CLIMATE FINANCE TRANSFORMATION MODEL: A GENERIC DECISION-SUPPORT FRAMEWORK FOR MITIGATION FINANCING

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SUMMARY

AKMA YENI MASRI. Climate Finance Transformation Model: A Generic Decision-Support Framework for Mitigation Financing. Supervised by RIZALDI BOER, MUHAMMAD FIRDAUS, and LILIEK SOFITRI.

Climate change has intensified the need not only to mobilize climate finance but also to evaluate whether it effectively delivers greenhouse gas (GHG) mitigation outcomes. Existing research has primarily focused on estimating future investment needs, with limited attention to assessing the effectiveness of realized climate finance. In Indonesia, this gap is reflected in two complementary but disconnected systems: Climate Budget Tagging (CBT), which records climate-related public expenditure, and the national Monitoring, Reporting, and Verification (MRV) system, which documents verified GHG emission reductions. The absence of an analytical framework linking these systems constrains the evaluation of climate finance effectiveness and the development of performance-based financing strategies.

This dissertation aimed to develop a Climate Finance Transformation Model (CFTM) as a generic decision-support framework for improving climate finance effectiveness through the integration of empirical evidence, mitigation performance, financing characteristics, and institutional capacity. Although the empirical development and demonstration of the model were undertaken using Indonesia's transportation sector, the proposed framework was designed to be conceptually applicable across sectors and adaptable to different national contexts. Specifically, the study sought to: (1) identify international best practices in climate finance; (2) evaluate the effectiveness of realized climate finance by linking expenditure with verified GHG emission reductions; (3) develop a generic climate finance transformation model for identifying appropriate financing pathways for mitigation actions; (4) demonstrate the application of the model using Indonesia's transportation sector, and (5) formulate policy recommendations for strengthening climate finance governance.

The research adopted a sequential analytical framework consisting of four interrelated stages. The first stage employed a systematic literature review using the PRISMA approach to examine international best practices in climate finance, with a more detailed assessment of financing strategies that support transport decarbonization. The review synthesized evidence on financing mechanisms, governance arrangements, institutional frameworks, and policy instruments to identify the fundamental components required for an effective climate finance system.

The second stage established the empirical foundation of the research through an evaluation of climate finance in Indonesia's transportation sector using realized expenditure and verified GHG emission reduction data for the period 2018–2022. To bridge the gap between financial accounting and mitigation performance, this dissertation developed the Realized Expenditure Attribution Pathway (REAP), a novel analytical framework that systematically attributes realized climate-related expenditure to verified mitigation outcomes. REAP integrates expenditure information derived from climate expenditures with verified emission reductions

recorded in the national MRV system, enabling climate finance to be assessed based on observed implementation rather than projected investment requirements. The analysis also introduced the Cost of Verified Emission Reduction (CoVER), which estimates mitigation costs using realized expenditure and verified GHG reductions under actual implementation conditions. The framework further distinguishes between direct mitigation actions that generate measurable emission reductions and enabling mitigation actions that establish the institutional and infrastructural conditions necessary for long-term decarbonization.

Building upon these empirical findings, the third stage developed the CFTM as a generic analytical framework rather than a sector-specific model. The model integrates financing requirements, mitigation potential, implementation timeframe, institutional capacity, and financing instrument characteristics into a multidimensional decision-support framework for identifying appropriate financing pathways for mitigation actions. Through a structured compatibility assessment, the model aligns the characteristics of mitigation interventions with the comparative advantages of available financing instruments. The framework is conceptually independent of any particular sector or country, allowing it to be adapted to different mitigation contexts while maintaining a consistent analytical structure.

The fourth stage demonstrated the empirical implementation of the CFTM using Indonesia's transportation sector as a case study. The model successfully identified financing pathways that correspond to the characteristics of individual mitigation actions and generated policy recommendations for strengthening climate finance governance through improved institutional coordination, greater integration of public and private finance, expanded use of blended and market-based financing mechanisms, and a transition from expenditure-based budgeting toward performance-oriented climate finance management.

This dissertation advances the climate finance literature in five principal ways. First, it shifts the focus of climate finance evaluation from estimating investment needs to assessing how realized climate finance contributes to verified GHG emission reductions. Second, it introduces the REAP framework to systematically link realized climate expenditure with verified GHG emission reductions. Third, it develops the CoVER approach to estimate mitigation costs based on observed implementation rather than projected assumptions. Fourth, it proposes the CFTM as a generic decision-support framework, empirically demonstrated in Indonesia's transportation sector and adaptable across sectors and national contexts. Finally, it establishes an evidence-based climate finance policy architecture to strengthen financing governance and support more effective climate mitigation.

Overall, the findings demonstrate that improving climate finance effectiveness requires more than increasing financial resources. It depends on aligning financing instruments with mitigation characteristics, institutional readiness, and implementation requirements within a coherent governance framework. The central conclusion of this dissertation is that public finance initiates climate finance transformation, institutional capacity enables its implementation, and diversified finance sustains its long-term effectiveness.

Keywords: climate finance transformation; decarbonization; greenhouse gas mitigation; realized expenditure; verified emission reduction

RINGKASAN

AKMA YENI MASRI. Model Transformasi Pendanaan Perubahan Iklim: Kerangka Pengambilan Keputusan untuk Pendanaan Mitigasi Perubahan Iklim. Supervised by RIZALDI BOER, MUHAMMAD FIRDAUS, and LILIEK SOFITRI.

Pembahasan terkait pendanaan perubahan iklim telah berkembang, tidak hanya terbatas pada bagaimana memobilisasi pembiayaan iklim, tetapi juga mengevaluasi sejauh mana pembiayaan tersebut menghasilkan capaian mitigasi emisi gas rumah kaca (GRK). Penelitian terdahulu lebih banyak berfokus pada estimasi kebutuhan investasi di masa mendatang, sementara perhatian terhadap efektivitas pembiayaan iklim terhadap pengurangan emisi GRK yang dihasilkan dari aktifitas yang dibiayai masih terbatas. Belum tersedianya kerangka analitis yang menghubungkan realisasi pendanaan iklim dengan capaian reduksi emisi merupakan kesenjangan dalam mengevaluasi efektivitas pembiayaan iklim dan mengembangkan strategi pembiayaan berbasis kinerja.

Disertasi ini bertujuan mengembangkan *Climate Finance Transformation Model* (CFTM) sebagai kerangka pendukung keputusan yang bersifat generik untuk meningkatkan efektivitas pembiayaan iklim melalui integrasi bukti empiris, kinerja mitigasi, karakteristik pembiayaan, dan kapasitas kelembagaan. Meskipun pengembangan empiris dan demonstrasi model dilakukan menggunakan sektor transportasi di Indonesia, kerangka yang dikembangkan dirancang agar dapat diterapkan secara konseptual pada berbagai sektor dan diadaptasi pada konteks negara yang berbeda. Secara khusus, penelitian bertujuan untuk: (1) mengidentifikasi praktik terbaik pembiayaan iklim di tingkat internasional; (2) mengevaluasi efektivitas pembiayaan iklim yang telah direalisasikan dengan menghubungkan belanja dengan penurunan emisi GRK terverifikasi; (3) mengembangkan model transformasi pembiayaan iklim yang bersifat generik untuk mengidentifikasi jalur pembiayaan yang sesuai bagi aksi mitigasi; (4) mendemonstrasikan penerapan model pada sektor transportasi Indonesia; dan (5) merumuskan rekomendasi kebijakan untuk memperkuat tata kelola pembiayaan iklim.

Penelitian menggunakan kerangka analisis berurutan yang terdiri atas empat tahap yang saling terkait. Tahap pertama menggunakan *systematic literature review* dengan pendekatan PRISMA untuk mengkaji praktik terbaik pembiayaan iklim internasional, dengan penelaahan lebih mendalam terhadap strategi pembiayaan yang mendukung dekarbonisasi sektor transportasi. Tahap kedua membangun landasan empiris melalui evaluasi pembiayaan iklim pada sektor transportasi Indonesia dengan menggunakan data realisasi belanja dan penurunan emisi GRK terverifikasi selama periode 2018–2022. Untuk menjembatani kesenjangan antara pencatatan keuangan dan kinerja mitigasi, penelitian ini mengembangkan *Realized Expenditure Attribution Pathway* (REAP), yaitu kerangka analitis baru yang secara sistematis mengatribusikan realisasi belanja terkait iklim terhadap capaian mitigasi terverifikasi. REAP mengintegrasikan informasi belanja yang berasal dari data pengeluaran terkait iklim dengan data penurunan emisi terverifikasi dalam sistem MRV nasional, sehingga efektivitas

pembiayaan iklim dapat dinilai berdasarkan hasil implementasi aktual, bukan semata-mata berdasarkan kebutuhan investasi yang diproyeksikan. Penelitian juga memperkenalkan *Cost of Verified Emission Reduction* (CoVER) untuk mengestimasi biaya mitigasi berdasarkan realisasi belanja dan penurunan emisi GRK terverifikasi dalam kondisi implementasi aktual.

Berdasarkan temuan empiris tersebut, tahap ketiga mengembangkan CFTM sebagai kerangka analitis generik, bukan sebagai model yang khusus ditujukan untuk sektor tertentu. Model ini mengintegrasikan kebutuhan pembiayaan, potensi mitigasi, jangka waktu implementasi, kapasitas kelembagaan, dan karakteristik instrumen pembiayaan ke dalam kerangka pendukung keputusan multidimensi untuk mengidentifikasi jalur pembiayaan yang sesuai bagi setiap aksi mitigasi. Melalui penilaian kompatibilitas yang terstruktur, model menyelaraskan karakteristik intervensi mitigasi dengan keunggulan relatif dari berbagai instrumen pembiayaan yang tersedia. Kerangka ini tidak bergantung pada sektor atau negara tertentu sehingga dapat diadaptasi pada berbagai konteks mitigasi dengan tetap mempertahankan struktur analisis yang konsisten. Tahap keempat mendemonstrasikan penerapan empiris CFTM pada sektor transportasi Indonesia sebagai studi kasus. Model mampu mengidentifikasi jalur pembiayaan yang sesuai dengan karakteristik masing-masing aksi mitigasi dan menghasilkan rekomendasi kebijakan untuk memperkuat tata kelola pembiayaan iklim.

Disertasi ini memberikan lima kontribusi utama terhadap pengembangan literatur pembiayaan iklim. Pertama, penelitian menggeser fokus evaluasi pembiayaan iklim dari estimasi kebutuhan investasi menuju penilaian kontribusi pembiayaan yang telah direalisasikan terhadap penurunan emisi GRK terverifikasi. Kedua, penelitian memperkenalkan REAP untuk menghubungkan secara sistematis realisasi belanja iklim dengan penurunan emisi GRK terverifikasi. Ketiga, penelitian mengembangkan CoVER untuk mengestimasi biaya mitigasi berdasarkan kondisi implementasi aktual, bukan asumsi proyeksi. Keempat, penelitian mengembangkan CFTM sebagai kerangka pendukung keputusan yang bersifat generik, yang didemonstrasikan secara empiris pada sektor transportasi Indonesia dan dapat diadaptasi pada berbagai sektor dan konteks negara. Kelima, penelitian membangun arsitektur kebijakan pembiayaan iklim berbasis bukti untuk memperkuat tata kelola pembiayaan dan mendukung efektivitas mitigasi perubahan iklim.

Secara keseluruhan, hasil penelitian menunjukkan bahwa peningkatan efektivitas pembiayaan iklim tidak cukup dicapai melalui peningkatan volume pembiayaan. Efektivitas tersebut bergantung pada kemampuan menyelaraskan instrumen pembiayaan dengan karakteristik aksi mitigasi, kesiapan kelembagaan, dan kebutuhan implementasi dalam suatu kerangka tata kelola yang koheren. Kesimpulan utama penelitian ini adalah bahwa pembiayaan publik menginisiasi transformasi pembiayaan iklim, kapasitas kelembagaan memungkinkan transformasi tersebut diimplementasikan, dan diversifikasi pembiayaan menopang efektivitasnya dalam jangka panjang.

Kata kunci: transformasi pembiayaan iklim; dekarbonisasi; mitigasi gas rumah kaca; realisasi belanja; penurunan emisi terverifikasi.

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PREFACE

All praise and gratitude are due to Allah Subhanahu wa Ta'ala for His infinite blessings, guidance, and mercy, which have enabled the completion of this dissertation entitled "Climate Finance Transformation Model: A Generic Decision-Support Framework for Mitigation Financing". This research was undertaken to advance the understanding of climate finance by developing a decision-support framework that strengthens the effectiveness of climate finance through the integration of mitigation performance, financing characteristics, and institutional capacity.

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It is hoped that this dissertation will advance climate finance scholarship and serve as a useful reference for strengthening climate finance governance and informing evidence-based policymaking to accelerate greenhouse gas mitigation.

Bogor, August 2026

Akma Yeni Masri

TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDICES