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Beyond the B60 Ambition: Can Indonesia's Palm Oil Biodiesel Expansion Deliver Inclusive Prosperity for Independent Smallholders?

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Abstract

Indonesia's ambition to advance its palm oil-based biodiesel programme toward B60 represents a significant opportunity to strengthen energy sovereignty, reduce dependence on imported diesel, and expand domestic value creation. However, whether this ambition can simultaneously improve the welfare of independent oil palm smallholders remains uncertain. This article critically examines the economic, institutional, agronomic, social, and environmental conditions under which B60 implementation could deliver inclusive and sustainable rural prosperity. Employing a qualitative literature review rather than a systematic literature review, the study synthesises interdisciplinary research published between 2020 and 2026, complemented by relevant policy documents. Six interconnected themes emerge: energy and fiscal feasibility; value-chain transmission and distributive equity; productivity and replanting constraints; institutional inclusion; environmental sustainability; and livelihood resilience. The synthesis suggests that higher biodiesel demand does not automatically translate into improved smallholder welfare because benefits are mediated by pricing structures, market access, productivity, financing, and institutional arrangements. The article develops an Integrated Biodiesel–Smallholder Prosperity Framework and compares expansion-led, integrated-development, and adaptive implementation scenarios. It argues that B60 can contribute to more inclusive development only when supported by sustainable feedstock production, transparent value distribution, accessible replanting finance, farmer institutional strengthening, and enforceable environmental safeguards. An integrated policy roadmap and multidimensional monitoring framework are proposed to reconcile national energy security with equitable rural development.

Keywords: B60 Biodiesel, Energy Sovereignty, Independent Oil Palm Smallholders, Smallholder Prosperity, Inclusive Energy Transition, Palm Oil Value Chain, Sustainable Intensification, Replanting Finance, Distributive Justice, Indonesia.

Introduction

Indonesia's Biodiesel Transition and the Emerging B60 Ambition

Indonesia has positioned palm oil-based biodiesel as an increasingly important component of its national energy security and agricultural industrialisation strategy. The policy reflects the country's comparative advantage in palm oil production and its continuing dependence on imported petroleum products. By converting domestically produced palm oil into transport and industrial fuel, policymakers seek to strengthen energy sovereignty, reduce exposure to international petroleum markets, stimulate domestic processing industries, and retain a greater proportion of agricultural value within the national economy. Nevertheless, the economic and environmental consequences of increasingly ambitious blending requirements are complex because additional domestic biodiesel demand competes with alternative uses of palm oil and creates new pressures on production, financing, and land resources [1-3].

Indonesia's mandatory biodiesel programme progressed through successive blending levels, including B30 in 2020, B35 in 2023, B40 in 2025, and the official launch of B50 in July 2026. In September 2026, government representatives identified 2027 as the target for advancing toward B60, although further assessments of feedstock availability, processing capacity, fuel specifications, and technical readiness were still required. The period following the B50 launch also involved transitional distribution arrangements. Consequently, B60 should be understood as a prospective national ambition rather than a fully implemented policy with empirically established economic or welfare impacts [4,5]. B60 generally denotes diesel fuel containing 60% renewable biodiesel components and 40% conventional petroleum diesel by volume. However, its eventual formulation is an important technical consideration. The government has considered whether higher blends should rely entirely on fatty acid methyl esters (FAME) or incorporate hydrotreated vegetable oil (HVO). These pathways differ in their production processes, compatibility characteristics, infrastructure requirements, and potential costs. Higher renewable content also demands rigorous evaluation of fuel stability, storage, engine performance, maintenance requirements, and logistical reliability across Indonesia's diverse climatic and geographical conditions. Therefore, successful B60 implementation cannot

be reduced to announcing a higher blending percentage [2,6,7].

The programme's strategic appeal is nevertheless substantial. A larger domestic biodiesel market could provide a more stable outlet for palm oil, support downstream investment, create employment, and moderate dependence on imported diesel. These possibilities are particularly relevant when global energy markets experience geopolitical disruption and price volatility. However, reducing fuel imports does not necessarily produce equivalent net foreign-exchange savings, because redirecting palm oil from exports to domestic biodiesel production entails opportunity costs. Halimatussadiah. demonstrated the importance of considering potential export losses alongside import substitution, while Fitrady highlighted fiscal vulnerability and diminishing economic returns associated with increasingly ambitious mandates [1,8].

Independent Oil Palm Smallholders and Rural Development

Independent oil palm smallholders occupy a critical but structurally disadvantaged position within Indonesia's palm oil economy. Unlike scheme-associated smallholders whose production is organised through formal arrangements with plantation companies or mills, independent smallholders generally manage their plantations and marketing relationships without equivalent contractual integration. Their production systems differ considerably in terms of plantation size, agronomic knowledge, planting materials, financial capacity, land documentation, geographical accessibility, and participation in farmer organisations. These differences affect both productivity and bargaining power, complicating the assumption that national industry expansion automatically improves rural livelihoods [9-11].

Oil palm cultivation has contributed to important improvements in rural livelihoods, but the benefits are not uniform. Using Indonesian household panel evidence, Mehraban found positive effects of oil palm cultivation on living standards and reduced exposure to certain forms of economic risk. However, these findings should not be interpreted as evidence that every additional increment in biodiesel demand produces similar benefits [12]. Household welfare depends on production costs, farm productivity, realised prices, debt obligations, asset ownership, and alternative income opportunities. The distinction between the economic effects of cultivating oil palm and the incremental welfare effects of a particular national biodiesel mandate is therefore essential [12,13].

Independent smallholders commonly face lower yields than attainable under locally suitable agronomic conditions. Monzon identified substantial yield gaps related to nutrient management, harvesting intervals, pruning, and weed control [14]. Sugianto. similarly demonstrated the importance of nutrient deficiencies in explaining production limitations [15]. These findings suggest that improving existing plantations could contribute to national feedstock availability while generating additional farmer income. However, productivity improvement requires coordinated access to extension services, inputs, technical assistance, and appropriate financing rather than relying exclusively on higher market demand [14,16,17]. Ageing plantations create another challenge. Oil palms gradually become more difficult to harvest and may become economically inefficient, making replanting essential for maintaining long-term production. Nevertheless, replanting generates substantial initial expenditure and interrupts household income while replacement palms mature. Farmers with limited savings or alternative livelihoods may rationally postpone replanting despite its potential long-term benefits. Research on Indonesian smallholder replanting identifies limited financing, insecure documentation, inadequate planting materials, and institutional barriers as major constraints [18-20].

The Central Policy Dilemma

The principal dilemma is whether Indonesia can reconcile three objectives that may not always move in the same direction: higher domestic renewable fuel consumption, increased independent smallholder prosperity, and environmentally sustainable palm oil production. Expanding biodiesel demand could potentially support farm-gate prices and investment. However, it could also increase competition for CPO, generate higher fiscal costs, and encourage additional plantation expansion when productivity gains are insufficient. The ultimate outcome depends on the behaviour of producers, processors, intermediaries, policymakers, and market institutions [1,3,21].

The distribution of economic benefits is particularly important. Palm oil passes through multiple value-chain stages before becoming biodiesel, including fruit collection, milling, refining, conversion, blending, and fuel distribution. Independent farmers often participate only at the beginning of this chain, while processing facilities, logistics networks, and biodiesel production are typically controlled by better-capitalised firms. Higher downstream demand may improve industry revenues without generating proportionate increases in farmers' real net incomes when marketing margins, procurement practices, transport costs, or market power weaken price transmission [22,11]. Environmental integrity introduces a further constraint. The climate benefits of replacing petroleum diesel with palm-based biodiesel depend on agricultural emissions, processing technology, transport, land-use history, and possible indirect land-use change. Biodiesel produced from existing sustainable plantations may have a different environmental profile from fuel associated with forest conversion or peatland development. Strategies that improve production per hectare and prevent expansion into high-carbon ecosystems are therefore central to evaluating the credibility of the B60 ambition [23-25].

Research Gap, Objectives, and Contributions

Existing studies offer valuable but fragmented insights into biodiesel economics, palm oil sustainability, agricultural productivity, certification, and rural livelihoods. Energy-policy studies frequently prioritise import substitution, production volumes, emissions, and fiscal sustainability, whereas agricultural development research examines yield gaps, replanting, household welfare, and institutional access. Relatively limited attention has been devoted to integrating these literatures into a coherent framework explaining how a prospective B60 mandate could affect independent smallholders through specific economic and institutional mechanisms [8,14,26,27]. This article addresses that gap through an interdisciplinary qualitative literature review. Its primary objective is to evaluate the feasibility of integrating the B60 ambition with measurable improvements in independent smallholder prosperity. Specifically, it examines economic and fiscal viability, value-chain price transmission, productivity and replanting opportunities, institutional inclusion, environmental safeguards, and household resilience. It also compares alternative implementation scenarios and develops an Integrated Biodiesel–Smallholder Prosperity Framework to guide more inclusive policy design.

The central argument is that B60 can contribute to national

development only if its implementation is judged against multiple objectives rather than blending compliance alone. National energy sovereignty and rural prosperity can be mutually reinforcing, but such alignment requires deliberate institutional intervention, sustainable agricultural development, transparent financing, and equitable distribution of opportunities. This perspective broadens biodiesel policy evaluation from aggregate energy and industrial indicators toward household-level outcomes and long-term environmental responsibility.

Literature Review

Energy Sovereignty, Biofuel Mandates, and Industrial Development

Energy sovereignty encompasses more than replacing imported energy with domestically produced substitutes. It also concerns the ability of a country to maintain reliable, affordable, and socially beneficial energy supplies while exercising meaningful control over production technologies, infrastructure, and strategic resources. Palm-based biodiesel can contribute to this objective by linking domestic agricultural production to liquid-fuel demand. However, policies that improve one dimension of energy security may create vulnerabilities in other dimensions, particularly when energy production becomes heavily dependent on a single agricultural commodity [1,2]. Biofuel blending mandates represent a form of state-directed market creation. By requiring a specified renewable component in diesel consumption, governments generate predictable demand for biodiesel producers and associated upstream industries. Such intervention can stimulate investments that might otherwise remain commercially unattractive. Nevertheless, obligatory demand does not eliminate underlying production costs. The difference between biodiesel and fossil diesel prices may require compensation through levies, subsidies, differentiated pricing, or other fiscal mechanisms. As blending requirements increase, the balance between public benefits and financing obligations becomes increasingly important [8,28].

Indonesia's biodiesel financing arrangements illustrate the interconnectedness of commodity markets and public policy. Export-related levy revenues have provided financial resources for biodiesel incentives and plantation-sector development. However, both the revenue base and financing requirements depend on international market conditions. When CPO prices rise relative to petroleum diesel prices, incentives may become more expensive precisely when export opportunities are also more valuable. Fitrady . emphasised the possibility of financing shortfalls under some conditions, supporting a more flexible approach to blending requirements and subsidy rules [8]. The food-versus-fuel debate is another fundamental consideration. Palm oil is used in food manufacturing, cooking oil, oleochemicals, and other industrial applications, while exports generate foreign exchange and sustain international market relationships. A higher domestic biodiesel mandate may alter the distribution of a limited feedstock supply among these uses. Hidayatno . demonstrated that alternative palm oil policy priorities create different economic, social, and environmental outcomes, with no single strategy necessarily maximising all objectives [3]. Consequently, biodiesel expansion requires coordinated planning across energy, agriculture, trade, industry, and consumer welfare policy.

Global Value Chains and Distributive Justice

Global value-chain theory provides a useful perspective for examining how economic benefits are distributed across interconnected production and marketing activities. In the palm oil sector, independent farmers supply fresh fruit bunches (FFB), which are processed into crude palm oil and subsequently transformed into refined products or biodiesel feedstocks. Value creation occurs throughout this chain, but value capture depends on market access, ownership of productive assets, bargaining capacity, information, and the governance of contractual relationships. Expansion at the downstream end of the chain does not necessarily generate equal benefits for all participants [9,11]. Independent farmers face several structural disadvantages. Harvested FFB deteriorates relatively quickly, restricting storage options and increasing the importance of proximity to mills. Farmers who cannot access mills directly may rely on collecting agents, transporters, or multiple intermediaries. These arrangements can provide important logistical services but may also reduce farmers' negotiating power and increase the distance between benchmark prices and realised farm-gate returns. Research on price transmission in West Sumatra highlights the importance of understanding how prices and margins move along independent smallholder marketing channels [22]. Further evidence of vulnerability comes from the 2022 Indonesian palm oil export restriction: in a survey of 382 smallholders, Reich . found a substantial average reduction in reported FFB sale prices during the disruption [29]. Their results also show that income diversification was associated with greater resilience, reinforcing the importance of market institutions and household buffers.

Distributive justice concerns whether the benefits and costs of economic development are allocated fairly. In the B60 context, the relevant questions extend beyond whether biodiesel producers obtain sufficient investment returns. They include whether farmers receive reasonable compensation, whether public financing reaches disadvantaged producers, and whether environmental and compliance costs are disproportionately transferred upstream. Procedural justice concerns who participates in setting policy and market rules, while recognitional justice requires acknowledging the diverse capabilities and constraints of independent producers [10,27,30]. Certification illustrates these issues. Sustainability standards can improve production practices and access to certain markets, yet certification often requires documentation, training, compliance expenditure, and organised institutional support. Independent smallholders may experience barriers that are less severe for integrated plantation companies and scheme-associated farmers. Studies examining certification adoption, its costs, and potential economic benefits demonstrate the importance of designing standards that reward sustainable production without systematically excluding less-capitalised participants [31-34].

Sustainable Livelihoods and Multidimensional Prosperity

The Sustainable Livelihoods Framework conceptualises household welfare through interconnected forms of capital, including financial, human, natural, physical, and social resources. Applied to independent oil palm smallholders, financial capital includes farm earnings, savings, credit, and alternative income. Human capital includes agronomic knowledge, education, and labour capacity. Natural capital encompasses land, soil quality, and productive trees, while physical capital includes transport infrastructure, equipment, and market connectivity. Social capital includes farmer organisations, cooperative networks, and relationships with buyers and public institutions. This framework demonstrates why agricultural revenue alone is an incomplete measure of prosperity. A farmer may receive higher FFB prices while experiencing increased fertiliser costs, transport expenses, debt servicing, or environmental vulnerability. Conversely, a

household may maintain stable consumption through income diversification despite fluctuations in palm oil earnings. Mehraban . showed that oil palm cultivation can improve household welfare and reduce exposure to some economic risks, while Hendrawan . highlighted the importance of resilience when smallholders confront future industrial challenges [12,13].

Gender and household labour arrangements further complicate welfare assessment. Oil palm production can alter the allocation of labour within households, including opportunities for off-farm employment, unpaid domestic work, and participation in farm management. These consequences may differ between women and men and among households with different landholdings. Evidence concerning gendered time use in Indonesian oil palm communities underscores the importance of examining who controls income, performs labour, and benefits from agricultural development [35]. Accordingly, this article defines independent smallholder prosperity as sustained improvements in real disposable household income, livelihood resilience, productive capabilities, bargaining power, and access to economically and environmentally secure opportunities. This definition recognises that household welfare is influenced by markets and institutions as well as plantation productivity. It also avoids equating higher national CPO demand with poverty reduction without evidence about how benefits reach individual households.

Sustainable Intensification and Replanting

Sustainable agricultural intensification seeks to increase output from existing farmland while limiting adverse environmental impacts. This approach is especially relevant to Indonesia's biodiesel ambitions because increasing feedstock supply through forest conversion would undermine the environmental rationale for renewable fuel development. Yield-gap research indicates that improvements in nutrient application, harvesting management, and other agronomic practices could increase production without necessarily expanding plantation area [14,16,24]. Evidence from Indonesian smallholdings also indicates that potassium management can affect palm performance and that understory vegetation can improve soil health. Such findings show why agronomic improvements must be evaluated for both yield and ecosystem outcomes rather than reduced to fertiliser volume alone [36].

Nevertheless, intensification is not automatically profitable or environmentally beneficial. Agricultural inputs involve financial costs, and the response to improved management depends on soil conditions, tree age, prior management, and implementation quality. Sugianto . reported substantial yield and profit improvements under better management practices, whereas Woittiez . identified more limited economic returns under the particular conditions of their field intervention [17,37]. Such differences underline the importance of location-specific agronomic advice, realistic payback expectations, and farmer financial constraints. Replanting represents a complementary pathway to long-term productivity. Replacing ageing palms with suitable planting material can improve future yields and harvesting efficiency, but farmers must cope with establishment costs and delayed income. Research identifies access to finance, planting materials, institutional support, and information as important determinants of replanting decisions. The financial attractiveness of replanting therefore differs between households, even where its long-term agronomic rationale is widely accepted [18,20,38]. Sustainable intensification also requires attention to potential rebound effects. Greater profitability may create incentives for further plantation expansion if land-use governance is weak. Intensification should therefore be combined with traceability, protection of forest and peatland areas, transparent land administration, and incentives that reward improvements on existing plantations. This interaction between productivity and land-use governance is critical to reconciling biodiesel feedstock demand with climate and biodiversity objectives [21,25,39].

Institutional Economics, Farmer Organisations and Market Access

Institutional economics emphasises how formal regulations, informal relationships, transaction costs, and information asymmetries influence economic outcomes. Independent smallholders often operate in markets where large buyers possess better information about prices, processing requirements, quality standards, and procurement opportunities. Farmers may face substantial costs when obtaining documents, organising transportation, accessing credit, or meeting certification requirements. Strengthening producer institutions can reduce some of these disadvantages by pooling production, improving information access, and supporting collective negotiation [9,40]. Farmer cooperatives and producer groups can play several roles, including collective marketing, access to inputs, training, financing facilitation, traceability administration, and representation in policy discussions. However, merely establishing a cooperative does not guarantee better performance. Effective organisations require transparent governance, capable management, financial accountability, member participation, and credible commercial relationships. Institutional development should therefore be evaluated through actual improvements in farmer services and bargaining outcomes rather than membership figures alone [41,42]. Land legality constitutes a particularly important institutional condition. Farmers without recognised or sufficiently documented land rights may face difficulties obtaining formal credit, accessing replanting assistance, or entering sustainability-certified supply chains. These problems can be especially challenging where longstanding farming activities overlap with areas legally classified as state forest. Policies intended to modernise agricultural production may therefore reproduce existing inequalities unless they include accessible legal clarification and appropriate remedies [20,43,44].

Market inclusion also depends on decisions made by downstream buyers. Ekaputri . showed that independent smallholders were underrepresented in certified mill supply chains relative to their contribution to regional production, partly reflecting spatial and purchasing arrangements [11]. Chandra . similarly identified limited reach of zero-deforestation commitments among independent producers [27]. These findings indicate that strengthening farmer capacity must be accompanied by changes in buyer behaviour, procurement systems, and market governance.

Environmental Sustainability and Climate Integrity

The environmental performance of palm-based biodiesel should be assessed across its life cycle rather than inferred from its renewable agricultural origin. Relevant stages include plantation establishment, fertiliser use, cultivation, FFB transport, milling, oil processing, biodiesel production, distribution, and final combustion. The overall greenhouse gas balance depends on methodological boundaries and assumptions regarding land-use change, carbon stocks, co-products, and displaced fossil fuels. Life-cycle assessments provide important evidence but should

not be treated as universally transferable across all production conditions [23,45]. Land-use change is particularly significant because emissions associated with forest conversion or peatland drainage may undermine expected climate benefits. Greater demand for palm oil may also alter international vegetable oil markets and land-use decisions beyond Indonesia. Chiriacò illustrated that replacing palm oil with alternative vegetable oils can involve complex deforestation and greenhouse gas consequences, while Rum. examined broader trade-related environmental implications [25,46]. These findings support careful comparative assessment rather than simplistic assumptions that either palm oil expansion or substitution necessarily improves environmental outcomes. Smallholder inclusion and environmental integrity should be treated as complementary objectives. Requirements that are prohibitively expensive or administratively inaccessible may encourage informal marketing, exclude vulnerable farmers, or weaken the reach of sustainability initiatives. Conversely, market access without credible safeguards may create incentives for unsustainable expansion. Effective governance therefore requires a combination of achievable compliance pathways, technical support, traceability, buyer accountability, and protection of ecologically sensitive land [27,47,48].

Integrated Theoretical Synthesis

The reviewed theoretical perspectives reveal four interconnected mechanisms. Energy-policy instruments create biodiesel demand and financial incentives. Value-chain governance determines how economic signals and benefits travel toward primary producers. Agricultural and institutional capabilities influence farmers' ability to respond, while livelihood and environmental conditions determine whether resulting changes constitute sustainable prosperity. Each mechanism is necessary to explain the potential relationship between B60 and independent smallholder welfare. The resulting conceptual contribution is the Integrated Biodiesel–Smallholder Prosperity Framework (IBSPF). Rather than presenting B60 as a single intervention with uniform consequences, the framework treats policy outcomes as conditional on market transmission, farmer capabilities, public financing, and environmental governance. It provides the foundation for the thematic synthesis and scenario-based discussion developed in the following sections.

Methodology

Research Design

This study adopts a qualitative literature review to critically interpret interdisciplinary evidence concerning Indonesia's palm oil biodiesel policy and independent smallholder development. Qualitative literature review is appropriate because the research questions concern interacting economic, institutional, agronomic, and environmental mechanisms rather than the estimation of a single average intervention effect. The approach permits synthesis of studies employing different methodologies, including household surveys, agronomic field experiments, economic modelling, life-cycle assessment, policy analysis, and qualitative institutional research. The study is explicitly not a systematic literature review or meta-analysis. It does not claim exhaustive capture of the global literature, apply statistical pooling, or rely on PRISMA-based screening procedures. Instead, it uses purposeful, transparent, and theoretically informed literature selection, critical comparison, and interpretive thematic synthesis. This methodological choice is consistent with the objective of developing an integrated analytical framework rather than generating a pooled causal estimate.

Literature Sources and Selection

The review considers peer-reviewed journal publications from January 2020 to October 2026. Relevant literature covers biodiesel policies, palm oil value chains, independent smallholder livelihoods, sustainable intensification, replanting, agricultural financing, certification, market access, and environmental governance. The literature base draws on publications available through major scholarly publishers and indexing platforms, including Elsevier, Springer Nature, Wiley, Taylor & Francis, and other established academic outlets. Official government and institutional publications are used selectively to establish contemporary policy status, rather than as substitutes for peer-reviewed academic evidence. Studies were selected for their substantive relevance, methodological contribution, geographic applicability, and capacity to inform the central research questions. Indonesian evidence was prioritised where available, while broader conceptual and comparative insights were considered when they improved understanding of the underlying mechanisms. Studies were interpreted with attention to differences in study design, scale, observation period, and institutional setting. For example, model-based predictions of biodiesel expansion were distinguished from observed household outcomes, and field experiments were not treated as automatically representative of every producing region. The evidence base was purposefully assembled to represent both enabling and cautionary findings, including experimental agronomy, household surveys, market-transmission studies, and energy-policy assessments. Because this is a qualitative rather than systematic review, the included studies do not constitute a statistically representative sample of all publications.

Thematic Analytical Procedure

The analysis follows an iterative thematic synthesis organised around six themes: macroeconomic and energy feasibility; transmission of economic benefits; productivity and replanting; institutional inclusion; environmental sustainability; and livelihood resilience. Within each theme, the review identifies recurring findings, contradictory evidence, mechanisms, and policy implications. Relationships across themes are subsequently interpreted to construct the IBSPF and evaluate alternative implementation scenarios. The coding frame distinguishes direct empirical observations, model-dependent projections, interpretive mechanisms, and normative policy recommendations. This distinction prevents prospective B60 scenarios from being reported as established impacts. Particular attention is given to identifying conditions under which evidence obtained from earlier blending mandates can inform prospective B60 policy. Because B60-specific welfare effects have not yet been observed, the review avoids attributing established causal impacts to the proposed mandate. Instead, it develops reasoned conditional propositions grounded in related empirical research and clearly differentiates evidence-supported findings from policy recommendations.

Evidence Quality, Credibility and Limitations

Analytical credibility is supported through cross-disciplinary triangulation and the comparison of studies with differing methods and perspectives. Findings from economic models are considered alongside agronomic studies, household-level research, and institutional analyses. Contradictory results are retained where they reveal differences in context, implementation quality, or underlying assumptions. This reduces the risk of presenting an uncritically favourable or uniformly negative assessment of biodiesel expansion. Three limitations should be acknowledged. First, the prospective nature of B60 prevents direct estimation

of its realised welfare effects. Second, available studies employ heterogeneous definitions of smallholders, welfare, certification, and economic performance. Third, a qualitative synthesis cannot establish nationally representative causal effects without complementary empirical research. Consequently, the conclusions are framed as conditional interpretations and policy propositions rather than definitive forecasts of B60 outcomes.

Results: Thematic Findings

Theme I: Energy-Security Benefits and Economic Constraints

The literature indicates that Indonesia's palm-based biodiesel programme presents a credible opportunity to reduce dependence on imported diesel, strengthen domestic processing activities, and diversify the country's energy supply. Mandated blending creates additional demand for renewable fuel and supports investments in production, logistics, and downstream industrial capabilities. These benefits become strategically important when international oil markets experience disruption. However, the same literature demonstrates that expanding biodiesel requirements creates significant economic trade-offs, particularly when domestic feedstock allocation competes with potentially profitable export markets [1,2]. Halimatussadiah . questioned whether the government's economic justification for progressively higher blending requirements fully accounted for the opportunity cost of CPO exports. Their analysis demonstrated that savings from lower diesel imports could be outweighed by potential export losses under the scenarios examined [1]. More recently, Fitrady . found positive short-run associations between biodiesel penetration and economic output but identified diminishing benefits as mandates increased [8]. Their analysis also highlighted the vulnerability of biodiesel incentive financing to fluctuations in CPO export revenues and the relationship between fossil diesel and biodiesel prices. These findings suggest that higher blending percentages should not automatically be interpreted as economically superior policy outcomes. The technological feasibility of B60 constitutes an additional consideration. Increasing FAME concentrations introduces requirements concerning fuel quality, oxidation stability, cold-flow characteristics, storage, and engine compatibility. Research on higher biodiesel blending ratios provides valuable technical insights, but successful experimental performance under selected operating conditions does not establish universal compatibility with Indonesia's complete vehicle and industrial equipment fleet. The potential integration of HVO further changes the technological and investment requirements because its production process and fuel properties differ from conventional FAME [6,7]. The first thematic finding is therefore that B60 feasibility is multidimensional. Adequate feedstock, processing capacity, transport infrastructure, technical compatibility, financing, and sustainable economic returns must be considered jointly. The policy cannot be evaluated exclusively through the amount of petroleum diesel displaced. An economically credible B60 pathway must balance energy security with fiscal resilience, industrial efficiency, and the opportunity costs associated with alternative palm oil uses [6,8,28].

Theme II: Economic Transmission from Biodiesel Demand to Smallholder Welfare

An important finding is that the relationship between biodiesel demand and smallholder prosperity is indirect. Higher demand for palm-based feedstocks may contribute to stronger CPO market conditions, which could support FFB prices under certain circumstances. However, the transmission of these benefits depends on mill demand, international prices, processing margins, production costs, transportation arrangements, and the bargaining position of primary producers. Because independent smallholders generally do not sell directly to biodiesel manufacturers, national downstream expansion does not guarantee equivalent increases in their farm-gate earnings [9,22]. The consequences of market shocks are not evenly distributed: Reich . documented substantial FFB price reductions during Indonesia's 2022 palm oil export ban and identified the buffering role of off-farm income [29]. This strengthens the case for analysing price vulnerability and income diversification alongside potential demand-related benefits from B60. A simplified representation of the transmission mechanism is presented in Figure 1. The figure illustrates that national demand must pass through multiple market and institutional stages before affecting household welfare. It also identifies the possibility that value generated through biodiesel expansion may be retained predominantly by downstream enterprises and better-integrated suppliers rather than reaching independent growers.

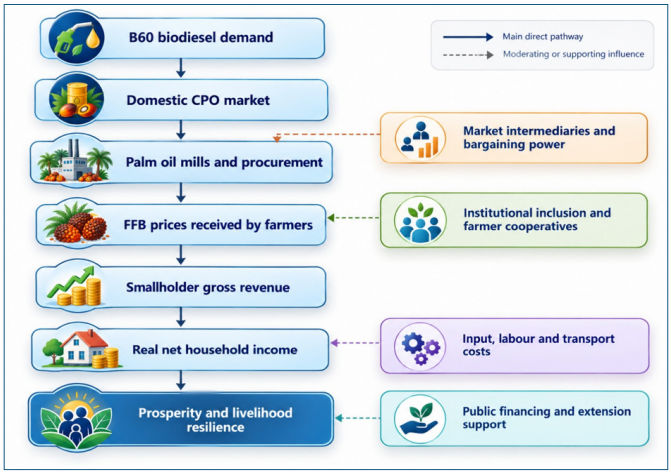


Figure 1: Economic Transmission Pathways between Indonesia's B60 Ambition and Independent Smallholder Prosperity.

The diagram identifies the relationships between biodiesel demand, CPO markets, FFB procurement, farm-level earnings, and household welfare, together with the institutional factors affecting value transmission. Solid arrows denote the hypothesised direct sequence, whereas dashed arrows represent mediating influences that may either amplify or weaken benefits. The figure is conceptual and does not imply that B60 has already caused the depicted welfare effects. The framework suggests that analysing FFB prices alone is insufficient. Farmers may experience higher gross sales while their net income remains stagnant because of rising fertiliser expenditure, transport charges, labour costs, or interest payments. Accordingly, welfare analysis should consider real net household income and financial resilience rather than assuming that a positive commodity price movement represents a comprehensive improvement in prosperity. This distinction is consistent with research on household welfare, smallholder production risk, and agricultural financial capacity [12,42,50].

The evidence also reveals considerable variation in smallholders' participation in formal and sustainability-oriented markets. Ekaputri . found that independent smallholders were substantially underrepresented in certified mill supply chains [11]. Such findings are especially important for biodiesel policy because production expansion could reinforce existing market inequalities if procurement preferences continue to favour larger or formally

integrated suppliers. Without transparent marketing arrangements and deliberate inclusion strategies, the potential benefits of additional CPO demand may reach independent farmers only partially.

Theme III: Productivity Gaps and Replanting as Strategic Opportunities

The literature consistently identifies improvements in existing plantation productivity as an important opportunity to strengthen palm oil supply without necessarily increasing cultivated land. Monzon. demonstrated that actual yields in surveyed independent smallholder fields were substantially below attainable levels, with agronomic management playing a major explanatory role [14]. Sugianto. highlighted widespread nutrient deficiencies, while Abdul. identified production inefficiencies that indicate opportunities for improving farm performance [15,50]. These studies support the proposition that national feedstock planning should prioritise more efficient production on established plantations. Evidence from improved management programmes suggests that meaningful gains are possible, although outcomes vary. Sugianto. reported substantial increases in FFB production and profitability under improved agronomic practices [17]. Sibhatu . examined the relationship between nature-based land management and yield dynamics, expanding the discussion beyond conventional input intensification [51]. However, Woittiez. demonstrated that management interventions do not invariably produce immediate financial benefits [37]. Taken together, these findings imply that productivity support should be evidence-based, context-sensitive, and accompanied by realistic assessments of costs and returns.

Harvesting practices provide an illustrative example of the interaction between agronomy and economics. In their analysis of Indonesian independent smallholder farming systems, de Vos. found that harvest intervals were influenced by yield levels, labour availability, plantation accessibility, and FFB prices [52]. Farmers sometimes adopted longer intervals to economise on labour and transportation, even where more frequent harvesting might reduce physical losses. This suggests that improving agronomic outcomes requires changes in marketing systems and financial incentives rather than technical advice alone. Replanting is equally important because the production capacity of ageing plantations will eventually decline. However, farmers must manage the substantial transition costs associated with immature replacement palms. Novra. examined the economic losses related to replanting, while Vinota. addressed the capacity of households to finance sustainable plantation renewal [53,54]. Zhao. further demonstrated that higher replanting subsidies may improve long-term returns without eliminating the income-recovery problem [20]. These findings establish that replanting support must include transitional livelihood protection, not merely assistance with plantation establishment. Figure 2 integrates these findings into a land-neutral feedstock development pathway. It distinguishes agronomic improvements in existing productive plantations from longer-term replanting interventions, while emphasising that both require financing, extension, and institutional coordination.

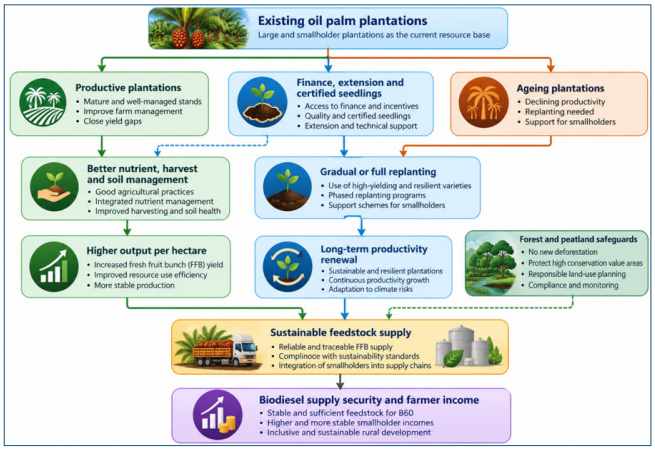


Figure 2: Productivity-led and Land-Neutral Feedstock Development Pathways for Prospective B60 Implementation.

The diagram separates short-term yield-gap closure, medium-term replanting, and cross-cutting environmental safeguards, showing how these mechanisms could jointly improve feedstock availability and farmer livelihoods. The two production pathways have different time horizons: improved management may affect current crops, whereas replanting requires a period of limited or absent production. Forest and peatland safeguards remain necessary to prevent increased profitability from encouraging expansion into ecologically sensitive areas. The central finding is that smallholder productivity improvement offers a potentially valuable bridge between national biodiesel objectives and household economic development. Nevertheless, productivity gains alone cannot guarantee environmental sustainability. If higher profits encourage additional land acquisition or forest conversion, some expected environmental benefits may be lost. Effective land-use regulation and monitoring must therefore accompany agricultural intensification [21,24,25].

Theme IV: Institutional Inclusion, Certification and Value-Chain Governance

Institutional barriers emerge as a recurring explanation for why independent smallholders may struggle to benefit from palm oil industry development. Farmers often operate under fragmented market relationships, with limited access to formal financing, extension services, recognised land documentation, and transparent procurement arrangements. Although farmer organisations can improve coordination and market access, their performance depends on institutional capacity, leadership, and accountability. These structural constraints influence whether independent smallholders can participate in the opportunities potentially generated by a higher biodiesel mandate [9,40,44]. The sustainability certification literature demonstrates that market upgrading may have unequal effects. Watts. identified challenges encountered by Indonesian smallholders seeking sustainable palm oil certification [10]. Ogahara. reported limited positive effects and important implementation gaps in the broader certification literature [30]. Financial evaluations further indicate that certification costs and benefits depend on programme characteristics and farmer circumstances, making generalised claims about automatic profitability inappropriate [32,33]. Recent research reinforces the importance of institutional differentiation. Muchlis, examining certified independent smallholders in Jambi, found variation in multidimensional sustainability performance, with economic and institutional dimensions requiring particular

attention [55]. Reich and Musshoff highlighted the role of training and economic incentives in certification uptake [34]. Rahutomo. explored how sustainable palm oil certification relates to smallholder productivity, while Supriatna. demonstrated the importance of evaluating sustainability across economic, social, institutional, environmental, and technological dimensions [48,56]. Certification and zero-deforestation commitments are also affected by downstream sourcing decisions. Chandra. found that corporate zero-deforestation commitments had limited practical reach among many independent Indonesian smallholders, including shortcomings in awareness, capacity building, and price differentiation [27]. Ekaputri. identified structural patterns of underrepresentation in certified mill sourcing [11]. Together, these findings indicate that farmer inclusion cannot be achieved solely by expecting smallholders to satisfy increasingly demanding standards. Buyers and policymakers must also support accessible compliance arrangements and equitable procurement practices.

Theme V: Environmental Sustainability and the Risks of Feedstock Expansion

The literature identifies environmental sustainability as a decisive condition for evaluating palm-based biodiesel. Life-cycle assessments suggest that environmental outcomes depend heavily on production pathways, land-use history, processing efficiency, and methodological assumptions. For example, greenhouse gas savings associated with replacing fossil diesel may be substantially reduced when production involves high-carbon land conversion. Consequently, the sustainability of B60 cannot be established solely by measuring the renewable share of blended fuel [23,45]. Higher feedstock demand may also intensify competition among agricultural uses of palm oil and create pressure for plantation expansion. Astuti. demonstrated the governance difficulties associated with illegal plantation development, illustrating the importance of spatial transparency and enforceable legal arrangements [57]. Lim. examined how market responses to intensification can influence land-use change, challenging assumptions that higher yields automatically prevent expansion [21]. These findings indicate that the environmental implications of B60 depend on the interaction between market incentives and land governance. The broader environmental literature also cautions against simple comparisons among vegetable oils. Chiriacò. demonstrated that replacing palm oil with alternative oils can involve substantial land-use and greenhouse gas implications [25]. Meanwhile, Rum . showed how international trade responses can influence environmental outcomes [46]. Such evidence supports the need to evaluate domestic biodiesel policy within interconnected agricultural and international markets rather than treating feedstock allocation as an isolated national decision. An important finding is therefore that B60 sustainability requires more than productivity growth or certification expansion independently. It requires coordinated safeguards covering deforestation, peatland protection, traceability, responsible procurement, and farmer access to compliance assistance. Evidence concerning village welfare, certification, and environmentally responsible smallholder development suggests that these objectives should be assessed together rather than treated as competing policy domains [25,39,47]. A complementary environmental-economic assessment found that oil palm smallholders could improve biodiversity outcomes without necessarily sacrificing production, and examined payments for ecosystem services as a possible policy mechanism. This evidence broadens the B60 sustainability discussion toward incentives that compensate farmers for ecological stewardship [58].

Theme VI: Social Differentiation and Livelihood Resilience

Independent smallholders are not a homogeneous category. They differ in landholding size, plantation age, financial resources, education, tenure status, geographical location, market accessibility, and household dependence on palm oil income. Consequently, a single policy instrument may produce different outcomes across farming households. Better-capitalised producers with established buyer relationships may respond positively to expanding market demand, while disadvantaged households remain constrained by low productivity, debt, or limited market access [12,13]. The distribution of opportunities also depends on how households allocate labour and manage financial risks. Rowland. demonstrated the relevance of gendered labour allocation to understanding oil palm livelihoods [35]. Research on smallholder production and income risks further highlights the importance of distinguishing financial stability from short-term profitability. Policies that increase average sectoral returns may leave vulnerable households exposed to price instability, crop failure, medical expenses, or the income losses associated with replanting [50,54]. The resilience perspective suggests that agricultural support should be complemented by livelihood diversification, savings mechanisms, accessible financial services, and social protection during major plantation transitions. In some communities, stronger non-farm economic opportunities may be equally important for sustaining household welfare. This is consistent with evidence that oil palm cultivation can influence household consumption stability through labour allocation and income diversification, rather than through plantation earnings alone [12,13]. Overall, the six themes establish that B60's potential contribution to smallholder prosperity is conditional and institutionally mediated. The evidence does not justify either an automatic expectation of widespread household gains or a categorical conclusion that biodiesel expansion cannot support rural development. Instead, it indicates that the quality of policy integration will determine whether national energy objectives and smallholder welfare become mutually reinforcing.

Discussion and Analysis

Reassessing the Relationship between Energy Sovereignty and Smallholder Prosperity

The thematic findings challenge the assumption that achieving a higher biodiesel blending percentage necessarily produces greater national welfare. Energy sovereignty and rural prosperity are related but distinct policy objectives. Energy sovereignty emphasises reliable energy supplies, reduced import exposure, and greater domestic productive capabilities, whereas smallholder prosperity concerns household income, livelihood security, institutional empowerment, and opportunities for sustainable economic improvement. Policy success in one domain cannot substitute for evidence of success in the other [1,12,25]. The relationship between these objectives can be described as conditional complementarity. If B60 increases effective demand for sustainably produced palm oil, improves farm-gate returns, stimulates productivity investment, and expands inclusive market access, it may generate benefits at both national and household levels. However, if additional demand mainly increases downstream processing revenues while independent farmers remain constrained by low yields, weak bargaining power, and restricted access to productive resources, the programme may reinforce rather than reduce existing structural inequalities. These contrasting possibilities are consistent with evidence on farmer participation in certified markets and the uneven reach of sustainability commitments [11,27]. This distinction implies that biodiesel policy should incorporate explicit distributional objectives. Rather than assuming that benefits will

flow automatically from biodiesel manufacturers through mills to agricultural households, policymakers should identify the institutions and market arrangements responsible for transmitting gains. Measurable objectives could include improvements in real smallholder net income, participation in transparent procurement systems, access to replanting assistance, and reduced vulnerability to price volatility. Such indicators would provide a stronger basis for evaluating inclusive development than aggregate production or domestic fuel substitution alone. The analysis further suggests that Indonesia should avoid treating biodiesel mandates as an isolated instrument of rural poverty reduction. A higher blending requirement creates demand, but demand alone cannot resolve insecure land tenure, ageing plantations, limited education, inadequate infrastructure, or exclusion from financial services. These constraints require complementary policies, some of which may deliver substantial benefits even if B60 implementation is postponed. Consequently, strengthening independent smallholders should be understood as a fundamental development objective rather than a benefit conditional on achieving a particular blending target [18-20].

Financing Reform and the Distribution of Biodiesel-Related Economic Benefits

Public financing represents one of the most important areas for integrating energy policy with smallholder development. Indonesia's biodiesel incentive arrangements have supported the commercial viability of domestic biodiesel consumption, but they have also generated questions about fiscal exposure, opportunity costs, and the distribution of public resources. The financing structure must therefore be evaluated against both energy-policy outcomes and alternative uses of agricultural development funds [1,8]. A more integrated financing approach would explicitly consider the long-term productive capacity of independent growers. Investments in extension services, certified seedlings, cooperative management, roads, digital traceability, and replanting finance could generate benefits extending beyond a particular biodiesel blending level. Such investments may strengthen feedstock security, reduce inefficiency, and improve the ability of farmers to respond to market opportunities. The justification for these expenditures should nevertheless rest on transparent assessments of their expected economic, social, and environmental returns rather than an assumption that all agricultural subsidies are equally effective [14,17,20].

An important policy proposal is to establish a clearly identifiable smallholder prosperity component within palm oil-related development financing, subject to fiscal affordability and transparent budget governance. Such a component could finance farmer registration, agronomic services, accessible replanting assistance, and time-limited livelihood support during immature plantation periods. Funding rules should prioritise households facing identifiable structural disadvantages and should avoid excessive administrative requirements that inadvertently favour better-resourced producers. Evidence concerning farmer preferences, financial constraints, and certification costs supports the importance of such differentiated programme design [19,44,32].

Reforming financing also requires confronting difficult trade-offs. Earmarking a fixed proportion of biodiesel-related resources for smallholder programmes may strengthen distributive accountability but could constrain budget flexibility when levy revenues decline or fuel-price differentials rise. A more resilient arrangement would establish transparent expenditure priorities, fiscal safeguards, and measurable performance commitments without promising an unconditional funding level unsupported by revenues. Fitrady. (2026) provide an important rationale for rules-based subsidy design and sensitivity analysis under changing CPO and petroleum prices [8]. The economic logic of financing integration can be expressed through three linked principles. First, public support should produce identifiable public benefits rather than merely compensate private production costs. Second, interventions should address genuine constraints that farmers cannot reasonably overcome individually. Third, programme evaluation should examine incremental welfare gains per unit of public expenditure. Together, these principles would help transform biodiesel financing from a predominantly downstream market-support mechanism toward a more balanced framework for energy security and agricultural development.

Making Sustainable Intensification a Core Component of B60 Planning

Sustainable intensification provides a plausible route for reconciling higher feedstock demand with restrictions on plantation expansion. Rather than relying on additional land conversion, policy could prioritise yield improvements on existing cultivated land and renewal of economically ageing plantations. Research demonstrating substantial agronomic yield gaps provides evidence that additional production may be attainable without proportionate increases in plantation area [24,14,16]. However, a national intensification strategy should not rely on generic recommendations such as increasing fertiliser application. Smallholder management conditions differ considerably, and inappropriate input use may reduce profitability or create environmental damage. Extension programmes should employ site-specific soil and leaf assessment, improved harvesting practices, suitable planting materials, financial planning, and locally appropriate conservation measures. Evidence on nutrient deficiencies and fertiliser-use constraints supports this more differentiated approach [15,59]. Thoumazeau. provide additional field-level evidence that the design of fertilisation and understory management can jointly influence agronomic performance and soil health. Their findings support the use of integrated guidance rather than uniform input prescriptions [36].

The relationship between agronomic advice and farmer behaviour is equally important. Farmers make management decisions within the constraints of household labour, liquidity, market prices, and access to transportation. For example, shorter harvesting intervals may improve fruit recovery or quality but become financially unattractive where farms are remote, transport costs are high, and marketed quantities are small. Collective transport arrangements and improved procurement systems may therefore be as important as conventional extension advice in achieving productivity gains [52,9].

Replanting policy requires a particularly careful balance between long-term returns and short-term vulnerability. Research on smallholder replanting demonstrates that farmers may postpone replacement even when ageing palms produce lower yields because existing plantations continue to generate immediate income. A financially vulnerable household may prefer reduced but predictable cash flow over a potentially superior investment that eliminates current earnings for several years. Public financing mechanisms should therefore account for income interruption, household consumption needs, borrowing risks, and gradual replanting possibilities [53,18,20]. A practical integrated approach could combine technical replanting assistance with

carefully assessed transitional income support, accessible credit, productive livelihood diversification, and community-level services. Farmers should receive transparent information regarding projected costs, expected yield trajectories, and realistic recovery periods. Programmes should also investigate gradual replanting where financially and agronomically appropriate. These measures would recognise the livelihood constraints that shape investment decisions while advancing the long-term productivity objectives relevant to biodiesel feedstock security [19,38,54].

The environmental consequences of intensification must also be monitored. Yield improvement can reduce the land needed to produce a given quantity of palm oil, but higher profitability may encourage expansion if forest protection and land administration remain weak. Therefore, land-neutral supply growth requires enforceable spatial safeguards, incentives to improve existing plantations, and monitoring of land-use outcomes. The resulting policy objective is not simply higher output per hectare but greater sustainable production accompanied by demonstrably improved livelihoods and reduced pressure on natural ecosystems [21,25,39]. Dalheimer . further suggest that well-designed payments for ecosystem services can support biodiversity conservation while maintaining economic incentives for smallholders [58]. Such mechanisms warrant evaluation alongside farm intensification and traceability programmes.

Institutional Inclusion, Cooperative Development and Fair Value Distribution

Institutional reform is essential for translating additional biodiesel demand into benefits for independent growers. Producer cooperatives and farmer groups can potentially increase bargaining power, reduce transaction costs, coordinate harvesting, facilitate direct mill relationships, and improve access to services. Nevertheless, these benefits depend on effective organisational governance. Institutions that are poorly managed, financially opaque, or dominated by narrow interests may fail to improve member welfare despite receiving external assistance [9,41,42].

One priority is transparent FFB pricing. Farmers should have access to understandable information concerning prevailing reference prices, quality deductions, transport charges, payment arrangements, and procurement conditions. Improved transparency would not eliminate market-price volatility, but it could reduce information asymmetry and facilitate more informed marketing decisions. Mechanisms such as cooperative aggregation, digital price information, standardised weighing, and independent grievance channels may support fairer market relationships where implemented effectively [22,11]. A second priority is equitable access to mills and sustainability-oriented supply chains. Certification programmes have generated opportunities for improved management, market recognition, and institutional development, but their benefits vary. Some independent producers face substantial compliance expenditure without guaranteed premiums or stable purchasing arrangements. Accordingly, certification support should be accompanied by transparent buyer commitments, accessible technical assistance, and realistic financial incentives [10,31,33,34]. Third, institutional inclusion requires practical solutions to land-documentation constraints. Farmers operating on land with incomplete or disputed documentation may be excluded from formal assistance, financial services, or certified market relationships. While environmental and land-use law must be respected, legitimate farmers should have access to transparent procedures for clarifying their legal status and resolving administrative barriers. Legal assistance, participatory mapping, and interagency coordination could reduce uncertainty without legitimising new encroachment into protected ecosystems [20,43,44].

The social dimension of institutional reform is also important. Cooperatives and assistance programmes should create opportunities for women, younger farmers, and households with limited assets to participate meaningfully in decision-making and benefit distribution. Monitoring should therefore extend beyond aggregate membership to effective representation, access to finance, control over proceeds, and changes in household welfare. Evidence concerning gendered labour arrangements and multidimensional sustainability supports this broader interpretation of institutional quality [35,55]. These findings imply that biodiesel value-chain integration should not be measured merely by the physical quantity of independent smallholder fruit entering mills. Meaningful inclusion requires fair commercial relationships, accessible services, transparent governance, and opportunities for farmers to influence decisions affecting their livelihoods. Without these conditions, expanded downstream industrialisation could increase national value addition while leaving existing distributive inequalities substantially unchanged.

Comparing Alternative B60 Implementation Scenarios

Three prospective implementation scenarios can be developed from the reviewed evidence. These scenarios are conceptual alternatives intended to organise policy discussion rather than quantitative forecasts. Their purpose is to identify how different combinations of policy instruments might affect economic feasibility, farmer welfare, feedstock security, and environmental sustainability.

- **Scenario A: Expansion-led B60:** Under this scenario, the government prioritises achieving the blending target through greater domestic biodiesel production and associated incentives, while upstream smallholder development continues through existing arrangements. The principal advantage is a clear industrial and energy-policy signal. However, the scenario risks increasing feedstock competition and financing obligations without addressing weak price transmission, low agricultural productivity, or institutional barriers facing independent growers. Research concerning biodiesel opportunity costs and certified supply-chain participation provides grounds for questioning whether its benefits would be equitably distributed [1,8,11].
- **Scenario B: Integrated B60 and Smallholder Development:** This scenario combines biodiesel expansion with coordinated productivity support, accessible replanting finance, transparent FFB procurement, farmer institutional strengthening, and enforceable environmental safeguards. Its principal attraction is the possibility of improving both feedstock security and household welfare. However, implementation would require substantial coordination, credible financing, and time for agricultural productivity improvements to materialise. Research on yield-gap closure, smallholder resilience, and plantation renewal suggests that this pathway could create broader development benefits, while also highlighting the difficulty of achieving rapid agricultural transformation [13,14,17].
- **Scenario C: Conditional and Adaptive B60:** Under this scenario, progression toward B60 is linked to verified readiness in fuel quality, production capacity, sustainable feedstock supply, fiscal affordability, and inclusive smallholder development. The blending level could be introduced through

defined phases or adjusted according to transparent policy rules where necessary. This approach reduces the risk of implementing an economically or technically premature mandate while maintaining the longer-term objective of domestic renewable fuel development. Its disadvantages include possible investor uncertainty and the need for credible monitoring institutions. The case for adaptive implementation is consistent with evidence on fiscal trade-offs, food-versus-fuel tensions, and the uneven outcomes of agricultural development programmes [3,8,20].

Table 1 consolidates the key differences among the three implementation pathways, including their strategies for feedstock expansion, financial sustainability, farmer inclusion, and environmental protection. Its judgements are analytical propositions informed by existing research and should not be interpreted as measured outcomes of an implemented B60 mandate.

Table 1: Qualitative Comparison of Alternative B60 Implementation Scenarios.

Evaluation Dimension	Scenario A: Expansion-led	Scenario B: Integrated Development	Scenario C: Adaptive Implementation
Blending ambition	Rapid target achievement	Expansion linked to smallholder programmes	Phased, conditional progression
Feedstock strategy	Primarily market-led supply response	Productivity and replanting support	Readiness-based supply assessment
Smallholder welfare	Indirect and uncertain gains	Explicit income and inclusion objectives	Welfare milestones inform progression
Public financing	Potentially greater exposure	Coordinated energy and rural investment	Financing adjusted to fiscal capacity
Institutional reform	Limited integration	Strong cooperative and market reforms	Reforms linked to implementation gates
Environmental safeguards	Risk depends on existing enforcement	Integrated land-neutral supply strategy	Environmental thresholds guide expansion
Main policy strength	Clear industrial growth signal	Comprehensive development integration	Greater flexibility and risk management
Principal limitation	Uneven distribution and supply pressure	High coordination and implementation demands	Risk of delays and policy uncertainty

Note: This table represents a qualitative analytical comparison developed from the literature, not observed B60 programme outcomes or calibrated simulation results. These comparisons are conditional conceptual assessments and do not constitute calibrated forecasts. The scenarios are compared schematically in Figure 3. The figure places the three approaches along dimensions of blending ambition, upstream inclusion, and implementation flexibility. These relationships are interpretive and should not be treated as numerical rankings of expected welfare or environmental performance.



Figure 3: Alternative Pathways for Integrating B60 Implementation with Independent Smallholder Development.

The diagram contrasts rapid expansion without structural reform, integrated biodiesel–smallholder development, and adaptive progression based on measurable readiness conditions. The integrated-development scenario places deliberate farmer inclusion at the centre of implementation, whereas the adaptive scenario conditions progress on verified readiness. All three pathways converge on a common comparison of net economic benefits, social equity, and environmental risks rather than treating higher blend percentages as the sole outcome. Scenario C, combined with the substantive smallholder development measures of Scenario B, emerges as the most defensible policy direction from the present qualitative synthesis. This judgement is conditional rather than predictive. It rests on the proposition that a credible blending target should be accompanied by demonstrable technical feasibility, sustainable feedstock availability, fiscal resilience, and progress toward inclusive household welfare. It does not imply that B60 must necessarily be implemented immediately or that the mandate is the most effective instrument for achieving every rural development objective.

The Integrated Biodiesel–Smallholder Prosperity Framework

The Integrated Biodiesel–Smallholder Prosperity Framework synthesises the reviewed evidence into a multilevel analytical model. At the macroeconomic level, biodiesel mandates influence domestic demand, energy security, public financing, and commodity allocation. At the value-chain level, these changes interact with mills, intermediaries, processors, and procurement institutions. At the smallholder level, outcomes depend on agricultural productivity, market access, financing, household assets, and livelihood vulnerability. Environmental governance and institutional accountability operate across all three [1,11,14]. The framework identifies institutional mediation as the critical link between aggregate economic change and household prosperity. An increase in demand can generate new market opportunities, but farmers must possess the means to participate effectively and retain an equitable share of the resulting value. This requires access to information, productive resources, fair purchasing arrangements, and functioning farmer institutions. Moreover, improvements in nominal income should be evaluated against

inflation, input costs, income volatility, and environmental risks before being classified as genuine welfare gains [9,12,22]. The framework also recognises feedback effects. Successful productivity improvements could reduce feedstock scarcity and strengthen the feasibility of higher biodiesel production. Conversely, excessive pressure to secure feedstock rapidly may increase incentives for land conversion, creating environmental costs and potential trade-related consequences. Fiscal support for biodiesel could stimulate investment but may also compete with resources needed for replanting and agricultural services. These feedbacks reinforce the importance of analysing energy, agriculture, trade, and environmental policy together [3,8,21]. Figure 4 presents the proposed IBSPF. It illustrates the causal pathways through which B60 might influence independent smallholder welfare while highlighting the enabling conditions and safeguards needed to convert potential economic opportunities into realised development outcomes.

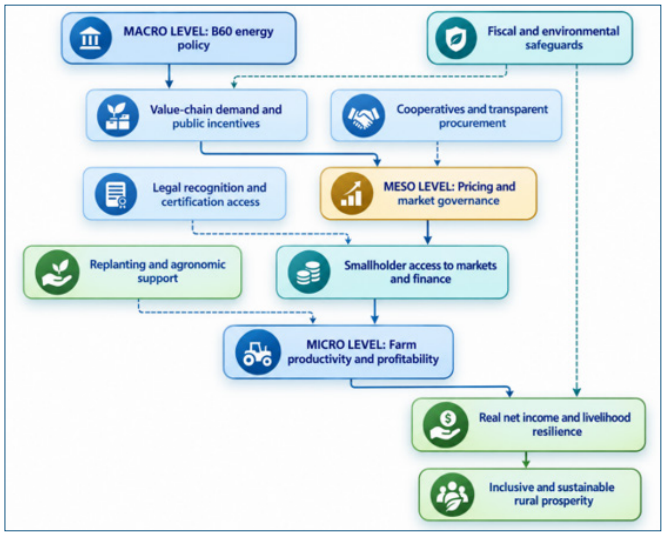


Figure 4: Integrated Biodiesel–Smallholder Prosperity Framework: Policy Drivers, Transmission Mechanisms, Enabling Conditions, and Welfare Outcomes.

The conceptual model presents a sequence from national B60 policy to value-chain transmission, agricultural and institutional enabling conditions, and multidimensional smallholder prosperity, with environmental and fiscal safeguards operating across the system. The framework distinguishes policy-level incentives, supply-chain institutions, and farm-household mechanisms to prevent aggregate industry growth from being mistaken for household-level welfare gains. It also places financial and environmental safeguards across the proposed transmission pathways. The framework contributes to the literature by explicitly integrating energy sovereignty with distributive and procedural justice. Its practical relevance lies in identifying the variables that should be monitored and the institutions that should be held accountable. It also provides testable propositions for future empirical research without claiming to establish causal relationships from the present qualitative synthesis alone.

An Integrated Implementation Roadmap

An implementation roadmap should recognise that some measures can be introduced relatively quickly, while others require several years before producing measurable results. Short-term priorities should include establishing reliable smallholder baseline data, identifying market-access constraints, improving FFB price transparency, assessing technical and fiscal B60 readiness, and piloting targeted extension and cooperative support. These activities would help reveal whether policy benefits can reach independent producers and where additional interventions are needed [8,10,44]. Medium-term priorities should focus on scaling effective productivity programmes, facilitating accessible replanting finance, strengthening farmer institutions, improving traceability, and expanding equitable procurement arrangements. Programmes should distinguish between households requiring basic legal and organisational assistance and those ready to undertake commercially oriented productivity investments. The long implementation horizon of replanting requires special attention because premature assumptions about production increases could undermine realistic feedstock planning [17,18,20]. Long-term priorities should include evaluating sustained improvements in real household welfare, enforcing land-use safeguards, maintaining stable agricultural productivity, and adapting biodiesel blending policy to evolving energy technology and economic conditions. Monitoring should also track whether additional production originates from higher yields on established plantations or new agricultural expansion. Such differentiation is necessary to evaluate environmental integrity and the legitimacy of sustainability-related claims [21,24,27]. The roadmap is summarised in Figure 5. It links phased implementation to measurable indicators rather than treating the achievement of a blending percentage as the sole definition of success. It also incorporates periodic reassessment so that policy adjustments can respond to changes in technology, fiscal capacity, feedstock supply, and smallholder welfare.

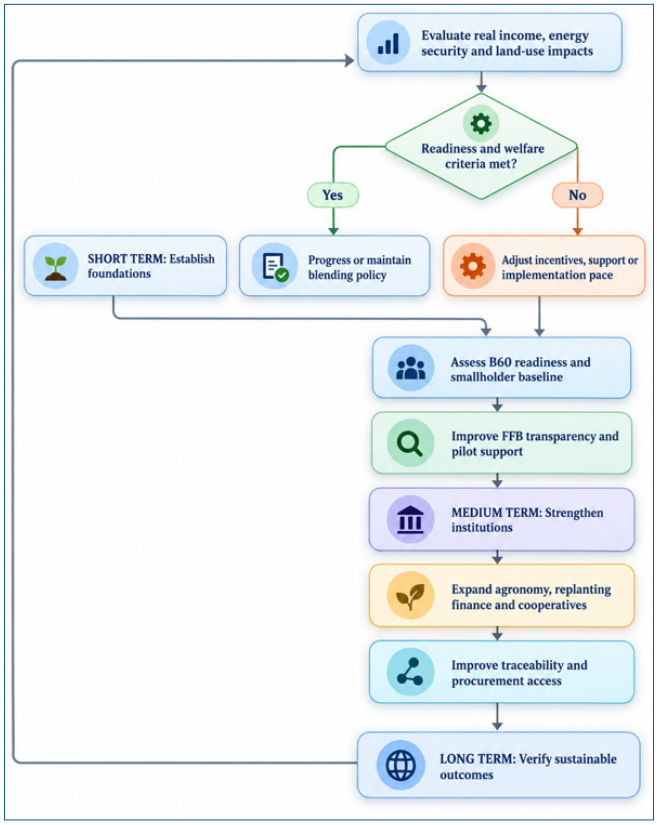


Figure 5: Proposed Phased Roadmap for Aligning B60 Readiness with Inclusive and Environmentally Sustainable Smallholder Development.

Figure 5 translates the review findings into sequential implementation priorities, beginning with feedstock and welfare baselines before progressing to producer organisation, replanting support, and verified outcomes. Its feedback loop emphasises that regulators should adjust the pace of blending if fiscal capacity, social inclusion, technical reliability, or environmental performance proves inadequate. The proposed roadmap represents a governance option rather than an adopted government timetable.

Institutional responsibility should be distributed clearly. Energy authorities would oversee fuel specifications, blending performance, and industrial readiness. Agricultural and plantation agencies would coordinate productivity and replanting programmes. Financial authorities and the relevant plantation fund-management institutions would evaluate expenditure priorities and funding sustainability. Regional governments would support farmer registration, land administration, extension, and local infrastructure. Farmer organisations, mills, biodiesel producers, and civil society institutions would contribute to procurement transparency, implementation, and independent accountability.

Monitoring Prosperity Rather than Blending Alone

An integrated policy requires indicators that reflect the different dimensions of success. Energy outcomes should include biodiesel consumption, import displacement, compliance, and fuel reliability. Agricultural indicators should measure FFB yields, oil extraction performance, replanting progress, and production changes on existing land. Institutional indicators should capture cooperative effectiveness, direct market access, certification participation, financing access, and the resolution of legitimate documentation barriers [16,55]. At the household level, evaluation should focus on real net farm income, total household consumption, debt obligations, livelihood diversification, and vulnerability to economic shocks. These measures should be disaggregated by region, plantation size, tenure status, gender, and institutional participation wherever feasible. Such disaggregation would reveal whether apparent improvements in average sectoral performance conceal limited gains among disadvantaged groups. Household welfare research provides strong grounds for distinguishing broad living standards and resilience from gross plantation revenues [12,13,35,].

Environmental indicators should include land-use changes, deforestation exposure, peatland protection, traceability performance, and life-cycle greenhouse gas emissions under consistent methodological assumptions. Monitoring should also investigate unintended effects such as additional land acquisition following productivity improvements. Environmental accountability is necessary because the renewable nature of biodiesel feedstock does not independently establish its climate benefits or guarantee environmentally responsible agricultural expansion [21,23,57]. Finally, policymakers should evaluate the cost-effectiveness of alternative interventions. A smallholder productivity programme may deliver increases in output and household welfare at a lower public cost than other mechanisms, but this must be demonstrated empirically. Similarly, a gradual blending progression may provide greater net welfare than an accelerated mandate under some market conditions. Periodic evaluation should therefore consider the marginal costs and benefits of each policy component rather than presuming that higher expenditure or faster implementation represents superior performance [3,8].

Synthesis: Can the B60 Ambition Be Achieved Inclusively?

The review supports a conditional answer to its central research question. Indonesia possesses important advantages for expanding palm-based biodiesel, including an established palm oil industry, domestic processing capabilities, and experience with successive blending mandates. However, B60's feasibility depends on further technical, economic, agricultural, and institutional assessments. It cannot be judged solely by the availability of palm oil or the political commitment to increase renewable fuel consumption [2,6,8].

The evidence also indicates that additional biodiesel demand is insufficient to guarantee smallholder prosperity. Farmers' ability to benefit depends on prices actually received, productivity, access to mills, financial capacity, and participation in functioning institutions. Strengthening these mechanisms requires deliberate action rather than reliance on general market expansion. Research on agronomic management, replanting, institutional inclusion, and household welfare provides a substantive basis for designing such complementary interventions [11,14,20].

Environmentally credible implementation introduces further conditions. Feedstock expansion should prioritise improved productivity on existing plantations, protection of forests and peatlands, and traceable supply arrangements. Farmers should receive the support necessary to comply with legitimate environmental requirements without being unfairly excluded from formal markets. These conditions are essential for ensuring that the broader economic objectives of biodiesel policy do not undermine climate integrity, biodiversity protection, or rural social justice [25,26,27]. The synthesis therefore rejects both the proposition that B60 will automatically deliver inclusive prosperity and the proposition that energy sovereignty and smallholder welfare are inherently incompatible. A more defensible conclusion is that alignment is possible but institutionally demanding. The most credible pathway combines adaptive biodiesel progression with purposeful investment in smallholder productivity, replanting, financial inclusion, market transparency, and environmental governance. Under this approach, the blending mandate becomes one component of a broader national development strategy rather than an end in itself.

Conclusion and Future Directions

Indonesia's ambition to implement B60 represents a significant extension of its palm-based biodiesel strategy and offers potential opportunities for domestic energy development, industrial investment, and agricultural value creation. Nevertheless, the findings of this qualitative literature review demonstrate that higher biodiesel blending requirements do not automatically translate into improved prosperity for independent oil palm smallholders. The relationship is mediated by economic, institutional, agronomic, social, and environmental conditions that must be addressed through deliberate and coordinated policy interventions. The article's principal conclusion is that **B60 and independent smallholder prosperity can become complementary objectives, but their successful integration is conditional rather than automatic.** A credible policy framework must combine technically feasible fuel production, sustainable feedstock availability, fiscal resilience, equitable market participation, higher agricultural productivity, accessible replanting finance, and effective environmental safeguards. Without these conditions, rapid biodiesel expansion could generate national industrial benefits while leaving substantial inequalities in upstream agricultural production unresolved. The

proposed Integrated Biodiesel–Smallholder Prosperity Framework provides a conceptual basis for understanding these relationships. It emphasises the importance of value-chain transmission, institutional inclusion, and household-level welfare indicators as essential components of energy-policy evaluation. Its application would shift attention from aggregate biodiesel volumes toward the quality, inclusiveness, and sustainability of the development outcomes generated.

A conditional and adaptive B60 implementation approach, integrated with comprehensive smallholder development measures, is therefore recommended. Short-term priorities should include reliable baseline information, market transparency, technical readiness assessments, and accessible farmer services. Medium-term efforts should strengthen cooperatives, expand productivity support, facilitate replanting, and improve sustainable market access. Long-term policy should focus on durable household welfare gains, environmental integrity, fiscal sustainability, and continuous evaluation. Further research is needed to quantify the transmission of biodiesel-related demand to farm-gate prices, compare the welfare effects of alternative financing arrangements, examine distributional differences across smallholder groups, and assess the environmental consequences of competing feedstock strategies. Longitudinal household studies and integrated economic–agronomic modelling would be particularly valuable for validating the proposed framework and evaluating future policy implementation. Ultimately, Indonesia's achievement should not be measured exclusively by whether B60 becomes operational. A more meaningful measure of success is whether the country's renewable fuel transition simultaneously strengthens energy sovereignty, protects ecosystems, and creates sustained and equitable prosperity for independent oil palm smallholders.

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