 million startup capital. By repositioning UMKM as active carbon and energy agents, WARUNG KARBON delivers innovation, resilience, and inclusive growth aligned with Indonesia's NDC commitments and the conference theme.

Keywords: *used cooking oil; green entrepreneurship; energy resilience; carbon credit; IDXCarbon; inclusive growth*

INTRODUCTION

Green entrepreneurship has emerged as a critical driver of sustainable economic development, enabling businesses to simultaneously generate profit and reduce environmental impact (Schaper, 2002; Pastakia, 1998). In Indonesia, the transition toward a green economy is a national strategic priority, with green economy policies projected to stabilize average economic growth at 6.22% through 2045 (Kemenko Perekonomian, 2026). Yet 87.81% of Indonesian UMKM, the backbone of the national economy with over 64 million units — have not adopted any green business practices, primarily due to financing barriers and absence of direct financial incentives (UGM, 2025). This structural gap between green economy ambition and UMKM-level reality represents both a policy challenge and a research opportunity.

Indonesia's energy security has been severely tested in 2026. Escalating geopolitical conflicts, including the Middle East crisis and the Russia-Ukraine war have disrupted global oil supply chains, pushing crude prices to five-year highs (Ekuatorial, 2026). As a net oil importer since 2003, Indonesia consumes 1.5 million barrels per day against domestic production of only 600,000 barrels, spending USD 36.28 billion on energy imports in 2024 (IEEFA, 2026). Every USD 1 rise in crude oil price adds approximately IDR 10.3 trillion to the state subsidy burden (Reccessary, 2026). Rupiah depreciation further amplifies these costs, making domestically sourced renewable fuel a strategic necessity (Tempo, 2026).

Used Cooking Oil (UCO) represents an underutilized strategic resource at the intersection of these challenges. Indonesia, as the world's largest palm oil producer, generates substantial UCO volumes annually from its dense UMKM culinary sector. When improperly disposed, UCO causes persistent soil and water contamination (ESDM, 2021). However, when collected and converted to biodiesel or Sustainable Aviation Fuel (SAF), UCO reduces lifecycle greenhouse gas emissions by up to 91.7% compared to fossil diesel (ICCT, 2023). Life cycle analysis confirms UCO biodiesel achieves a Net Energy Ratio (NER) of 5.49, six times higher than fossil diesel (NER 0.83) with a carbon footprint of only 0.22 kgCO2eq/kg versus 9.87 kgCO2eq/kg for palm oil biodiesel (Springer Nature, 2026). These verified avoided emissions can be monetized as certified carbon credits under CDM AM0047 methodology (UNFCCC CDM, 2021).

Simultaneously, Indonesia's carbon exchange (IDXCarbon) faces a structural supply shortage. Launched in September 2023, IDXCarbon recorded a 98.5% decline in trading volume by June 2025, with the government targeting a fully operational market by late 2026 (IDX Carbon, 2025; Antara News, 2026). Existing UCO collection programs, including Pertamina Patra Niaga's 35 collection

points in Jabodetabek operate as commodity businesses without capturing the carbon credit value layer (Traction Energy Asia, 2024). No existing model has systematically combined UMKM-level UCO aggregation with formal carbon credit generation, representing a clear research gap.

This paper addresses this gap by proposing WARUNG KARBON a community-based UCO aggregation model designed for Indonesia's UMKM sector generating dual revenue from commodity sales and carbon credits. Three original contributions are made: (1) the first conceptual framework for UMKM-level carbon credit aggregation from waste streams in Indonesia; (2) application of CDM AM0047 at micro-scale to demonstrate financial viability with low startup capital; and (3) positioning of UMKM as active agents within Indonesia's formal carbon market architecture, directly responsive to the national B50 mandate effective July 2026 (ESDM, 2026).

RESEARCH METHODOLOGY

This paper employs a conceptual research design combining Business Model Design with quantitative feasibility analysis. The Business Model Canvas (BMC) framework (Osterwalder & Pigneur, 2010) structures the WARUNG KARBON model across nine building blocks: value propositions, customer segments, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. The BMC is widely applied in green entrepreneurship research as it enables systematic mapping of value creation, delivery, and capture (Schaltegger et al., 2016).

For carbon credit quantification, this study applies CDM Approved Methodology AM0047: 'Production of waste cooking oil-based biodiesel for use as fuel' (UNFCCC CDM, 2021). The methodology calculates emission savings as the difference between the baseline emission factor for fossil diesel displacement (2.68 kgCO2eq/liter) and the project emission factor for UCO-derived biodiesel (0.54 kgCO2eq/liter), yielding a net emission saving of 2.14 kgCO2eq per liter. This approach is consistent with lifecycle assessment principles under ISO 14040/44 (ISO, 2006).

Revenue projections are calculated under two scenarios: (1) a pilot scenario of 100 UMKM in the Surakarta metropolitan area (Solo Raya), and (2) a scale-up scenario of 1,000 UMKM across Central Java. Financial parameters are sourced from verified 2026 market data: UCO purchase price from Pertamina Patra Niaga (IDR 5,500-6,000/liter); biodiesel selling price (IDR 7,500-8,500/liter); and IDXCarbon carbon credit price range (IDR 30,000-80,000/tCO2e). Average UCO output is estimated at 5 liters per UMKM per operating day based on field data from Traction Energy Asia (2024).

RESULTS AND DISCUSSION

The WARUNG KARBON Business Model

WARUNG KARBON operates as a three-tier value chain connecting UMKM waste producers, biofuel manufacturers, and the carbon market. Four sequential processes define its operation: (1) UCO collection from UMKM at premium prices (IDR 6,000-7,000/liter) to incentivize participation; (2) quality sorting and chain-of-custody documentation at a local aggregation hub; (3) sale to licensed biodiesel or SAF producers aligned with the government's B50 mandate effective July 2026; and (4) carbon credit calculation, verification, and trading via IDXCarbon or voluntary platforms such as Fairatmos (2025).

The value proposition is asymmetric and mutually reinforcing. For UMKM operators, WARUNG KARBON offers IDR 6,000-7,000/liter significantly above the informal market rate of IDR 3,000-4,000/liter plus a 'Green UMKM Certificate' that enhances access to green financing instruments (Bank Indonesia, 2026). For the aggregating entity, revenues derive from commodity margins on UCO sales and verified carbon credits. The model requires no capital investment from participating UMKM, eliminating the primary barrier to green business adoption identified in the literature (UGM, 2025).

Carbon Credit Quantification and Revenue Projection

Applying CDM AM0047, the emission saving per liter of UCO-derived biodiesel replacing fossil diesel is 2.14 kgCO2eq (2.68 - 0.54 kgCO2eq/liter). For the pilot scenario of 100 UMKM averaging 5 liters per day over 26 working days per month, monthly UCO volume reaches approximately 13,000 liters, yielding 156,000 liters annually and avoided emissions of 2,000-3,000 tCO2e per year (Tran, 2025). At IDXCarbon prices of IDR 30,000-80,000/tCO2e, carbon credit revenues range from IDR 60,000,000 to IDR 240,000,000 annually (IDX Carbon, 2025). Table 1 presents the complete revenue projection.

Table 1. WARUNG KARBON Revenue Projection — Surakarta Pilot (100 UMKM)

Revenue Stream	Calculation Basis	Annual Value (IDR)
UCO Commodity Margin	156,000 L/yr × IDR 1,500/L	234,000,000
Carbon Credits — conservative	2,000 tCO2e × IDR 30,000/tCO2e	60,000,000
Carbon Credits — optimistic	3,000 tCO2e × IDR 80,000/tCO2e	240,000,000
Total Revenue — conservative	Commodity + conservative credits	294,000,000
Total Revenue — optimistic	Commodity + optimistic credits	474,000,000

Source: Authors' calculation based on CDM AM0047 (UNFCCC CDM, 2021) and IDXCarbon market data (2026).

Geopolitical Context and Energy Security Nexus

WARUNG KARBON operates within a uniquely urgent geopolitical and energy policy context. The Middle East conflict threatening the Strait of Hormuz through which approximately 25% of Indonesia's crude oil imports transit creates direct supply vulnerability (CASE for SEA, 2026). Combined with the Russia-Ukraine war's impact on global energy prices, Indonesia's 20-22 days strategic oil reserve becomes critically inadequate (Ekuatorial, 2026). The government's B50 mandate effective July 2026 and President Prabowo's directive to halt diesel imports create structurally growing demand for UCO feedstock, independent of carbon market price volatility (ESDM, 2026; S&P Global, 2025).

The NER superiority of UCO biodiesel (5.49 vs 0.83 for fossil diesel) means every liter of UCO converted to biodiesel delivers 5.49 times more energy output than the energy invested in its production, making it among the most energy-efficient biofuel pathways available to Indonesia (Springer Nature, 2026). This efficiency advantage, combined with a 91.7% GHG reduction versus fossil diesel, positions UCO biodiesel not merely as an environmental choice but as a superior energy security instrument aligned with Indonesia's drive toward energy sovereignty (ICCT, 2023).

Scalability and Replication Potential

At 1,000 UMKM across Central Java covering Solo, Semarang, Yogyakarta, Purwokerto, and Magelang annual UCO volume reaches approximately 1.56 million liters, generating 20,000-30,000 tCO2e and revenues of IDR 3-5 billion annually. This volume justifies direct registration with Fairatmos or Indonesia's Carbon Accreditation Body (IDECAS) and commands premium prices from international SAF buyers under CORSIA obligations. Startup capital under IDR 40 million is accessible through KUR Mikro at 6% annual interest, with a projected payback period of under 8 months from commodity margin alone. The Kemenkop-Dekopin-MENA UCO cooperative ecosystem MoU of June 2026 provides an institutional foundation for scaling WARUNG KARBON through cooperative networks.

CONCLUSION

WARUNG KARBON presents a viable, low-capital, and high-impact green entrepreneurship model that simultaneously addresses Indonesia's UMKM green transition deficit, energy security vulnerability, and carbon market supply shortage. By aggregating UCO from 100 UMKM operators in Surakarta, the model generates IDR 294-474 million in annual revenues from commodity margins and CDM AM0047-verified carbon credits, with initial capital under IDR 40 million. The model's geopolitical relevance is heightened in 2026: as crude oil prices surge due to Middle East and Russia-Ukraine conflicts and Rupiah depreciation amplifies import costs, UCO biodiesel with NER 5.49 represents both an energy sovereignty instrument and a financially viable green business opportunity for Indonesian UMKM. WARUNG KARBON's most significant conceptual contribution is repositioning UMKM traditionally passive waste generators as active, compensated participants in Indonesia's formal carbon market and national energy resilience strategy, delivering innovation, resilience, and inclusive growth aligned with Indonesia's NDC commitments.

RECOMMENDATION

Future research should conduct field quantification of UCO volumes across UMKM clusters in Solo Raya and assess willingness-to-participate among UMKM operators. Policymakers are encouraged to develop simplified MRV (Measurement, Reporting, and Verification) pathways for small-volume UCO carbon projects within the national carbon market roadmap. BRIDA Central Java is identified as a strategic implementation partner for a provincial pilot, given its mandate to support locally grounded innovation. The Kemenkop-Dekopin-MENA UCO cooperative ecosystem MoU of June 2026 provides an institutional foundation for scaling WARUNG KARBON through cooperative networks across Central Java.

ACKNOWLEDGMENTS

The author acknowledges the support of the Master's Program in Environmental Science, Sebelas Maret University (UNS), Surakarta, and expresses gratitude to the organizing committee of

the International Conference and Call for Papers 2026, organized by IDEABI in collaboration with BRIDA Central Java Province, for the opportunity to present this research.

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