



RESEARCH ARTICLE

From Waste to Value: Examining Ethiopia's Coffee By-Product Circular Economy Commercialization Gap

Soliyana Afework Gebreananya^{1,*}

¹*Independent Researcher, Addis Ababa, Ethiopia*

(*Corresponding author's e-mail: soliyanaafework7@gmail.com)

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Abstract

Coffee husk, pulp, and spent grounds form a large, underused waste stream with established conversion pathways (biochar via pyrolysis, biogas via anaerobic fermentation, compost, cascara), yet Ethiopia, among the world's five largest coffee producers, generates an estimated 192,000 metric tons of coffee husk waste annually with almost none valorized commercially. Ethiopian universities have validated these technologies, yet little has become a functioning industry. Countries producing a fraction of Ethiopia's coffee, and one producing none, have already built profitable by-product sectors on the same technologies. This paper argues Ethiopia's constraint is commercial rather than technological: the country clears research and technology validation but stalls before commercial feasibility and investment. Weighing production scale, scientific capacity, and market demand against international literature, Ethiopian research, and a small exploratory sample of five Ethiopian coffee-sector professionals, this paper finds each an unlikely sole explanation and identifies a missing institutional bridge between research and commercialization as a plausible, potentially significant contributor, while acknowledging that the relative weight of institutional, economic, infrastructural, and market constraints cannot be established from this evidence alone. Ethiopia's recent investment reforms, plastics restriction, and rising demand for biodegradable materials have converged into a favorable commercialization window. The paper contributes a diagnostic framework for scaling circular-economy waste valorization, connecting university research, industry perspectives, and policy timing.

Keywords: biochar, circular economy, coffee by-products, technology commercialization, waste valorization

Introduction

Circular-economy approaches to agricultural waste, converting a crop's residue into fertilizer, fuel, or feedstock through fermentation, pyrolysis, or composting, depend on more than proving the technology works; they depend on it being commercialized at scale. Coffee husk and pulp are among the largest such residues globally, and Ethiopia illustrates the gap. Ethiopia is coffee's country of origin: the Kaffa region is where the plant is believed to have originated, and Ethiopia has grown and consumed it for centuries as a fixture of family and community life [1]. The country now produces roughly 11.6 million 60-kilogram bags a year [2], enough to generate an estimated 192,000 metric tons of coffee husk waste annually, of which some 134,400 metric tons piles up in the Jimma area alone (Sime et al., 2017 [3], a figure this paper could not cross-verify against a second source; an accurate regional waste baseline, measured directly rather than inferred from this single widely cited estimate, should be a priority for future research). Jimma University and Addis Ababa University have spent more than a decade publishing peer-reviewed research on what to do with that waste: composting it

into agricultural inputs [4], and converting it into biogas via anaerobic fermentation [5, 6] and biochar via pyrolysis [7, 8].

Other countries have taken these same raw materials and built real industries generating export revenue and rural employment. Brazil converts coffee residue into bioethanol, cosmetics, and activated carbon. Indonesian cooperatives turn coffee pulp into cascara tea, with returns reported, in two small peer-reviewed cooperative-scale case studies, in the 48–49 percent range. A single roastery in Japan, which grows no coffee at all, runs a fully circular operation that burns its own spent grounds to roast the next batch of beans [9]. These cases establish that by-product commercialization is technically and organizationally achievable, not that Ethiopia could replicate any model on comparable terms: Brazil, Indonesia, Costa Rica, and Japan differ from Ethiopia in industrial structure, infrastructure, factor prices, and financing, and this paper treats which business model, if any, is feasible under Ethiopian conditions as open rather than settled by these examples.

Ethiopia has the crop, the waste, and the research. It does not have the industry, the export earnings, or the rural employment that industry would create. Composting, mulching, and informal fuel burning remain the ceiling of what happens to Ethiopian coffee by-products at any meaningful scale, despite the crop, waste, and research all being in place.

This paper takes up the resulting question directly: why has that potential gone unrealized? It argues that the evidence points to commercialization, not a lack of scientific knowledge, as Ethiopia's primary constraint, and that recent policy and market shifts may have created a realistic opportunity to solve that problem for the first time. The next section develops a conceptual model of how research becomes industry and locates precisely where Ethiopia stalls; the Results and Discussion section tests three competing explanations for that stall and finds each unlikely to be sufficient alone, brings in original questionnaire evidence, develops the paper's positive argument and policy implications, and addresses robustness and limitations before the Conclusion.

A Conceptual Model of Commercialization, and Where Ethiopia Stalls

Coffee by-product research is easiest to interpret against an explicit model of how a laboratory finding becomes an industry. The technology-commercialization literature does not converge on a single stage count: Jolly's [10] influential model of moving technology "from mind to market" identifies five subprocesses (imagining, incubating, demonstrating, promoting, sustaining) linked by stakeholder-mobilization steps, while the broader transitions literature distinguishes more simply between niche innovation and regime-level diffusion [11]. This paper adapts rather than adopts that literature: the seven labels used here, scientific research, technology validation, commercial feasibility assessment, investment, pilot production, market adoption, and industrial scale (Figure 1), are the author's own decomposition, chosen because they map cleanly onto the evidence available for Ethiopian coffee by-products (a published research base, documented pilot-scale validation, and an absence of anything past that point), not a framework independently validated elsewhere. The model is a heuristic for organizing the evidence, not a tested theory of technology commercialization.

Ethiopia's coffee by-product sector clears the first two stages capably. Jimma and Addis Ababa University have published peer-reviewed research establishing scientific feasibility [3, 4] and validated the underlying technology at laboratory or pilot scale [5, 6, 7, 8]. What does not consistently occur is the transition from a validated technology to a costed, financeable commercial proposition. This paper's central argument is that the evidence points to a stall around this transition, not earlier, for lack of science, and not later, for lack of demand, although the relative contributions of technological, market, economic, infrastructural, and institutional constraints cannot be distinguished conclusively; every barrier below is best understood as a cause or consequence of that stall.



Figure 1. A conceptual model of technology commercialization, showing the stage at which Ethiopia's coffee by-product sector consistently stalls.

Research Questions and Contribution

The existing literature on coffee by-products answers three questions well. A technical strand documents what can be done with coffee husk, pulp, and spent grounds (biochar, biogas, bioplastics, cascara) [12, 13, 14]. A country-case strand documents what other producers have built [15, 16, 17]. And a substantial Ethiopian strand documents the composition and technical potential of Ethiopian coffee waste specifically [3,4,5,6,7,8]. Almost none ask the question connecting them: why hasn't Ethiopia commercialized its own research? That gap, between three literatures that rarely engage each other, is this paper's contribution: combining university research, industry perspectives, international case comparisons, and current Ethiopian policy and market conditions to answer a question none of the underlying literatures answer alone.

Main research question: Why has Ethiopia failed to commercialize coffee by-products despite favorable raw material, scientific capacity, and professional interest, and what would it take to change that?

Three subquestions organize the investigation:

1. Which explanations for the stall between technology validation and commercial feasibility: production scale, scientific capacity, market demand, or institutional capacity, survive comparison against the international and Ethiopian evidence?
2. How do Ethiopian coffee-sector professionals themselves describe the barriers, and where do they agree or disagree with the literature and with each other?
3. What recent policy developments create a window of opportunity to close the gap now, rather than five years ago or five years from now?

A question phrased as "why" ordinarily calls for evidence from the full range of actors who shape an outcome: producers, financiers, regulators, and buyers among them. This paper cannot fully meet that bar. Its primary evidence is a five-person exploratory questionnaire, and it compensates for that narrowness by triangulating against the international and Ethiopian literatures rather than resting the causal claim on the survey alone; even so, the survey evidence should be read as illustrative of how some practitioners describe the barriers, not as a representative account of why the sector has stalled.

Research Methodology

This paper draws on three bodies of evidence. The first is the international literature on coffee by-product valorization: technical, economic, and country-case studies published mainly between 2017 and 2026, identified through targeted searches combining terms such as "coffee husk," "valorization," "circular economy," and "Ethiopia," cross-checked against at least one independent source wherever a specific figure is used. The second is the Ethiopian scientific

literature, concentrated at Jimma University and Addis Ababa University. The third is primary data: a structured questionnaire distributed to Ethiopian coffee-sector professionals between July 15 and July 21, 2026, which returned five responses: one coffee processing site manager, three researchers (one also a freelance consultant and teacher), and one quality control professional, with reported experience ranging from five to more than ten years. Five respondents recruited through cold outreach via email and LinkedIn cannot support representative claims about the sector; they are used throughout as exploratory evidence that can corroborate, complicate, or unsettle conclusions drawn from the literature, not as a survey standing on its own. The sample is also heterogeneous in role and omits several stakeholder groups bearing directly on this paper's questions: coffee farmers and cooperatives, investors and financial institutions, government officials, exporters, and downstream manufacturers. Their absence limits what the questionnaire can say about financing, regulation, and buyer-side demand, and is a primary reason this paper treats the survey as exploratory rather than conclusive throughout.

Two further bodies of theory sharpen the interpretation of this evidence beyond the pipeline model. The multi-level perspective on socio-technical transitions [11] frames Ethiopia's university research as a niche innovation that has not accumulated enough institutional support to displace an established regime built around raw green-bean export. The literature on global coffee value chains [18, 19] warns that a new revenue stream does not automatically benefit the smallholder farmers who generate the raw material, a caution this paper returns to before recommending anything.

This paper uses four terms in distinct, non-interchangeable senses: valorization (converting waste into any usable output, market-bound or not), commercialization (selling a valorized product through a market transaction, at any scale), industrialization (production requiring dedicated capital equipment and a supply chain beyond a single cooperative or pilot facility), and scaling (the transition from pilot- or cooperative-level commercialization to industrialization). This paper's claims concern only the first transition and make no claim about whether Ethiopia could subsequently industrialize or scale.

All five respondents were contacted individually, informed of the study's academic purpose and voluntary, anonymous nature, and gave consent before completing the questionnaire; no respondent received compensation, and no identifying information is reported or retained beyond role and years of experience in aggregate. The questionnaire was administered between July 15 and July 21, 2026, after Ethiopia's 2025 investment reforms, its February 2026 replacement (Regulation No. 586/2026), and the plastics restriction were all already in effect. This limits the independence of the timing argument from the survey evidence: respondents' confidence that plastics restrictions create a market opportunity may partly reflect awareness of an already-effective policy, not an independent forecast. The full questionnaire is reproduced in Appendix A.

Results and Discussion

Testing Explanation One: Production Scale

The simplest explanation: perhaps by-product industries appear only once a country produces enough coffee to generate waste at real scale, and Ethiopia has simply not caught up.

Brazil is the first piece of evidence, and at first it looks confirming. Producing roughly 64.7 million bags a year, about six times Ethiopia's output, Brazil has built one of the world's most advanced coffee by-product industries, and a 2026 study found pyrolysis of Brazilian spent coffee grounds could reach a 105 percent internal rate of return when the process first extracted coffee oil for separate sale [15]. Vietnam, the second-largest producer at roughly 29 million bags, tells a similar story, having commercialized husk into biomass energy, biochar, fertilizer, and mushroom substrate [20].

The hypothesis collapses once smaller producers enter the comparison. Costa Rica produces about 1.3 million bags, a ninth of Ethiopia's output, yet a number of Costa Rican mills generate biogas through anaerobic digestion of coffee wastewater and pulp, using it to power on-site drying, reduce grid electricity purchases, and recycle wastewater. Indonesia, at roughly 10.7 million bags, produces slightly less coffee than Ethiopia; two cooperative-scale Indonesian studies report internal rates of return of 48–49 percent for cascara tea, with payback under a year. Both are peer-reviewed and published, but neither is directly comparable to the Brazilian analysis discussed below, and both describe a single cooperative rather than the sector as a whole, so these figures are read as case-specific, not sector-representative [16, 17]. Mexico, at a third of Ethiopia's volume, converts residue into biochar, briquettes, and food and pharmaceutical ingredients. And Japan, which grows no coffee, runs a commercially operating circular roastery on nothing but its own spent grounds [9, 21]; as a high-income economy with energy, labor, and regulatory costs very different from Ethiopia's, the Japanese case shows niche, high-value applications are technically possible at zero production scale, not that they are economically viable at Ethiopian factor prices.

Table 1. Cross-country comparison of coffee production scale, primary by-product uses, and documented returns. Ratios to Ethiopia are approximate and illustrate scale only. The Brazilian IRR (*) is scenario-specific; the Indonesian IRR figures (**) come from two peer-reviewed cooperative-scale case studies and are specific to those cooperatives, not representative of the Indonesian sector as a whole [20, 16, 17, 15].

Country	Annual Production (60-kg bags, 2024/25)	Main By-Products Used	Reported IRR	Other Documented Cost/Revenue Signal
Brazil	~64.7 million (~6x Ethiopia)	Bioethanol, biodiesel, cascara, activated carbon, coffee oil	105%*	*Scenario-specific: oil-extraction + pyrolysis; not typical of coffee-waste processing generally
Vietnam	~29 million (~2.7x Ethiopia)	Biomass energy, biochar, fertilizer, mushroom substrate	Not published	Reduced energy purchase costs reported
Colombia	~13.2 million (~1.2x Ethiopia)	Compost, biogas, cascara, antioxidant extracts	Not published	—
Indonesia	~10.7 million (~0.9x Ethiopia)	Cascara tea, briquettes, animal feed	48–49%**	**Two peer-reviewed cooperative-scale case studies
Mexico	~3.9 million (~0.3x Ethiopia)	Biochar, briquettes, compost, food/pharma ingredients	Not published	—
Costa Rica	~1.3 million (~0.1x Ethiopia)	Biogas, electricity, compost, wastewater recycling	Not published	Reduced grid electricity purchase reported
Japan	0 (net importer; not a grower)	Fuel pellets from spent grounds	Not published	Operator-reported carbon neutrality;

		(single documented roastery)		high-income cost structure
Ethiopia	~11.6 million (5th-largest global producer)	Composting, mulching, informal fuel use	Not applicable	No commercial-scale valorization to measure

If scale determined commercialization, a country growing no coffee should have no industry, and a country producing a ninth of Ethiopia's volume should trail it by a decade. The evidence runs the opposite direction: production scale is unlikely to be a sufficient explanation.

A common feature across Brazil, Vietnam, Costa Rica, Indonesia, Mexico, and Japan, more than tonnage, is investment: in processing infrastructure, in financing willing to fund a new revenue stream, and in technology-transfer arrangements that move a laboratory result into a factory. That matches the value-chain literature's prediction, since capturing value from a by-product stream draws on the same capital and market access that determines who captures value in the primary green-bean chain [18,19].

Testing Explanation Two: Scientific Capacity

If scale does not explain the gap, perhaps the underlying science does: perhaps Ethiopia knows it has a waste problem but has not worked out what to do about it technically.

This explanation does not survive a look at the Ethiopian research record. Researchers at Jimma University and Addis Ababa University have demonstrated the technical feasibility of co-composting coffee husk and pulp with municipal solid waste to produce stable, agriculturally useful compost [4]; converted coffee by-products into biochar and biogas [7, 6, 5]; and built coffee-husk biochar composites for water treatment [8]. Untreated coffee-processing wastewater in the Jimma Zone has been shown to measurably reduce downstream dissolved oxygen, evidence that Ethiopian researchers are not only capable of the science but are actively documenting the cost of not applying it [22].

In some cases this research is as methodologically current as anything from Brazil or Indonesia. A caveat: publication of laboratory- or pilot-scale results demonstrates scientific feasibility, not that the underlying processes have reached a commercialization-ready readiness level. None of the cited studies reports the scale-up trials, process robustness under continuous operation, standardized specifications, or techno-economic performance data a commercial-scale facility would require, and this paper found no evidence such data exist for Ethiopian coffee by-products specifically. Scientific capacity therefore appears insufficient on its own to explain the gap, but this paper cannot rule out a residual technology-readiness gap, short of a knowledge gap, contributing alongside the institutional constraints below. Ethiopia's problem is not that it does not know what to do with coffee husk; it is that knowing has not reliably become doing, consistent with, though not conclusive proof of, a stall that sits after, rather than at, technology validation.

Testing Explanation Three: Market Demand

A third, more recent and harder to dismiss: perhaps there is simply no market for Ethiopian coffee by-products, so building an industry around them would mean building supply with no corresponding demand.

Three recent developments complicate this. First, Ethiopia's plastic imports rose from an estimated 86,000 metric tons in 2007 to 386,000 metric tons in 2022, a 421 percent increase, 58.2 percent of it packaging plastic [23], and the country has since restricted single-use plastics nationwide. This increases the incentive to explore biodegradable alternatives; combined with Ethiopia's research base and abundant by-product supply, it is best read as one contributor to a more favorable environment, not proof a market already exists. Second, cascara, the dried

coffee cherry skin used in tea, has a defined, if regulated, export pathway into the European Union, which classifies it and several related coffee by-products as "novel foods" requiring safety authorization before sale; that is a cost and a delay, not a closed door [13]. Third, coffee by-products contain bioactive compounds, including chlorogenic acid, caffeine, caffeic acid, and other phenolic compounds, with documented antioxidant, anti-inflammatory, and antimicrobial properties [12], attracting interest from cosmetics and pharmaceutical manufacturers, where naturally derived ingredients can command a premium; Brazil has already built commercial cosmetic applications from coffee residue, and a recent techno-economic analysis of Brazilian spent coffee grounds found combining oil extraction with pyrolysis could achieve a 105 percent internal rate of return under that scenario, though the pyrolysis-only scenario was unfeasible at any evaluated interest rate [15], evidence this higher-value segment is not merely theoretical.

Participation in that higher-value segment requires more than raw-material access: extraction technology, purification capacity, quality control, regulatory compliance, and formulation expertise, at a moment when the broader market for natural, plant-derived cosmetic ingredients is itself expanding [14]. Ethiopia's published coffee by-product research has concentrated on composting, biogas, and biochar [5, 4, 6, 7, 8], with comparatively little work isolating and commercializing the bioactive compounds cosmetic and pharmaceutical buyers would want. That gap is telling: higher-value demand does exist internationally, but Ethiopia's research-to-commercialization pathway, the same missing bridge this paper identifies elsewhere, has not yet been built to reach it in this category specifically.

None of these three developments amounts to a mature market today, and no Ethiopia-specific market study was located. But a market cannot be judged absent when the products it would supply barely exist yet to be rejected by buyers, and demand for at least one category, bioactive-compound extracts for cosmetics and pharmaceuticals, already exists internationally. Whether Ethiopian producers could profitably reach that demand is a separate question this paper cannot answer, but insufficient demand cannot yet be established as the sole, or even primary, explanation; the more defensible statement is that demand appears to be emerging, at least in one segment, faster than Ethiopia's supply-side capability to reach it.

Primary Evidence: Ethiopian Coffee-Sector Professionals

The analysis so far finds three plausible explanations unlikely to be sufficient alone, based on published sources. It has not yet asked the people who would have to build this industry what they think is stopping them.

A short structured questionnaire distributed to Ethiopian coffee-sector professionals in July 2026 returned five responses. Though limited by sample size, they were consistent on one point: every respondent disagreed or strongly disagreed that Ethiopian coffee by-products are used to their full economic potential, matching the literature.

Underneath that consensus, the same barriers surface that this paper has now tested and organized rather than merely listed: every respondent cited limited investment and a lack of affordable processing technology; four of five cited inadequate infrastructure and weak government policy; fewer mentioned training gaps, low market demand, or competition from more profitable crops such as khat.

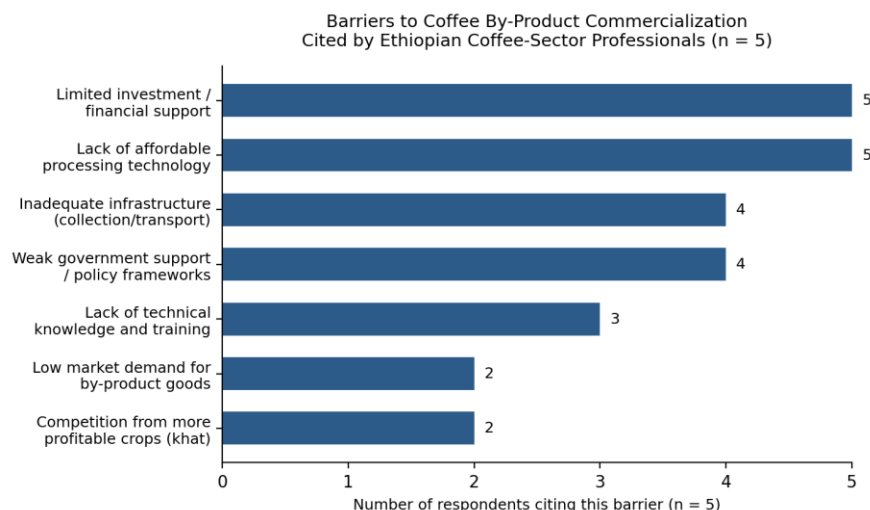


Figure 2. Barriers to coffee by-product commercialization cited by five Ethiopian coffee-sector professionals surveyed in July 2026 (respondents could select multiple barriers).

Then the agreement breaks, in a way this paper treats as informative rather than noise to be averaged away, though "informative" here means hypothesis-generating, not confirmatory, given the sample size. Asked whether Ethiopia would generate more value processing by-products domestically before export, three of five agreed or strongly agreed and one was neutral; the single respondent who actually manages a coffee processing site disagreed. The most operationally experienced respondent is also the most cautious. That is a sample of one and no claim here rests on it alone; but it is treated below as the most direct empirical challenge to this paper's institutional argument, not an outlier to set aside.

What the researcher-respondents agree on, independently and almost word for word, is the sequence that should come next. Two of the three, without prompting each other, described the same pathway: study the raw material and production capacity, run an economic feasibility analysis, then bring findings to investors, "including the government." Asked which single action would matter most, R&D funding was the most-cited answer, ahead of tax incentives and industry–university collaboration. Asked whether plastic restrictions create a market opening for biodegradable products, three of five strongly agreed and none disagreed, including researchers more cautious on nearly every other question. Only one respondent, the processing site manager, reported ever being personally involved in a coffee by-product project, in a room of five professionals whose work puts them closest to the problem.

Synthesis: The Missing Institutional Bridge

Considered together, the evidence against these three explanations points toward a consistent pattern. Countries producing a ninth of Ethiopia's coffee, and one producing none, have built functioning by-product industries, weighing against production scale as the explanation. Jimma University and Addis Ababa University have already done the relevant research, clearing the first two stages of the pipeline in Figure 1, weighing against a shortage of scientific capacity. And plastic restrictions together with cascara's export pathway are creating real demand for by-product goods, weighing against market demand as a sufficient explanation alone. Even the professionals who would build this industry agree, unanimously, that the potential is currently wasted.

What is missing is the mechanism that would move a laboratory result at Jimma University into a financed, licensed enterprise: the transition from technology validation into commercial feasibility and investment. Survey respondents pointed to exactly this: asked which single action would matter most, they named research and development funding and industry–university collaboration, not further scientific study — a description of the missing bridge from the people who would have to cross it, not merely this paper's inference.

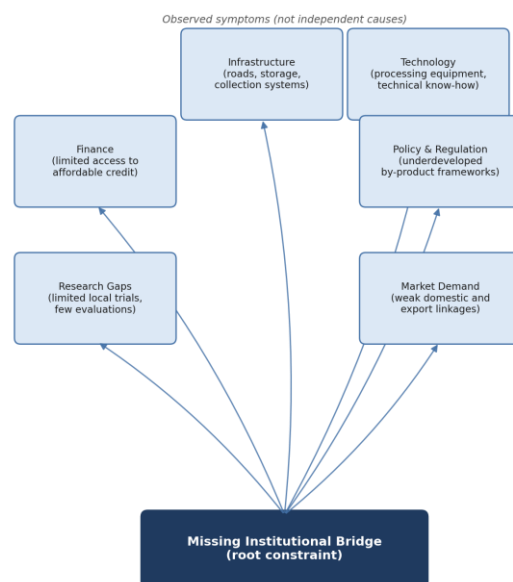


Figure 3. Six commonly cited barriers to coffee by-product valorization in Ethiopia, shown as downstream symptoms of a single missing institutional bridge rather than as independent causes.

Isolated start-ups and pilot initiatives, such as an Ethiopian energy start-up processing coffee waste [24] and a cascara commercialization project [25], do not contradict this diagnosis; they confirm it. The bridge exists in fragments, not as a systematic pathway for scaling multiple projects across the sector.

What the Missing Bridge Looks Like Elsewhere

The country comparison above established that Brazil, Indonesia, and Costa Rica have built by-product industries; it did not establish how. In Brazil, the relevant institution is EMBRAPA, the federal agricultural research corporation, which operates a central Technology Transfer Office and regional technology-transfer offices with an explicit mandate to license university research to private firms, negotiate commercialization partnerships, and manage the resulting intellectual property [26]. No coffee-specific equivalent exists in Ethiopia, even though the underlying research, biochar, biogas, and compost formulations developed at Jimma and Addis Ababa University, is not different in kind from what EMBRAPA licenses for other Brazilian crops.

Ethiopia is not starting from zero here, which makes the gap more precisely locatable than "no institutions exist." The Ethiopian Institute of Agricultural Research maintains a Deputy Director General post mandated for technology commercialization, and the Agricultural Transformation Institute is mandated nationally to incubate, pilot, and scale agricultural innovations [27]. Neither institution, on the evidence available here, has been applied specifically to coffee by-product research. A 2025 review of publicly funded Ethiopian agricultural innovation found inadequate financing, a misaligned intellectual-property framework, and weak public-private collaboration as recurring, sector-wide barriers rather than ones unique to coffee [28], consistent with the broader claim that institutional gaps, not knowledge gaps, separate technology availability from adoption in developing economies [29]. A comparable diagnosis of Uganda's research institutions finds the same fragmentation and financing gaps [30], suggesting a regional rather than idiosyncratically Ethiopian pattern, grounds for cautious optimism, since Ethiopia need not invent a solution from nothing.

Financing, infrastructure, and policy gaps are real, but treating them as independent barriers is misleading: they behave less like four separate obstacles than four manifestations of the same institutional gap. This paper's respondents named limited investment and financing as

the barrier they saw most often, but the more precise problem may be the pathway, not the capital: without an established, de-risked route from a university pilot to a bankable proposal, cooperatives struggle to get financed regardless of how much capital exists in the broader economy. Infrastructure investment stalls for a related reason: the transport problem is solvable in principle, but no institution is positioned to identify which valorization pathway the infrastructure should be built around. Policy has been slow to move for a third version of the same cause, not because Ethiopia lacks the legal tools, but because a sector with no functioning industry generates little pressure on policymakers to write rules for one.

One qualification belongs here before this argument becomes a set of recommendations. Building the institutional bridge this paper argues for is not, by itself, a guarantee the resulting value reaches the smallholder farmers and cooperatives who generate the raw husk and pulp. The value-chain literature is explicit that new revenue streams in globally traded commodity chains tend to be captured by exporters, processors, and buyers positioned closer to market than farm [18,19]; more recent, Ethiopia-specific evidence on how upstream value has and has not reached coffee producers over the last decade supports treating this as a live risk, not a dated concern [31]. Fixing the institutional gap and fixing who benefits from it are two different problems, and only the first is what the evidence here directly tests.

Timing: Why Now

An institutional gap like this could plausibly have been diagnosed at any point in the last fifteen years. What makes this a live question in 2026, not a historical curiosity, is that three conditions have changed at once.

This is not the first time Ethiopia has offered agro-processing investment incentives, and the timing argument here depends on the current regime differing in kind from what came before, not just degree. The 2012 Investment Proclamation No. 769/2012 already granted agro-processing investors tax holidays of up to eight years alongside duty-free capital equipment imports [32], and the 2020 Investment Proclamation No. 1180/2020 broadened foreign investment access without changing that structure [33]. A 2022 regulation and its 2025 amendments then tied eligibility more explicitly to export performance and investment thresholds [34, 35]. That regime was repealed and replaced, effective February 23, 2026, by Regulation No. 586/2026, which trades blanket tax holidays for reduced rates conditioned on binding performance agreements [36, 37]. None of these earlier reforms coincided with a domestic regulatory shock creating new demand for by-product goods, or comparable donor interest in coffee specifically; the current regime is the first to overlap with both.

As of February 2026, Regulation No. 586/2026 governs Ethiopia's investment incentives, replacing the earlier tax-holiday system with reduced income tax rates, 5 percent for Special Economic Zone developers and start-ups, 15 percent for most priority sectors including agro-processing, tied to binding Performance Agreements with the Investment Commission, alongside a first-year capital-expenditure write-off above a \$2 million threshold [36, 37, 38]. This changes, but does not close, the opportunity this paper describes. A large-scale, export-oriented facility, of the kind envisioned in Phase 2 or 3 below, could in principle qualify for the reduced agro-processing rate. The cooperative-scale pilots Phase 1 recommends, by contrast, sit below the new thresholds and would need other instruments, such as Investment Commission incentives for smaller enterprises or targeted grant and donor financing. The plastics restriction still adds a policy-driven incentive to explore biodegradable materials, at a moment when this paper's survey respondents are already unusually confident about that opportunity, and a €10 million concessional credit facility launched with the Italian Agency for Development Cooperation in March 2025 still signals renewed investment interest across the Ethiopian coffee value chain, even if not targeted at by-products specifically [39, 40].

None of these three developments constitutes a by-product industry on its own, and their coincidence with this paper's writing is not itself evidence they have caused, or will cause, commercialization. Together, they describe a theoretical enabling environment: a policy

landscape more favorable to closing the institutional gap than at any point this paper's sources cover. This paper found evidence of actual investment or market response for the Ethiopian coffee sector broadly, such as the credit facility below, but no by-product-specific evidence investors, processors, or buyers have yet acted on this environment. Whether the window converts into a functioning industry, and how quickly, remains to be observed, not demonstrated by policy timing alone.

There is also a reason this window should not be treated as indefinitely open. The most detailed available climate modeling for Ethiopian Arabica projects a mixed picture: bioclimatically suitable area could contract by 39 to 59 percent by century's end under a business-as-usual scenario in areas currently cultivated, while suitability could expand in some highland areas if cultivation shifts upward, a net effect the underlying study treats as uncertain, not a straightforward decline [41]. A more recent national-scale projection using different climate models similarly finds a net increase in suitable area by 2080, alongside a westward and northwestward shift away from some currently cultivated zones [42], reinforcing that the direction of change is contested by location, not settled either way. Multilateral climate finance institutions already treat the risk to existing growing areas as material: the Climate Investment Funds has funded forest-protection programming explicitly framed around safeguarding Ethiopia's coffee-growing landscapes [43], independent of this paper's argument about commercialization timing. Any industry built on coffee husk and pulp depends on the volume of cherry harvested, and the two projections above disagree about where that volume will concentrate by mid-century. That disagreement, rather than either scenario alone, is the reason to build institutional capacity now: a bridge is useful whether growing areas contract, relocate, or expand, whereas waiting for the climate picture to resolve forfeits time this paper's other findings suggest Ethiopia does not need to lose.

A Phased Implementation Roadmap

Five separate recommendations, funded evenly, would spread limited public and donor resources across problems that do not carry equal weight. The evidence points instead to a sequence, in which each phase removes the bottleneck the previous phase exposes.

Phase 1 — Build the pathway itself, through named institutions rather than in the abstract. Route existing Ethiopian research on composting, biochar, biogas, and pyrolysis [4, 5, 6, 7] into cooperative-scale pilot plants using capacity already identified but not yet applied: the Ethiopian Institute of Agricultural Research's Technology Commercialization directorate for licensing and IP management, the Agricultural Transformation Institute's incubate-pilot-scale mandate, and funded liaison arrangements with the Jimma and Addis Ababa University groups that produced the underlying science, the same mechanisms this paper's respondents independently named as most impactful. Nothing later in this roadmap matters if this phase does not produce at least one working example of Ethiopian research reaching commercial scale.

Phase 2 — Solve infrastructure and financing around whatever pilot succeeds. Coffee husk's low bulk density (50–80 kg/m³) makes it expensive to move; centralized collection hubs solve that, but only once Phase 1 has identified which pathway they should be built around. Larger, export-oriented enterprises should also be explicitly recognized as qualifying agro-processing activities under Regulation No. 586/2026, so investors need not argue eligibility case by case; cooperative-scale pilots below the threshold will need a separate, SME-specific incentive pathway. The Investment Commission's existing smaller-enterprise incentives, combined with targeted donor financing such as the €10 million Italian facility discussed below, are the two instruments already available to fill that gap while Phase 1 pilots are underway.

Phase 3 — Connect to export markets with distribution designed in from the start. Cascara, cosmetic oils, and biodegradable packaging have real export pathways, but EU novel-food authorization for cascara-based products is not automatic [13], and any export partnership should direct revenue back to the cooperatives and smallholders who produce the raw material — the distributional caveat above belongs here as a design requirement, not an afterthought.

Each phase is a precondition for the next, not an alternative to it.

Robustness and Alternative Explanations

This paper's own primary data supplies the most direct challenge to its argument, addressed first rather than buried. The single respondent with direct daily operating responsibility, the coffee processing site manager, disagreed that domestic processing would generate more economic value than raw material export, a view no researcher shared. If the practitioner closest to real operating costs is unconvinced, the institutional argument above may underestimate a genuine economic constraint rather than correctly diagnose an institutional one.

Taking that possibility seriously means stating the competing explanation plainly: perhaps the economics genuinely do not work in Ethiopia. Dispersed smallholder production, coffee husk's low bulk density, and an underdeveloped rural road network could make collection and transport costs high enough that valorization is unprofitable at Ethiopian factor prices, regardless of institutional support. This paper cannot rule that out: the techno-economic returns cited throughout are Brazilian and Indonesian, and no Ethiopia-specific cost model adjusted for local labor, capital, and transport could be located. Two pieces of indirect evidence weigh against it without settling it: Costa Rica's smallholder-dominated sector, sharing Ethiopia's fragmented structure, supports profitable cooperative-scale valorization, and Ethiopian farmers' habit of burning husk in open piles looks more like a missing market than a rejected one. The honest position: the institutional explanation is more probable, not demonstrated; an Ethiopia-specific feasibility-grade cost study would most directly confirm or overturn it.

A fully specified Ethiopia cost model is beyond what published data can support, and this paper does not attempt one from global benchmarks; doing so would risk implying a viability finding the data cannot support. A more disciplined way to take the processing manager's skepticism seriously is to state plainly what would need to be true for it to hold. Coffee husk's low bulk density and Ethiopia's rural road network make transport the most likely point of failure: if collection and transport costs run above roughly \$50–80 per ton, a threshold consistent with other bulky, low-value agricultural residues, that alone could erase the margin implied by the Brazilian and Indonesian figures above. Three further conditions would each independently undercut viability: formal-sector processing-labor costs exceeding the opportunity cost of farmers' current informal disposal; commercial financing available only above roughly 15–20 percent, beyond what the return profiles reported elsewhere here could service; or international prices for biochar, cascara, or comparable outputs sitting below Ethiopian production cost once transport is included. This paper's evidence cannot confirm or rule out any of these four conditions — precisely the gap an Ethiopia-specific feasibility study would need to close, and a more useful research agenda than a literature-based estimate.

A further gap, distinct from the economic-viability question, is that smallholder farmers, who currently burn coffee husk in open piles rather than selling it, appear in neither the literature reviewed nor the five-respondent survey. The earlier inference that farmers would plausibly sell husk if a buyer existed is a plausible interpretation of current disposal behavior, not a finding: this paper interviewed no farmer, and a first-order question for any future feasibility study is at what price, if any, farmers would prefer selling husk to burning it — a clear limitation of the evidence here, not a settled premise this argument depends on.

Three further risks temper the argument without reversing it. Not every valorization pathway is climate-neutral: a life-cycle assessment of biochar from Brazilian sugarcane residue found the electricity and processing burden of production cut its net greenhouse-gas benefit by roughly 25 percent relative to simply burning the residue for energy [44]; no coffee-husk-specific equivalent exists, so Ethiopian pilots should not assume "carbon neutral" framing without a feedstock-specific assessment. EU market access for cascara-based foods is real but not automatic, given novel-food authorization requirements [13]. And the distributional risk raised above is not resolved by this paper's evidence; it is a design problem for Phase 3, not a reason to doubt Phases 1 and 2.

Limitations

The questionnaire is the clearest limitation in this study. Five respondents, recruited by convenience rather than random or stratified sampling, cannot support representative claims about Ethiopian coffee-sector professionals, and the sample skews toward research roles over investors, officials, or smallholder farmers. Every survey claim is treated here as exploratory and hypothesis-generating; confirming it would need a larger, structured survey including cooperative leaders, exporters, and relevant officials.

The literature component has a narrower limitation: sources were identified through targeted keyword searches rather than a pre-registered protocol, so relevant non-English-language Ethiopian sources may have been missed, and financial indicators across countries are not directly comparable given differing currencies, capacities, and assumptions. This paper attempts no Ethiopia-specific techno-economic model, since no verified Ethiopian cost data of the required granularity could be located, and any such model would otherwise rest on invented, not sourced, inputs.

Conclusions

Return to the paradox this paper opened with. Ethiopia has the crop, the waste, the university research, and, by the professionals' own unanimous account, the unmet potential. It does not have the industry, or the export earnings, employment, and foreign exchange that industry would generate. Having weighed production scale, scientific capacity, and market absence and found none sufficient alone, the evidence points toward institutional barriers, a missing bridge between laboratory and marketplace capable of turning a university pilot into a financed, licensed enterprise, as an important, potentially underexamined contributor, at the point where Ethiopia consistently stalls. The relative contributions of institutional, economic, infrastructural, and market constraints, however, cannot yet be distinguished with the evidence here.

That gap has likely existed for over a decade. What makes it worth writing about now is that the conditions for closing it, a reformed investment incentive framework, a plastics restriction manufacturing exactly the demand a biodegradable-materials industry needs, and growing international investment interest in Ethiopian coffee, have converged unlike at any earlier point this paper's sources cover. Ethiopia's coffee by-products hold real economic value, but for now that value remains potential, discarded in the husk, pulp, and grounds left behind every harvest. Whether it converts into actual value, and who it reaches when it does, are now open questions rather than foreclosed ones — a meaningfully different position than Ethiopia's coffee by-product sector was in five years ago.

Conflict of interest

The author declares no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Artificial intelligence (AI) use statement

Claude (Anthropic) was used for limited language editing, restructuring, reference checking, and manuscript formatting. All final content, citations, and figures were reviewed and verified by the author, who takes full responsibility for the manuscript.

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