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Abstract

In 2024, Ethiopia became the first country in the world to ban the import of fossil-fuel vehicles. A ban is best understood as a necessity-driven energy transition: acute foreign-exchange constraints made continued petroleum dependence increasingly difficult to sustain just as electric vehicles became commercially accessible through Ethiopia's expanding trade relationship with China. This mechanism has a century-old precedent. In the 1920s, Latin American economies rapidly switched from coal to oil when an external shock disrupted coal supplies just as oil became available through a new trading relationship with the United States, with countries having less incumbent infrastructure switching fastest. We show that Ethiopia had the highest fossil-fuel import burden relative to export earnings among large African economies over 2000–2023. Counterfactual analysis suggests that the ban could prevent the fossil-fuel vehicle fleet from reaching 3.1–3.8 million vehicles by 2035, avoiding substantial oil imports, CO_2 emissions and foreign-exchange outflows. Across Africa, we identify other economies where similar structural conditions coincide with EV readiness. Ethiopia may therefore be the first visible instance of a broader pathway in which economic necessity, technological opportunity and limited incumbent lock-in accelerate energy transitions in latecomer economies.

Introduction

Energy transitions are usually framed as a response to technological opportunity, environmental policy or changing relative energy prices. In many low-income economies, however, a more immediate constraint can shape the choice of energy technology: the ability to pay for imported energy. When imported fossil fuels absorb a large share of a country's foreign-exchange earnings, an energy transition can become an instrument of macroeconomic adjustment rather than an outcome of climate policy[1]. If an alternative technology is available before the incumbent system becomes deeply embedded, the resulting transition may also occur much faster than the gradual diffusion typically associated with energy-system change.

Ethiopia provides an unusually clear contemporary illustration. In January 2024, Ethiopia became the first country in the world to ban the import of gasoline- and diesel-

powered vehicles, requiring newly imported vehicles to be electric. The decision could be portrayed, as an act of climate leadership: a developing economy apparently leapfrogging directly to electric mobility while wealthier countries continued to negotiate the timing of their own combustion-engine phase-outs. Yet the origins of the policy point to a different story. Ethiopia was experiencing an acute foreign-exchange shortage, with international reserves covering less than one month of prospective imports, while imported fuel was among the goods for which foreign exchange remained available at official rates[2]. The World Bank subsequently linked Ethiopia's dependence on imported oil and its foreign-exchange shortages directly to the government's decision to ban internal-combustion-engine vehicles[3]. Ethiopian officials have likewise described the measure explicitly as an economic strategy aimed at rationalizing foreign-currency expenditure, rather than primarily as an environmental intervention[4]. Thus, even when the policy will have clear environmental and climate benefits, and was readily incorporated into Ethiopia's broader green-development agenda, but its immediate economic rationale was to reduce dependence on imported petroleum. This distinction matters. If Ethiopia's experience is understood not as climate leadership but as an energy-transition response to a balance-of-payments constraint, it changes how we interpret the case and, crucially, how we think about which other countries might follow a similar path, and why.

Our central claim is that Ethiopia's ban is best understood as an instance of a more general phenomenon, energy transitions driven by acute macroeconomic necessity and the opportunities brought by new technologies for latecomer countries. This is not a novel mechanism in economic history. Latin American countries switched from coal to oil within less than a decade in the 1920s, thirty years ahead of and independently from any equivalent shift in wealthier, industrialized economies[5,6]. That transition was driven by an external shock, the First World War, and the switching to the United States as main trading partner which offered a new technological alternative to coal burning: the combustion engine. We argue that Ethiopia's 2024 ban follows the same underlying logic nearly a century later, with China's EV supply chain playing a role analogous to that played by the United States in the 1920s: an available, cost competitive alternative arriving through existing trade relationships at the moment external pressure made the status quo untenable.

We develop this argument in three steps. First, we measure the foreign-exchange burden of fossil-fuel dependence using an Energy Import Coverage (EIC) indicator: fossil-fuel import expenditure expressed as a share of total merchandise export earnings. Conventional measures of energy dependence capture how much energy an economy imports, but not how large a claim those imports make on its capacity to earn foreign currency. Second, we ask what the 2024 vehicle-import ban changes in practice. Using reconstructed vehicle-registration data for 2000–2023, we estimate a range of trajectories that the fossil-fuel fleet might have followed in the absence of the ban and compare them with alternative post-ban retirement paths. The resulting divergence is substantial within a single political cycle. Third, we ask whether Ethiopia represents an isolated case or an early manifestation of the broader transition mechanism made evident in the Latin America's case over a century ago. The historical episode suggests three conditions under which necessity can accelerate an energy transition. First, an external or macroeconomic shock must make continued reliance on the incumbent energy carrier increasingly difficult to sustain. Second, a technically viable substitute must already be commercially accessible. Third, the incumbent technology must not yet be deeply embedded in infrastructure, capital and consumption patterns. The combination is important. Economic pressure alone cannot produce a transition if no alternative exists; technological opportunity alone may not overcome an entrenched incumbent system. But where necessity and opportunity coincide before technological lock-in becomes strong, switching can be rapid.

Ethiopia exhibits all three conditions. Its foreign-exchange crisis created acute pressure to reduce petroleum dependence; its electricity system is overwhelmingly renewable while Chinese vehicle manufacturers were rapidly gaining access to the Ethiopian market; and its vehicle fleet remains small by international standards. We use this framework to examine where comparable conditions exist elsewhere in Africa. We distinguish structural need, measured by the foreign-exchange burden of fossil-fuel imports, from opportunity, captured by access to China's trade network and the limited scale of incumbent vehicle markets. We then compare these conditions with an existing measure of EV readiness. The resulting framework does not predict which governments will introduce an import ban: political decisions remain outside the model. Instead, it identifies economies in which the economic incentives for a necessity-driven transition resemble those present in Ethiopia.

The macroeconomic case for Ethiopia to phase out fossil-fuel vehicles

Ethiopia is Africa's second most populous country, with approximately 126.5 million people in 2023, yet its per capita gross national income of just US$1,020 places it among the continent's poorest large economies. The country has nonetheless been one of East Africa's fastest growing economies in recent years, expanding 7.1% in 2022/23 despite facing the Tigray conflict, drought, and severe foreign exchange shortages simultaneously. Its economy remains dominated by agriculture (32% of GDP) and services (40%), with a growing industrial share (28%), and persistent high inflation that, while easing from 34% to 29.2% between 2021 and 2023, continues to strain household purchasing power[7].

This economic profile sits within a specific political trajectory. Prime Minister Abiy Ahmed came to power in 2018, replacing the previous state led development model with a Prosperity Party reform agenda aimed at shifting the economy toward private sector led growth[8]. That reform path was complicated by political instability and the Tigray conflict, which strained public finances to the point that, by 2022 to 2023, the government was spending 37% of its budget on military operations and debt servicing combined. In 2023, with foreign reserves covering less than two weeks of imports, Ethiopia defaulted on a bond payment to private creditors, prompting negotiations with the IMF for financial support[9].

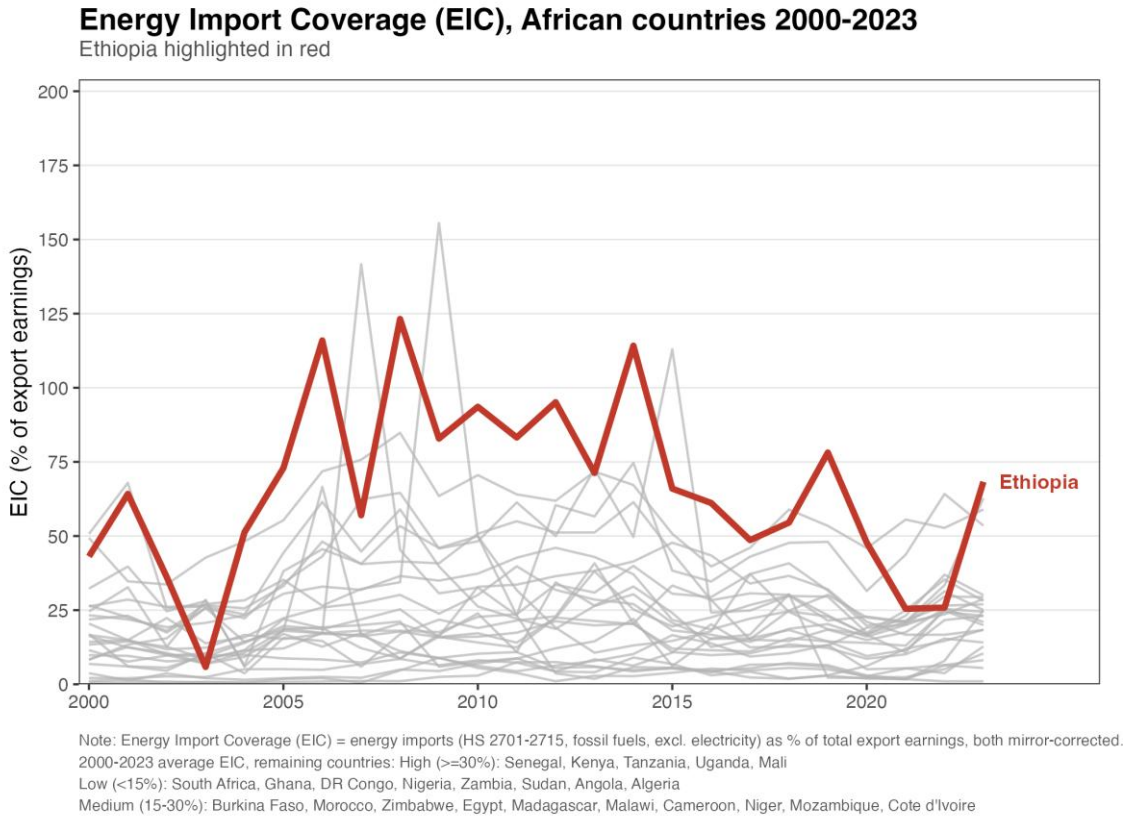
It was against this backdrop that Ethiopia's foreign exchange position deteriorated into acute crisis. Reserves peaked at US$3.99 billion in 2018, then fell to just US$1.19 billion by 2022, equivalent to 0.58 months of import cover, far below the three-month minimum generally recommended by the IMF[10]. Fossil fuel subsidies, through which the government absorbed part of the cost of rising oil prices to shield consumers, reached US$1.5 billion in 2022, a direct fiscal cost layered on top of the foreign exchange drain. By 2023, total fossil fuel import spending approached US$6 billion, more than half of it attributable to fueling the combustion engine vehicle fleet[7]. It was this convergence of macroeconomic pressures, that set the stage for the 2024 ban[11].

Standard measures of energy dependency, the physical share of energy imports within total energy consumed, do not capture this kind of stress. Two countries with identical energy dependency rates can face very different economic pressures depending on their

export capacity and foreign exchange reserves, since dependency describes a physical quantity of energy rather than what a country can actually afford to pay for it. To measure the economic burden more precisely, we introduce the Energy Import Coverage (EIC) ratio: which quantifies energy imports (fossil fuels: coal, petroleum, and gas) as a percentage of total export earnings, both drawn from BACI (CEPII)[12], a reconciled version of bilateral trade data in which each country's reported trade is cross-checked against its partners' own records. Physical energy dependence does not reveal the macroeconomic vulnerability created by that dependence; EIC measures the claim that imported energy makes on a country's capacity to earn foreign exchange.

Figure 1 plots EIC for African countries with populations of at least 15 million between 2000 and 2023. Among the 24 economies meeting this threshold (excluding small trade-hub states whose reported trade volumes are disproportionate to the size of their domestic economies) Ethiopia records the highest average EIC over the period, at 66.1% of export earnings, followed by Senegal (56.6%) and Kenya (42.7%).This framework reveals that Ethiopia, despite its modest per capita energy consumption, allocated roughly two-thirds of its export earnings to fossil fuel imports on average, a burden that fundamentally constrains its macroeconomic stability and development capacity. This pattern places Ethiopia in a distinct category of energy import stress. Countries such as Algeria and Nigeria, net oil exporters, spend a modest share of export earnings on fossil fuel imports and sit near the bottom of the panel. A middle group of import dependent but relatively diversified exporters, cluster around 30 to 50%. Ethiopia belongs to a small group of countries, for which fossil fuel imports at times exceeded total export earnings outright, a level of exposure that leaves essentially no room for absorbing price shocks without drawing down reserves or compressing other imports.

Figure 1



Fossil fuel vehicles were an increasingly important contributor to this pressure, since each vehicle entering the country represented not a one-time import cost but a claim on many future years of fuel imports over its operating life. Read against the country background set out above, the 2024 import ban targeted the single largest and most controllable source of future foreign exchange demand available to policymakers[11]. But how big is the expected impact of the ban for Ethiopia's energy imports and CO_2 emissions versus the alternative of having no ban?

A historical-growth counterfactual

To answer this question, we model the fossil fuel vehicle (FFV) fleet Ethiopia would have accumulated in the absence of the 2024 import ban, using historical registration data from 2000 to 2023 as the basis for extrapolation to 2035. Two independent specifications generate this counterfactual: one capturing accelerating, non-linear growth, and one assuming a constant proportional growth rate typical of developing economies (full model specifications are given in Methods). Both were fitted to pre-ban

data and projected forward, producing a plausible range rather than a single point estimate. The purpose is not to forecast Ethiopia's vehicle stock, but to estimate the order of magnitude of the divergence created by eliminating new fossil-fuel vehicle imports.

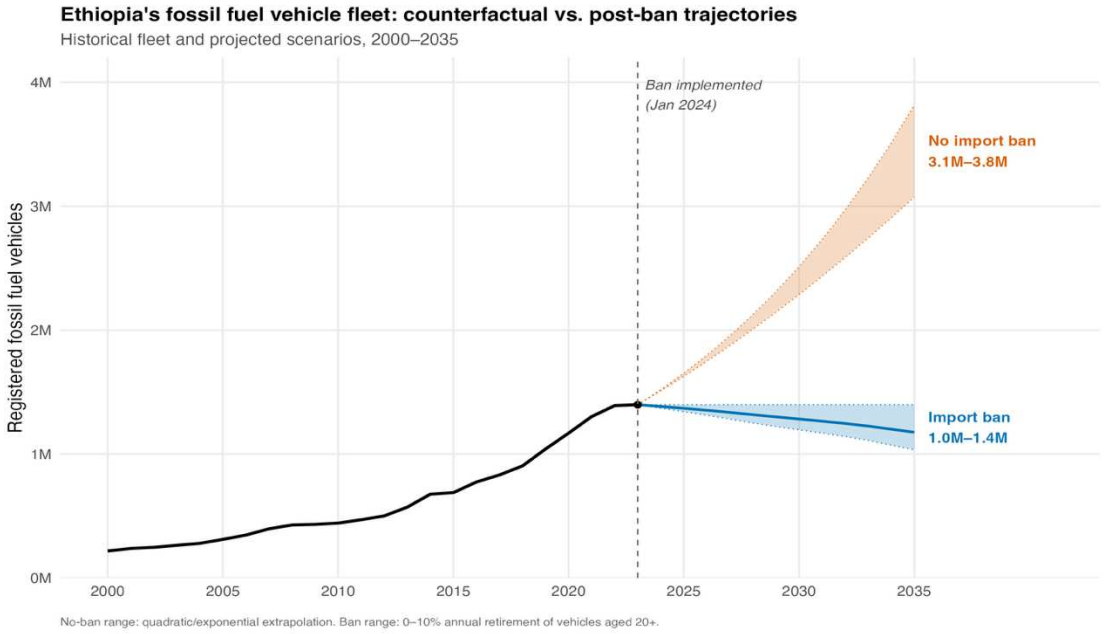
The two models converge on a striking picture. Absent the ban, Ethiopia's registered FFV fleet was on track to exceed 3.5 million vehicles by 2035, up from a baseline of just 217,561 in 2000. This trajectory did not emerge in isolation: over the past two decades, Ethiopia's oil import volume rose 518%, from an average of 106,712 terajoules to recent levels of 296,378 terajoules, tracking a 542% expansion in the vehicle fleet over the same period. The resulting supply pressure is visible in prices, with gasoline (USD per unit) up 115% since 2000. Even so, Ethiopia's motorization rate remains modest by regional and global standards: fossil fuel vehicles per 1,000 inhabitants grew from about 2 in 2000 to about 11 by 2022, still far below Libya's 490 or South Africa's 176 per 1,000[13]. The counterfactual therefore does not describe a fleet approaching saturation, but one still early in its growth curve, which is precisely what makes the projected trajectory to 2035 so consequential.

The emissions implications follow directly. Transport already accounts for approximately 24% of global energy-related CO_2 emissions[14], and Ethiopia's transport emissions grew 418% over the past two decades as motorization accelerated. Critically, over 99% of Ethiopia's electricity generation comes from renewable sources, overwhelmingly hydropower. This means the ban does not simply displace emissions from tailpipes to power plants: it lets Ethiopia decouple transport growth from carbon emissions almost entirely, rather than trading one fossil dependency for another.

Against this no-ban counterfactual, we model four post-ban scenarios applied to the vehicle stock registered through 2024, varying only in the annual retirement rate assumed for vehicles aged 20 years or older: no retirement, a low rate of 1%, a moderate rate of 5% (our base case), and a high rate of 10%. The choice to vary retirement assumptions, rather than fleet growth assumptions, reflects the ban's mechanism: it freezes the inflow of new FFVs, so the remaining uncertainty concerns how quickly the existing stock ages out.

The results are notable less for their spread than for their convergence. All four retirement scenarios plateau around 1.2 million vehicles after 2024, compared with nearly 3.5 million under the no-ban counterfactual by 2035, a roughly threefold difference (Figure 2). The relative insensitivity of the outcome to the retirement rate is itself informative: it indicates that the ban, rather than natural fleet turnover, is the dominant mechanism constraining fleet growth over this horizon. Put differently, whether Ethiopia's vehicles retire quickly or are kept running for decades matters far less to the 2035 outcome than the fact that no new fossil fuel vehicles are entering the country at all.

Figure 2. Counterfactual and forecasted scenarios



Beyond its effect on fleet size, the ban's avoided oil imports translate directly into avoided CO_2 emissions and avoided foreign exchange outflow. Table 1 compares the no-ban counterfactual against the 5% (base case) post-ban retirement scenario in specific years and the cumulative effect over the next decade. Cumulative oil imports avoided by the ban reach approximately 0.6 to 0.7 million terajoules five years after implementation (2029), and 2.0 to 2.4 million terajoules ten years after implementation (2034), depending on which no-ban growth specification is used. At standard emission factors, this corresponds to approximately 42 to 49 megatons of avoided CO_2 emissions by 2029, rising to approximately 140 to 175 megatons by 2034. Valued at a flat, conservative oil price of approximately US$9,500 per terajoule (the 2017 to 2019 average, held constant

in nominal terms), the ban avoids approximately US$5.6 to 6.5 billion in foreign exchange outflow by 2029, and approximately US$18.7 to 23.3 billion by 2034. Absent the ban, the resulting oil-import bill would therefore absorb foreign exchange well above Ethiopian current exports of US$2.9 billion (in 2023, UN Comtrade). Even under this deliberately conservative accounting, which allows a 1% annual fuel-efficiency improvement in the fossil fuel vehicles that would otherwise have been imported and holds future oil prices flat at recent levels, the ban's cumulative environmental and macroeconomic benefits are substantial and grow rapidly over the following decade.

Table 1. Estimates of avoided oil imports, CO_2 emissions, and foreign exchange outflow, ban vs. no-ban scenarios in Ethiopia

	5 years post-ban (2029)		**10 years post-ban (2034)**	
	Annual (in 2029 alone)	**Cumulative (2024–2029)**	**Annual (in 2034 alone)**	**Cumulative (2024–2034)**
Avoided oil imports (million TJ)	0.17–0.21	0.6–0.7	0.34–0.46	2.0–2.4
Avoided CO2 emissions (Mt)	12.5–14.9	42–49	24.6–33.0	140–175
Avoided forex outflow (US$ billion)	1.7–2.0	5.6–6.5	3.3–4.4	18.7–23.3

Note: Ranges reflect the quadratic and exponential no-ban specifications, computed as separate coherent trajectories (see Methods). "Annual" figures give the single year's avoided flow; "Cumulative" figures sum avoided quantities from 2024 through the indicated year. CO2 uses a blended IPCC (2006) default of 71,700 kg CO2/TJ. Forex uses a flat nominal price of approximately US$9,500/TJ (2017–2019 average).

The scale of these avoided costs raises an obvious question beyond Ethiopia's own borders: was this a one-off policy response to a country-specific crisis, or an early instance of a pattern that other foreign exchange constrained African economies are likely to follow? The remainder of this paper turns to that question, first situating Ethiopia's ban within a longer historical precedent of necessity-driven energy transitions and then developing a structural framework to identify which other African countries face comparable pressures today.

A century-old precedent and the new technological partner arriving in Africa

Early transitions in latecomers, previous evidence

The energy transition represented by Ethiopia's ban follows a pattern that predates the current concern with decarbonization by a century. An economy dependent on an imported energy carrier faces an external shock, that makes continued reliance on that carrier increasingly unaffordable. At the same moment, a substitute technology is already arriving through a trade relationship with a different supplier, one not previously central to the country's import structure. When the relative cost calculus tips decisively, the country switches, and it does so because the substitute happens to be available and cheaper.

Three conditions recur across cases that follow this pattern: an external shock large enough to make the status quo untenable, a technological substitute already present in the trading relationships available to the country when the shock hits, and a limited installed base of the incumbent technology, which lowers the political and infrastructural cost of switching. When these three conditions coincide, energy transitions can occur much faster than conventional diffusion models based on gradual technological substitution would predict.

The third condition is not incidental. It is the specific reason smaller and later-adopting economies tend to transition differently from the wealthy, industrialized economies whose experience dominates the energy transitions literature. Grübler[15,16] shows that smaller systems, with less installed infrastructure and fewer sunk investments, generally change faster than larger, more complex ones, an acceleration pattern visible in transport systems as well as in energy carriers more broadly. Marcotullio and Schulz[17] find that developing countries as a group have made energy transitions earlier, faster, and with greater diversity of pathway than wealthy economies, even though average outcomes still lag behind. The mechanism is not exotic: with less installed base to displace, the threshold external shock required to tip the cost calculus is lower, and the transition that follows can be correspondingly sharper. In Africa specifically, this general tendency combines with a distinct macroeconomic context. Vanegas Cantarero[18] argues that the imperatives driving energy transitions in African economies often differ fundamentally from those in developed economies, with foreign exchange and balance

of payments constraints playing a more central role than climate policy design. This is the setting in which Ethiopia's ban, and the broader pattern this paper investigates, should be understood, not as an instance of climate ambition catching up with wealthier economies, but as a distinct transition logic that operates on its own terms in exactly the economies least studied by the literature's dominant, wealthy country cases.

The clearest historical instance of this mechanism is the coal-to-oil switch that swept the Latin American economies over the 1920s, completing within less than a decade and well ahead of the equivalent shift in wealthier, industrialized economies[5]. The switch was not the product of energy policy or technological ambition. Coal had to be imported from Britain, and the First World War disrupted that supply and raised its cost at the same time as foreign exchange became scarce[6]. Oil, by contrast, was arriving through a rapidly strengthening trade relationship with the United States, whose companies were already exploiting nearby reserves in Venezuela and Mexico. The switch in energy carrier therefore coincided with a switch in dominant trading partner, from Britain to the United States, as Latin American economies reoriented their import structure around the new, cheaper source of energy[19]. Countries with the smallest existing coal infrastructure moved fastest, exactly as the mechanism predicts.

Ethiopia's 2024 ban on fossil fuel vehicle imports can be read as an instance of the same mechanism, a century later, and the same three conditions apply. The external shock is the foreign exchange crisis, reserves covering less than a month of imports against an IMF recommended minimum of three, a pressure severe enough to force a bond default in 2023. The new partner already arriving is China's rapidly rising share of Ethiopia's own vehicle imports, from 2.1% in 2020 to 58.1% by 2024, overtaking Japan as the country's leading vehicle supplier within the same four year window as the ban itself [12]. The limited installed base is the vehicle fleet, at roughly 11 vehicles per 1,000 inhabitants in 2022, among the lowest motorization rates on the continent[13] and far below the levels at which an entrenched constituency of vehicle owners, dealers, and fuel importers could mobilize against a ban. All three conditions that produced the Latin American switch a century earlier are present in Ethiopia today.

What is not yet established is whether Ethiopia is unusual in satisfying all three conditions simultaneously, or whether it is simply the first African economy where an already broader pattern became visible. We turn to that question next.

Is a new trade partner already arriving in Africa?

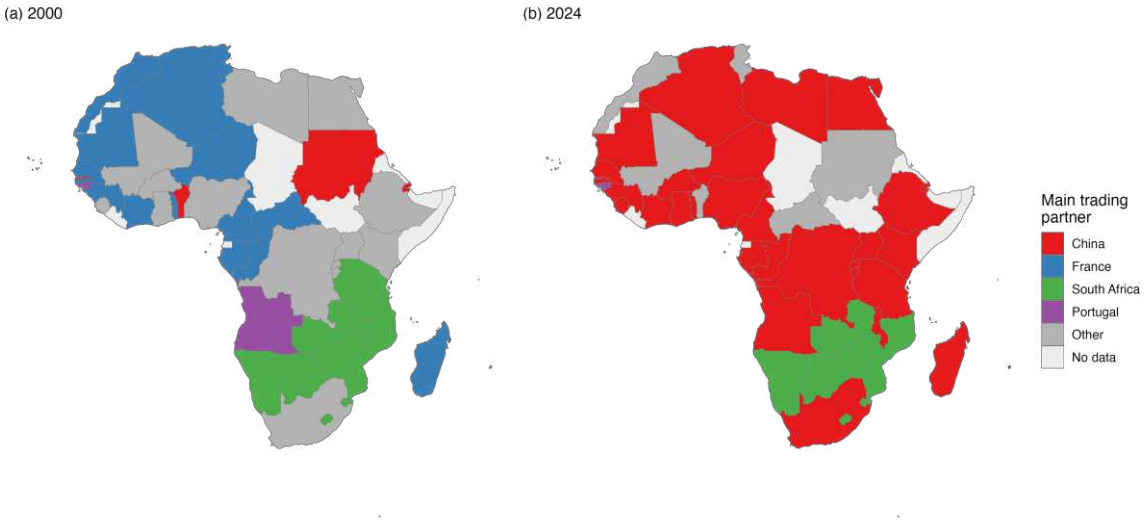
The historical mechanism outlined above depends on a specific empirical condition beyond the external shock itself: a substitute technology arriving through a strengthening trade relationship with a supplier not previously central to the country's import structure. For Ethiopia's ban to be read as an instance of a general, recurring pattern rather than an isolated policy choice, this condition should be visible across the African continent more broadly, not only in the country that acted on it.

We test this using bilateral trade data from the BACI database[12], which reconciles reported trade flows across partner countries and offers substantially fuller coverage than relying on any single country's own trade reporting. For each of 47 African countries, we identify the leading source of total merchandise imports in 2000, 2010, 2020, and 2024. The pattern is unambiguous. In 2000, China was the leading import partner for only 4 of the 47 countries, while France alone led in 14, reflecting colonial-era trade relationships that had persisted for decades. By 2020, China had become the leading partner for 28 of the 47 countries, and by 2024 for 30, close to two thirds of the sample. The median share of a country's total imports sourced from China rose from 3.0% in 2000 to 18.3% in 2024, a rise that is continuous across each of the four snapshots rather than concentrated in a single interval (Figure 3). This confirms that the second condition outlined above, the arrival of a new dominant trading partner, is already a broad, continent-wide phenomenon, not a circumstance unique to Ethiopia.

The pattern is not uniform across the continent, but the exception is regional rather than national. South Africa's immediate neighbors, Botswana, Lesotho, Eswatini, Namibia, Mozambique, Zambia, and Zimbabwe, still source the largest share of their imports from South Africa itself rather than China, in some cases (Lesotho, Eswatini) at shares above 75%, reflecting the region's long-standing integration around a regional hub through the Southern African Customs Union and associated trade arrangements. South Africa itself is not an exception to the continental pattern: its own leading import partner became China in 2010 and has remained so since, in line with the timing of the broader shift documented above. What is distinctive is South Africa's dual position, a regional supplier that its neighbors still depend on, while its own trade has already reoriented toward China at the national level. The continental shift toward China is therefore not absent in southern Africa so much as mediated through a regional hub that

has itself already made the switch, a pattern worth watching rather than treating as a stable exception: Namibia's dependence on South Africa has fallen steadily across all four snapshots (82.0% in 2000 to 37.1% in 2024), the weakest hold of the seven, and could plausibly flip to China in the near future.

Figure 3: Main trading partner of African countries, 2000 vs 2024



Sources and notes: own elaboration with bilateral trade values from BACI, CEPII, HS92 revision, version 202601.

Total merchandise trade, however, is not the commodity this paper is about. Repeating the same exercise restricted to motor vehicles (HS 8703) tells a markedly narrower story. Japan remained the leading vehicle supplier for most African countries throughout the period, and as of 2024, only three countries, Djibouti, Egypt, and Ethiopia, source a plurality of their vehicle imports from China. The median vehicle import share sourced from China across all 47 countries was negligible through 2020 (1.0% or below) and reached only 4.7% by 2024.

The divergence between these two results is itself informative. China's rise has already transformed Africa's general import structure, but the EV-specific supply chain remains geographically and commercially thin. Ethiopia is unusual because the two transitions, macroeconomic dependence on imported energy and access to Chinese EV supply, coincided. We turn next to what this implies for reading Ethiopia's ban as a leading indicator rather than an outlier.

Which countries might follow? Need and Opportunity vs Readiness framework

The historical parallelism with the early switch in Latin America elevates the Ethiopian case from a policy anecdote to an instance of a recurring structural mechanism: "necessity-driven transitions" among import-constrained economies when an alternative technological partner arrives. The implication is that similar transitions may be approaching elsewhere in Africa today, not because governments have adopted climate ambitions, but because macroeconomic arithmetic is forcing the same calculus. Crucially, this is not a prediction of political outcomes: political will is the one variable our framework cannot capture, as Ethiopia itself demonstrated when it acted with no prior international signaling. Rather, we identify countries where the structural preconditions are present and where, therefore, a similar policy would be economically rational.

We separate the underlying logic into two conceptually distinct components: a *Need* indicator capturing the macroeconomic pressure to act, an *Opportunity* indicator capturing the structural conditions that make a transition feasible once that pressure exists. We map the structural need and opportunity against the already existing EV Readiness indicator by Mutiso et al.[20] which captures a country's existing capacity to support electric vehicle adoption. It averages ten indicators grouped in five dimensions: enabling policies (national EV targets and EV incentives); grid infrastructure (the additional generation needed for a 30% EV share and grid reliability); market conditions (current motorization rate and public charging infrastructure); power sector maturity (the electricity regulatory index and utility cost recovery); and EV affordability (the cost of charging relative to gasoline and access to formal finance). We use the average score including enabling policies and leave aside the index's separate Impact component.

Need is measured directly by the Energy Import Coverage ratio introduced above, averaged over 2020–2023 using the same BACI-derived series used throughout this paper. We use a single indicator here, rather than a composite, because EIC already captures the specific mechanism this paper argues drove Ethiopia's decision: the foreign exchange burden of energy imports relative to what a country earns from trade.

Opportunity combines two indicators, each expressed as a percentile rank within the sample and averaged: the share of a country's total merchandise imports sourced from

China, proxying the supply-side availability of affordable electric vehicles, and the value of a country's vehicle imports per capita, inverted, proxying vehicle-market lock-in, the extent to which an existing fossil-fuel vehicle sector might resist disruption. We use per-capita rather than total vehicle import value because total import value is confounded by country size rather than reflecting lock-in specifically. Both are averaged over the same 2020–2023 window as Need. The 2020–2023 window excludes 2024 for two reasons. First, Ethiopia's ban took effect in January 2024, and its post-ban vehicle import composition understandably shifts toward China as the dominant EV supplier; including 2024 would measure the consequence of Ethiopia's policy rather than the precondition that made it feasible, undermining the comparison the framework is designed to support.

We restrict the main analysis to 41 of the 47 African economies in our BACI-derived sample, excluding six micro-states and entrepôt economies (Cabo Verde, Djibouti, Mauritius, São Tomé and Príncipe, Eswatini, and Seychelles), all with a 2020 population below approximately 1.75 million (World Bank, SP.POP.TOTL). These economies combine very small absolute trade volumes with, in several cases, a disproportionate transshipment role that inflates trade-based ratios in ways unrelated to the mechanism under study.

Then, we weight Need more heavily than Opportunity in the combined index (0.7 and 0.3 respectively), since Need is the motivating force in this mechanism: a country cannot undergo a necessity-driven transition without the macroeconomic pressure that makes fossil fuel dependence unsustainable, whereas Opportunity determines whether that pressure translates into feasible policy action. Therefore, Need and Opportunity are combined into a single index:

$$Combined = 0.7 \times Need\ (percentile) + 0.3 \times Opportunity\ (percentile),$$

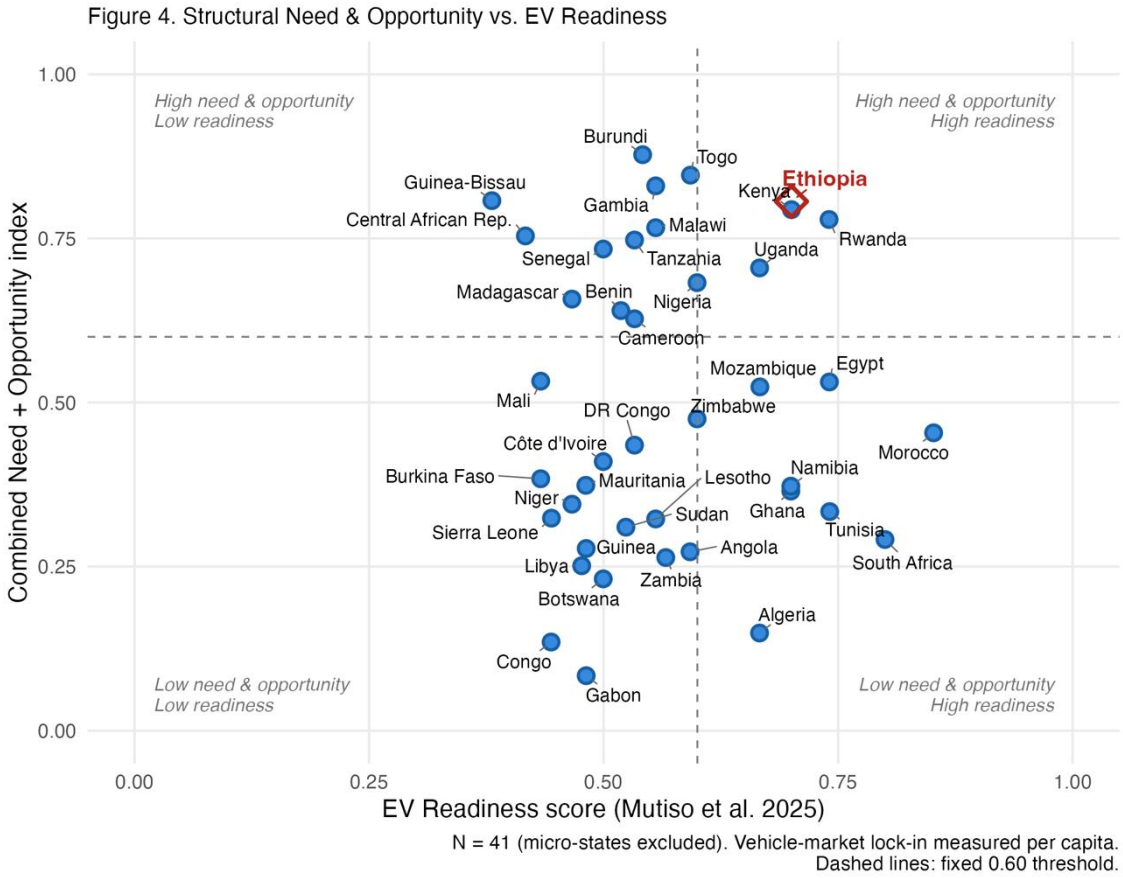
both expressed as percentile ranks within the 41-country sample. Plotting this combined index against each country's EV Readiness score[19] yields four quadrants. The vertical threshold, 0.60, corresponds to Mutiso et al.'s own tier boundary and is not derived from our sample; we use the same fixed value, 0.60, for the horizontal threshold, so that quadrant boundaries are identical whichever version of the sample is examined. A sensitivity analysis varying this weight from 0.5 to 0.9 leaves the identity of the highest-scoring countries essentially unchanged. The results are also robust to alternative

specifications of the index, including additional variables, and alternative scoring methods (see Methods).

Results

Figure 4 plots the combined Need and Opportunity index against EV Readiness for the 41-country main sample. Four countries occupy the upper-right quadrant, combining high structural need and opportunity with high EV readiness: Ethiopia, Rwanda, Kenya, and Uganda. In fact, quadrant I (high need and opportunity plus high EV readiness) is the most policy-relevant zone identified by the framework.

Figure 4



Sources and notes: Own elaboration with data on Table 2 and the methodology in the Methods section

Ethiopia's position here is a basic validation of the framework's construct: the country that implemented the ban scores among the highest in the sample on both dimensions, despite Need and Opportunity being derived entirely independently of the ban itself. More striking is Kenya's presence beside it. Kenya's combined index (0.79) is close to

Ethiopia's (0.81), and its EV Readiness score is identical (0.70), yet Kenya has taken no comparable policy action. This is not a weakness in the framework so much as a direct illustration of its central limitation: the framework identifies where the economic logic for a necessity-driven transition is compelling, not where a government has chosen to act on it. We insist that political will remains the one variable this framework cannot capture, and Kenya's position alongside Ethiopia demonstrates precisely why that caveat matters. A second cluster occupies the upper-left quadrant (II), high need and opportunity but readiness below threshold: Gambia, Burundi, Togo, Guinea-Bissau, Central African Republic, Senegal, Malawi, Tanzania, Benin, Madagascar, Nigeria, and Cameroon. These are economies where the macroeconomic case for a necessity-driven transition is arguably as strong as Ethiopia's, in several cases stronger (Togo's EIC of 109% and Burundi's 99% both exceed Ethiopia's 42% over the same window), but where charging infrastructure, grid reliability, or utility solvency have not developed to a comparable degree. Burundi is the clearest example: its combined index (0.88) is the highest in the sample, driven by its very high EIC combined with a moderate opportunity score; Togo (0.85) and Gambia (0.83) follow closely. Gambia's ranking is instructive here: under a total-import construction of vehicle-market lock-in it scores highest of all 41 countries (0.92), but falls to third under the per-capita construction we report, because Gambia's small population inflates its per-capita vehicle-import value and correspondingly narrows its apparent lock-in advantage; its Readiness score (0.56) sits below the threshold under either construction. Nigeria sits closest to the readiness boundary of any country in the sample (0.5997, effectively indistinguishable from the 0.60 cutoff), so its placement in this quadrant rather than the highest one should be read as marginal rather than decisive. Quadrant III is occupied by countries that have low readiness, but also show low need and opportunity, so is the more unlikely group were EVs will happen in the short run. Finally some of the countries with the largest level of EV readiness (South Africa, Morrocco) appear with low need and opportunity in quadrant IV.

Table 2 reports the underlying data for all 41 countries: the raw EIC ratio (Need), the two Opportunity sub-components, the combined Need and Opportunity index, EV Readiness, and quadrant. We report the raw sub-components rather than only the combined index because two countries can arrive at a similar combined score through different mechanisms. Robustness checks include the full 47-country sample including

micro-states, a min-max normalized version of Need, a parallel construction of vehicle-market lock-in using total rather than per-capita vehicle import value (Spearman's ρ = 0.976 across the 41-country sample; 0.965 across the 47-country sample), and the 0.5–0.9 weight sensitivity. Across all variants, Ethiopia, Rwanda, Kenya, and Uganda remain the only countries in the highest-need, highest-readiness quadrant (II).

Table 2. Need, Opportunity, and EV Readiness for 41 African countries

Country	EIC avg % (Need)	China import share %	Veh. import vol. per capita (US$)	Opportunity index	Combined N&O index	EV Readiness	Quad
Burundi	98.7	15.7	3.3	0.65	0.88	0.54	II
Togo	109.2	20.1	17.2	0.49	0.85	0.59	II
Gambia	84.7	24.4	20.3	0.55	0.83	0.56	II
Guinea-Bissau	51.1	15.2	2.8	0.65	0.81	0.38	II
Ethiopia*	41.8	25.5	5.5	0.76	0.81	0.70	I
Kenya	48.2	21.3	8.6	0.66	0.79	0.70	I
Rwanda	29.3	19.3	3.1	0.79	0.78	0.74	I
Malawi	35.0	16.7	3.5	0.69	0.77	0.56	II
C. African Rep.	51.6	11.6	5.1	0.41	0.75	0.42	II
Tanzania	26.4	25.4	4.8	0.80	0.75	0.53	II
Senegal	53.3	13.4	16.6	0.29	0.73	0.50	II
Uganda	26.7	17.8	5.1	0.60	0.70	0.67	I
Nigeria†	24.6	29.1	10.3	0.70	0.68	0.60	II
Madagascar	20.9	20.7	2.3	0.85	0.66	0.47	II
Benin	24.7	19.0	12.3	0.50	0.64	0.52	II
Cameroon	23.9	18.7	6.5	0.57	0.63	0.53	II
Mali	19.3	14.5	4.7	0.55	0.53	0.43	III
Egypt	23.7	16.0	25.7	0.31	0.53	0.74	IV
Mozambique	19.8	10.5	3.9	0.46	0.52	0.67	IV
Zimbabwe	18.2	12.3	4.7	0.47	0.47	0.60	III
Morocco	23.6	11.1	56.6	0.11	0.45	0.85	IV
DR Congo	9.1	24.9	1.5	0.93	0.44	0.53	III
Côte d'Ivoire	17.9	15.6	14.4	0.38	0.41	0.50	III
Burkina Faso	16.5	12.4	5.0	0.46	0.38	0.43	III
Mauritania	17.7	16.3	30.3	0.31	0.37	0.48	III
Namibia	18.7	7.0	47.3	0.07	0.37	0.70	IV
Ghana	12.8	27.4	22.5	0.58	0.37	0.70	IV
Niger	5.1	20.9	3.8	0.80	0.35	0.47	III
Tunisia	18.0	10.4	61.2	0.06	0.33	0.74	IV
Sierra Leone	4.5	31.3	6.3	0.79	0.32	0.44	III
Lesotho	17.4	8.1	16.0	0.20	0.32	0.56	III
Sudan	3.9	22.7	4.6	0.80	0.31	0.52	III
South Africa	12.1	20.6	58.3	0.39	0.29	0.80	IV
Guinea	3.6	38.7	9.7	0.75	0.28	0.48	III
Angola	5.7	17.2	9.8	0.50	0.27	0.59	III
Zambia	6.8	14.3	9.3	0.41	0.26	0.57	III
Libya	13.1	14.0	89.0	0.14	0.25	0.48	III
Botswana	15.1	2.9	66.9	0.01	0.23	0.50	III
Algeria	1.7	19.1	21.1	0.44	0.15	0.67	IV
Congo	1.4	16.4	12.1	0.45	0.14	0.44	III
Gabon	2.1	11.8	36.8	0.16	0.08	0.48	III

Quadrants (matching Figure 4): I = High N&O, High readiness (upper-right); II = High N&O, Low readiness (upper-left); III = Low N&O, Low readiness (lower-left); IV = Low N&O, High readiness (lower-right).

Notes: EIC = Energy Import Coverage (energy imports as % of total export earnings), averaged 2020–2023, BACI-derived. China import share = average share of total merchandise imports sourced from China, 2020–2023. Veh. import vol. per capita = average annual total vehicle import value (HS 8703, all partners), 2020–2023, divided by 2020 population (World Bank SP.POP.TOTL). Opportunity index = average of percentile ranks on China import share and inverted per-capita vehicle import value (vehicle-market lock-in). Combined N&O index = 0.7 × Need percentile + 0.3 × Opportunity index. EV Readiness = Mutiso et al. (2025), average score including enabling policies.

*Ethiopia implemented the ban in January 2024. †Nigeria's Readiness score (0.5997) is effectively indistinguishable from the 0.60 cutoff; its placement in Quadrant II rather than Quadrant I should be read as marginal rather than decisive.

Discussion

Ethiopia's 2024 ban is best understood as a necessity-driven energy transition. The country faced an exceptionally high foreign-exchange burden from imported fossil fuels. At the same time, a commercially viable alternative, that is electric vehicles supplied increasingly through China's expanding trade relationship with Ethiopia, became available. The ban therefore did not require climate policy to make the switch economically attractive: the macroeconomic cost of continuing to import petroleum had already created the pressure to act, while technological change had made switching feasible. Our Energy Import Coverage (EIC) measure identifies Ethiopia as unusually exposed among Africa's larger economies, while the historical comparison with Latin America's rapid coal-to-oil transition shows that this combination of external pressure and technological opportunity can produce unusually rapid energy-system change.

The Ethiopian case is therefore more than a policy anecdote. The continental evidence suggests that one element of the mechanism, the emergence of China as a major trading partner, is already widespread across Africa. What remains much less widespread is access to the specific technology involved here: in 2024, Ethiopia was one of only three African countries for which China was the leading source of motor-vehicle imports. Ethiopia's distinctiveness lies precisely in the coincidence of these two developments: a severe need to reduce imported fossil-fuel expenditure and access to an alternative vehicle technology before the incumbent fleet had become deeply entrenched. This sets Ethiopia apart from the prevailing global pattern of combustion-engine phase-outs, which are typically policy-led, negotiated, and gradual: the European Union's 2035 target for new combustion-engine sales remains under negotiation years after being announced, and as of the mid-2020s no country had passed comparable binding legislation[21].

The historical comparison suggests that the relevant unit of analysis is not technological diffusion alone, but the interaction between necessity and technological opportunity. In

Latin America, the First World War disrupted access to imported coal just as oil became increasingly accessible through the region's strengthening economic relationship with the United States. Countries with less coal infrastructure switched fastest. Latin America's coal-to-oil switch was not merely early relative to wealthy economies, it was fast in absolute terms: every country in the region still relied on coal as its primary energy carrier in 1919, and none did by 1929. Ethiopia presents the same configuration in a different technological and geopolitical setting: foreign-exchange scarcity raises the cost of continued petroleum dependence, while Chinese EVs provide an accessible substitute before motorization has created a deeply entrenched fossil-fuel vehicle system. The historical evidence therefore provides a mechanism for interpreting the Ethiopian case rather than a claim that the two transitions were identical.

The speed implied by the Ethiopian counterfactual is consistent with this mechanism. In the absence of the ban, the fossil-fuel vehicle fleet could reach approximately 3.1–3.8 million vehicles by 2035, compared with approximately 1.0–1.4 million under the post-ban retirement scenarios. The resulting divergence implies substantial avoided oil imports, CO_2 emissions and foreign-exchange outflows within five and ten years. These estimates should not be interpreted as a forecast of Ethiopia's vehicle stock: they quantify the potential difference between continued pre-ban growth and a policy that eliminates new fossil-fuel vehicle imports. Their significance is that the effects of the ban become material within a decade, rather than only over a distant decarbonization horizon.

The cross-country analysis supports the possibility of a broader pathway, while also showing why Ethiopia should not simply be expected to be replicated. Four countries, Ethiopia, Kenya, Rwanda and Uganda, combine relatively high Need and Opportunity with high EV Readiness. Ethiopia is therefore not alone in possessing the structural conditions identified by the framework. Kenya is particularly revealing: its Need and Opportunity index and EV Readiness score are almost identical to Ethiopia's, yet it has introduced no comparable policy. The framework can therefore identify where the economic conditions for a necessity-driven transition are strong, but not whether governments will act on them or when they will do so. Policy remains exogenous to the model.

The broader implication is that decarbonization need not always begin with decarbonization policy. In economies constrained by foreign-exchange availability, reducing fossil-fuel dependence can become an economic objective in its own right, with decarbonization following as a consequence when low-carbon substitutes are available. This creates a pathway that is largely absent from transition narratives centred on climate policy, carbon prices and technological diffusion in wealthy economies. For latecomer economies, the combination of economic necessity, technological opportunity and limited incumbent lock-in may therefore be as important to understanding the timing of energy transitions as environmental policy or relative energy prices.

Several limitations bear on how these results should be read. The flat oil-price assumption in the counterfactual, while deliberately conservative, means the avoided foreign exchange outflows we report are a floor rather than a central estimate. Uncertainty remains around both future fleet growth and vehicle retirement. The Need and Opportunity framework identifies structural conditions rather than political outcomes, and its weighting and sample definition are necessarily choices rather than uniquely determined parameters. The robustness checks nevertheless leave the main cross-country pattern unchanged.

Conclusion

Ethiopia's 2024 ban reveals a pathway to energy transition that is driven not by climate policy, but by economic necessity. The country's exceptionally high dependence on imported fossil fuels relative to its export earnings created a strong incentive to reduce future petroleum expenditure. At the same time, electric vehicles had become commercially accessible through Ethiopia's rapidly expanding trade relationship with China, while the country's still-small vehicle fleet limited the infrastructural and economic lock-in associated with the incumbent technology. The ban therefore brought together the three conditions that can make a transition unusually rapid: necessity, technological opportunity and limited incumbent lock-in.

The consequences could be large within a remarkably short period. Relative to a continuation of pre-ban fleet growth, our counterfactuals imply a roughly threefold difference in the fossil-fuel vehicle fleet by 2035, together with substantial avoided oil imports, CO_2 emissions and foreign-exchange outflows. The significance of the ban is therefore not only that it changes the technology of vehicles entering Ethiopia today, but

that it prevents a rapidly growing fossil-fuel fleet from becoming tomorrow's source of fuel dependence.

Ethiopia may also be the first visible instance of a broader pathway. The historical parallel with Latin America's rapid coal-to-oil transition shows that latecomer economies can switch energy carriers rapidly when an external shock makes the incumbent technology difficult to sustain just as a viable substitute becomes available. Across Africa, China's emergence as a major trading partner has already created part of this enabling environment, although Chinese dominance in vehicle imports remains much less widespread. Our Need and Opportunity framework identifies Rwanda, Kenya and Uganda alongside Ethiopia as economies with relatively strong structural conditions for such a transition. Yet Kenya's near-identical position to Ethiopia also shows the limit of the framework: economic conditions can make a transition rational without making it politically inevitable.

The broader lesson is that decarbonization can sometimes emerge from the arithmetic of economic survival. For foreign-exchange-constrained economies, reducing fossil-fuel dependence may become desirable before climate policy becomes decisive, and the arrival of a viable alternative can turn that economic pressure into a rapid technological transition. Ethiopia should therefore not be viewed simply as an exceptional climate-policy pioneer. It may instead represent the first clearly visible case of a necessity-driven pathway to decarbonization, one that deserves greater attention as energy-transition research turns beyond the experience of wealthy economies.

Methods

This section discusses the data and methods of the main contributions of the paper in the order they are presented above, namely: the Energy Import Coverage Index (EIC) for African countries; the reconstruction of the Ethiopian fossil fuel vehicle fleet and the counterfactual effects in vehicle fleet, CO_2, emissions, oil imports and foreign exchange savings; and the construction of the need and opportunity framework for switching to EV in Africa, starting with the bilateral trade with China and the reminder of the elements of the framework.

Construction of the Energy Import Coverage indicator (Figure 1)

EIC is calculated as:

$EIC_{it} = (energy\ imports_{it} / total\ merchandise\ exports_{it}^{*}) \times 100$

where total merchandise exports is each country's total export value to World across all commodities in the same year.

The data comes from BACI HS92 (CEPII, version V202601), a reconciled bilateral trade dataset that adjusts each country's self-reported trade against its partners' corresponding records. This matters for Ethiopia specifically: cross-checking Ethiopia's 2020 self-reported COMTRADE imports against BACI's reconciled figure shows the former understating true import value by a factor of roughly 3.5, and a parallel comparison on the export side across 2000-2020 shows Ethiopia's self-reported exports understated by a factor ranging from roughly 1.0 to 1.9 depending on the year (mean 1.4), with no consistent time trend, consistent with reporting gaps rather than a fixed measurement convention. The energy-import numerator (HS headings 2701-2715: coal, coke, petroleum, and gas, excluding HS 2716 electrical energy) is essentially unaffected by this correction (mean ratio of BACI to self-reported COMTRADE values across 2000-2020: 1.08), indicating that the divergence between this paper's BACI-based EIC and earlier COMTRADE-based figures is attributable to the export-earnings denominator, not to a difference in how energy imports are defined or classified.

Figure 1 restricts the displayed sample to the 24 African economies with a 2020 population of 15 million or more (World Bank, SP.POP.TOTL), a threshold chosen to separate diversified national economies from small transshipment-hub states (e.g. Djibouti, Cabo Verde) whose trade statistics can be disproportionate to their domestic economic scale.

Reconstructing the Ethiopian fossil fuel vehicle fleet, 2000 to 2023

Ethiopia’s officially reported vehicle registration series contains an implausible discontinuity consistent with a change in registration or reporting practice rather than a genuine change in the underlying vehicle stock: reported registrations rise from approximately 155,000 in 2015 to 831,265 in 2017, a more than fivefold increase over

two years, with no corresponding change in oil import volumes over the same period, according to the annual vehicle registration counts (OICA and Ethiopia's Ministry of Transport and Logistics, MOTL). We therefore treat the official series as understated in the years preceding this reporting break, and reconstruct it using the historical relationship between the vehicle stock and oil import volume (data extracted from the International Energy Agency), under the assumption that fleet-average fuel consumption per vehicle did not change materially over the estimation period.

We calibrate this relationship, r, as the mean ratio of oil import volume to registered vehicles in the two years following the reporting break for which both series are considered reliable and available (2017 and 2019):

$$r = (1/n) \Sigma_{t \in \{2017, 2019\}} \; OilImportsVol_t / RegFFV_t$$

This yields $r \approx 0.212$ terajoules per vehicle (0.213 in 2017 and 0.212 in 2019, a difference of under 0.5% across two years eight years apart), consistent with a stable fleet-average fuel consumption rate over this period.

For years in which the official series is considered unreliable (2000 to 2016 and 2018), the fleet is reconstructed as:

$$RegFFV_t^{recon} = OilImportsVol_t / r$$

For years in which the official series is considered reliable (2017 and 2019 to 2023), the official figure is retained without adjustment. The resulting combined series yields a reconstructed baseline of approximately 217,300 vehicles in 2000, consistent with the figure reported elsewhere in the text, and a final pre-ban observation of 1,398,009 vehicles in 2023.

Counterfactual (no-ban) forecasting models

We estimate two ordinary least squares (OLS) models on the reconstructed 2000 to 2023 series to characterize the plausible range of fleet growth in the absence of the 2024 import ban. The first is a quadratic specification capturing accelerating, non-linear growth:

$$RegFFV_t = \beta_0 + \beta_1 Year_t + \beta_2 Year^2_t + \varepsilon_t$$

The second is a log-linear (exponential) specification capturing constant proportional growth:

$$ln(RegFFV_t) = \alpha_0 + \alpha_1 Year_t + \mu_t$$

Both models are fit on the full reconstructed 2000 to 2023 series and extrapolated to 2035. Because each model's own fitted value for the final year of the estimation sample (2023) differs from the actual reconstructed or official figure for that year, as is standard for a regression residual, extrapolating the raw fitted trajectory from 2024 onward would introduce a discontinuity between the historical series and the forecast that does not correspond to any real change in the fleet. We therefore rebase both models to pass exactly through the last actual observation (2023: 1,398,009 vehicles, an official figure requiring no reconstruction), while preserving each model's own estimated growth dynamics:

$$RegFFV_t^{poly,adj} = RegFFV_t^{poly} + (RegFFV_{2023} - RegFFV_{2023}^{poly})$$

$$RegFFV_t^{exp,adj} = RegFFV_t^{exp} \times (RegFFV_{2023} / RegFFV_{2023}^{exp})$$

The no-ban counterfactual range reported in Figure 2 is the pointwise minimum and maximum of the two rebased forecasts in each year. The two specifications cross during the projection window (the quadratic specification lies above the exponential specification through approximately 2025, and below it from 2026 onward); the range is therefore reported without labeling either specification as a fixed upper or lower bound. Under this approach, the fleet is projected to reach approximately 3.1 to 3.8 million vehicles by 2035 in the absence of the ban, compared with a reconstructed baseline of 217,300 vehicles in 2000 and 1,398,009 vehicles at the time of the ban.

Post-ban retirement scenarios

Following the January 2024 ban, no new fossil fuel vehicles can legally enter the registered fleet, so the post-ban fossil fuel vehicle stock can only decline through retirement of the existing fleet. Vehicle age is not directly observed in the available data, so we model this decline using a vintage-cohort structure constructed from the reconstructed 2000 to 2023 series. Each year's increase in the reconstructed stock is treated as a distinct cohort of vehicles first registered in that year, with the 2000 baseline stock treated as a single bulk cohort of unknown internal vintage:

$$cohort_v = RegFFV_v^{final} - RegFFV_{v-1}^{final} \text{ for } v > 2000; \; cohort_{2000} = RegFFV_{2000}^{final}$$

A cohort becomes subject to retirement once it reaches an age of 20 years. From that point forward, the scenario's annual retirement rate ρ is applied to the cohort's remaining stock each subsequent year, compounding:

$$remaining_{v,Y} = remaining_{v,Y-1} \times (1 - \rho), \text{ if } Y - v \geq 20; \; remaining_{v,Y} = remaining_{v,Y-1}, \text{ otherwise}$$

with remaining stock initialized at the 2023 cohort sizes and total fleet stock in year Y given by the sum of remaining stock across all vintages. We evaluate four values of ρ, reflecting a plausible range of retirement intensity: 0% (no retirement), 1% (low), 5% (moderate, treated as the base case), and 10% (high), consistent with Ethiopia's strong vehicle maintenance and repair culture and correspondingly extended service lives. Because cohorts registered in 2004 or earlier are already at or beyond the 20-year threshold by 2024, a substantial share of the pre-ban fleet becomes eligible for retirement from the first post-ban year; younger cohorts age into the threshold progressively across the 2024 to 2035 window.

Under this construction, the four scenarios yield a fleet of approximately 1.0 to 1.4 million vehicles by 2035 (1.18 million under the 5% base case), compared with the 3.1 to 3.8 million vehicles projected in the absence of the ban. This spread is wider than a description of the scenarios as insensitive to the retirement rate would suggest; the four trajectories are better understood as a plausible band bounded by no attrition of the aging fleet (0%) and comparatively rapid attrition (10%), rather than as closely clustered estimates of a single quantity. The vintage-cohort structure is a modeling construction required by the absence of directly observed fleet age data in Ethiopia, and is reported here as such rather than as an observed feature of the vehicle fleet.

Avoided oil imports, CO2 emissions, and foreign exchange outflow

To quantify the ban's broader impact, we estimate avoided petroleum imports, avoided CO2 emissions, and avoided foreign exchange outflow by comparing the no-ban counterfactual (quadratic and exponential specifications) against the 5% (base case) post-ban retirement scenario described above.

We assume the existing (pre-ban) fleet, present in both scenarios, continues to consume oil at the stable historical intensity r (approximately 0.212 terajoules per vehicle per year) calibrated in the fleet reconstruction above, with no change in per-vehicle fuel consumption for vehicles already on the road. In the no-ban counterfactual, each year's new vehicle cohort, defined as the year-over-year increase in the no-ban forecast, is assumed to be 1% more fuel-efficient than the previous year's cohort, compounding annually from 2024 onward, and each cohort's intensity is fixed at the point of

introduction rather than improving further over its service life. This 1% assumption is deliberately conservative relative to global benchmarks: the International Energy Agency and the Global Fuel Economy Initiative report that new light-duty vehicle fuel economy improved by an average of 1.7% per year globally between 2005 and 2017, with the improvement rate in emerging economies accelerating to 2.3% per year over the same period (IEA and ICCT for the Global Fuel Economy Initiative, 2019). In the ban scenario, no new fossil fuel vehicles are added after 2023, so consumption tracks the surviving (retiring) fleet at the constant historical intensity r.

Total annual oil consumption under the no-ban counterfactual in year Y is:

$$Consumption^{Ynoban} = RegFFV_{2023} \times r + \Sigma_{v=2024}^{Y}\ cohort_v \times r(1 - 0.01)^{v-2023}$$

where $cohort_v$ is the increase in the no-ban forecast between year v−1 and year v. This calculation is performed separately for the quadratic and exponential specifications, since, as noted above, the two forecasts cross during the projection window and their pointwise envelope is not itself a coherent single trajectory. Total annual oil consumption under the ban scenario (5% base case) in year Y is the surviving fleet stock from the retirement simulation, multiplied by r. Avoided oil imports in a given year are the difference between the two, cumulated from 2024 through the milestone year of interest.

Avoided CO_2 emissions are obtained by applying a blended emission factor of 71,700 kg CO2 per terajoule, the average of the IPCC (2006) default factors for motor gasoline (69,300 kg CO2 per terajoule) and gas/diesel oil (74,100 kg CO2 per terajoule), in the absence of a fuel-type breakdown in the underlying trade data.

Avoided foreign exchange outflow is obtained by valuing avoided oil imports at a flat nominal price of approximately US$9,500 per terajoule, the average of the implied unit price of Ethiopia's oil imports (import value divided by import volume) in the three most recent years for which both series are available (2017 to 2019). This price is held constant in nominal terms through 2035. We do not attempt to model a future oil price path: long-dated oil futures beyond two to three years are illiquid and are widely understood to reflect storage and financing costs rather than genuine price expectations, and are therefore not a meaningful basis for extrapolation over a decade-long horizon. Since oil prices have historically trended upward in nominal terms over multi-decade horizons, holding the price flat is, if anything, a conservative choice that understates the true foreign exchange savings.

The 0%, 1%, and 10% retirement scenarios yield qualitatively similar, and in the case of the 10% scenario somewhat larger, avoided quantities; we report the 5% base case for consistency with the fleet projections presented above.

Bilateral trade data and main trading partner classification

Bilateral trade values were drawn from BACI, a database maintained by CEPII that reconciles bilateral trade flows reported to UN Comtrade with the corresponding mirror flows reported by partner countries, substantially improving country coverage relative to relying on a single country's own trade reporting (Gaulier & Zignago, 2010). We used the HS92 product revision, version 202601, the only revision spanning the full period of interest in a single consistent classification. Four snapshot years were extracted, 2000, 2010, 2020, and 2024, rather than a continuous annual panel, chosen to give roughly even decadal spacing while including the most recent year available at the time of construction.

The analysis sample comprises 47 African countries, matched to BACI's numeric country codes via CEPII's accompanying country classification file. Sudan is recorded under two distinct BACI country codes; both were summed into a single Sudan series for consistency across the sample period.

For each country and year, we identified the leading source of total merchandise imports by summing bilateral import values across all reported products for every trading partner and ranking partners by value. The same procedure was applied restricted to Harmonized System 6 digit codes falling under HS 8703 (motor cars and other motor vehicles principally designed for the transport of persons) to identify the leading vehicle supplier separately from the leading supplier overall.

Country boundaries for the map were taken from Natural Earth's 1:50m Admin 0 Countries dataset. Because this dataset classifies several small island nations, Seychelles, Mauritius, Cabo Verde, Comoros, and São Tomé and Príncipe, outside its African continent grouping, these countries were rejoined to the African sample by ISO3 code prior to mapping. For map presentation, the four most frequently occurring leading partners across the sample, China, France, South Africa, and Portugal, were

retained as distinct categories; all remaining leading partners were grouped as Other to preserve legibility. Countries outside the 47 country analytical sample are shown as No data, a sample coverage distinction rather than a reflection of missing underlying trade data.

One limitation should be noted. Djibouti serves as Ethiopia's principal trade corridor, and its own bilateral trade statistics likely include a substantial volume of goods in transit to Ethiopia rather than consumed domestically. Djibouti's classification as having China as its leading vehicle supplier by 2024 should therefore be interpreted with this caveat, and may in part reflect Ethiopia's own import composition rather than an independent instance of the same pattern.

Building the Need and Opportunity index

Need. For country *i,* Need_*i* is the average Energy Import Coverage (EIC) ratio over 2020-2023 (energy import value, BACI HS 2701-2715, as a percentage of total merchandise export value).

Opportunity. Combines two percentile-ranked components over the same window: China's average share of country i's total merchandise imports, and country i's average vehicle import value per capita (HS 8703, summed across all partners and divided by 2020 population, World Bank SP.POP.TOTL), inverted so lower per-capita values rank higher. Both indicators are averaged over the same 2020–2023 window as Need.We use per-capita rather than total vehicle import value because total import value conflates country size with the entrenchment of an incumbent fossil-fuel vehicle sector: a large country can register a large absolute import volume while importing few vehicles per resident, and the reverse holds for small countries. Dividing by population removes this size confound, though the measure remains an imperfect proxy, since low per-capita vehicle imports can also reflect low income, low motorization, or limited infrastructure rather than a genuinely weak incumbent import sector specifically. Results using total import value are highly correlated with the reported measure (Spearman's $\rho = 0.976$) and do not change the composition of the highest-scoring quadrant.

Sierra Leone illustrates the sensitivity of the Opportunity construction to how vehicle-market lock-in is measured: under total vehicle import value its Opportunity score is the highest in the sample, but under the per-capita measure we report it falls to a more

moderate 0.79, since Sierra Leone's small population had inflated its per-capita apparent lock-in advantage. Either way, its Need score is among the lowest (EIC of 4.5%), placing it in the lowest quadrant overall despite meaningful China-trade integration (31% import share).

Combined index. Need is percentile-ranked within the sample and combined with Opportunity:
$Combined_i = 0.7 \times P(Need_i) + 0.3 \times Opportunity_i.$

Readiness. Taken directly from Mutiso et al. (2025), their country-level average score including enabling policies.

The main text excludes Cabo Verde, Djibouti, Mauritius, São Tomé and Príncipe, Eswatini, and Seychelles (all below ~1.75 million population, World Bank SP.POP.TOTL, 2020);

The 2020-2023 was chosen after confirming rankings are stable across 2019-2022, 2020-2023, and 2021-2024 (Spearman correlation >0.85 across variants). 2024 excluded because Ethiopia's own ban (January 2024) shifts its vehicle-import China share to 58% (from 22% in 2023, 1% in 2021), reflecting the ban's consequence rather than a precondition; Mali's 2024 EIC (162%, unverified) is an independent reason for the same exclusion.

For Figure 4 both axes use a fixed 0.60 threshold (Mutiso et al.'s tier boundary for Readiness; matched for Need and Opportunity for cross-sample comparability, rather than a sample-relative cut that would shift between the 41- and 47-country versions).

We tested the sensitivity of the results to the construction of the index in two further ways. First, we repeated the analysis adding the share of electricity generated from clean sources (2021; Mutiso et al. 2025) as a third, equally weighted component of Opportunity, keeping the 0.7/0.3 weighting and the 0.60 thresholds. The four countries in the high need and opportunity, high readiness quadrant (Ethiopia, Kenya, Rwanda and Uganda) and the set of 16 high need and opportunity countries are unchanged (Spearman correlation of the combined index with the baseline: 0.98). Second, we compared the results with an earlier specification that scored five criteria (EIC, clean

electricity share, vehicles per 1,000 inhabitants, vehicle import volume and China import share) in quartiles, summed to a maximum of 20, with EIC computed from UN Comtrade for 2015-2020. The main findings hold: Ethiopia, Rwanda and Uganda fall in the target quadrant under both specifications, and the group of high-readiness, low-urgency economies (Morocco, South Africa, Tunisia, Egypt, Ghana, Algeria and Namibia) is unchanged. Kenya, one point below the threshold in the earlier version, crosses it in the present one, and the differences for Sierra Leone and Guinea arise because Comtrade export values understate BACI's, which inflates EIC.

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AI Statement

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