

The Settlement Layer

The missing financial infrastructure of the circular economy

Ioan-Codrut Lazaroiu

Independent advisor · Vienna

Working paper — for discussion · August 2026

Abstract

Europe is about to multiply its return systems. From August 2026 the Packaging and Packaging Waste Regulation, a cornerstone of the EU's circular-economy programme, applies across the Union; by January 2029 every Member State must either run a deposit system for beverage containers or collect ninety per cent of them without one. Austria trained its population in twelve months: 1.4 billion containers came back in the first year. This paper argues that the circular economy's binding constraint is financial: return is a settlement, not a virtue. Wherever a binding consequence attaches to non-return, whether a bearer deposit at the counter or a quiet deposit charged to an account, return rates run between 85 and 99 per cent; wherever it is absent, no level of goodwill makes them reliable. The paper maps the anatomy of return from the container anyone can buy to the settlement layer no one sells, prices the instruments in use today, and locates the seams where every solved loop stops: the border, the category, and the neighbouring system. It closes with a decision framework for operators, merchants, and investors weighing when to run a loop, when to join the layer, and when to wait.

1. A claim dies at Freilassing

Cross the Saalach bridge at Freilassing with an empty German water bottle and you are carrying a live financial claim. The label says so: twenty-five cents, printed beside the barcode, redeemable at tens of thousands of counters in the country behind you. Walk three hundred metres into Austria and present it to a reverse-vending machine that handles millions of containers a year, built by the same manufacturers, reading the same barcodes, and the machine will hand it back. The claim has not expired, and nothing about the bottle has changed. What you are holding is an orphaned deposit: twenty-five cents of settlement that no counter on this side of the line will honour.

The anecdote is the architecture. On 12 August 2026 the Packaging and Packaging Waste Regulation begins to apply across the Union, and by 1 January 2029 every Member State must either run a deposit-return system for single-use bottles and cans or collect ninety per cent of them without one. Austria's system, eighteen months old, took back 1.4 billion containers in its first year. Germany's, twenty-two years old, cycles eighteen to twenty billion a year. More systems are coming, on a statutory schedule, and each one will clear perfectly inside its own border and stop at the line, exactly as the bottle did. A deposit paid in Munich is worth nothing in Salzburg.

This paper argues that what Europe's return systems prove, and what they lack, are the same thing. What they prove is a financial mechanism: return is a settlement, not a virtue. Wherever a binding consequence attaches to the moment of non-return, containers come back at rates between 85 and 99 per cent; wherever none does, no level of goodwill makes them reliable. What they lack is the layer that would let the settlement travel: the shared register of identity, obligation and clearing, which this paper calls the settlement layer, that nets who owes whom across every counter a claim might reach. Without it, the regulation now applying will produce bordered loops: national systems that clear only their own containers, category rails that clear only their own asset class, city schemes that cannot

honour a neighbour's token. Each loop is a real achievement. The sum is a continent of orphaned claims.

The argument runs from the market to the map. Sections 2 to 4 establish the mechanism, price the five instruments that run on it today as financial positions, and locate the one thing none of those instruments sells. Section 5 follows every position to the seams where it stops. Sections 6 and 7 set the admission order for the categories a settlement layer should carry, and state what the layer is worth beyond any of them. Section 8 gives the case against building it, at full strength, including the condition under which the honest answer is not to build. Sections 9 and 10 close with four tests, four dispositions, and the cost of being wrong in either direction.

A note on method. The method here — treating the unbuilt layer as the scarce asset and reading the instruments around it as financial positions — follows my earlier working paper, *Molecules of Optionality* (SSRN, 2026), which asked the same question of Europe's energy corridors. The subject, evidence and conclusions are this paper's own; what repeats is the finding, which appears to be general: Europe solves its coordination problems nationally, and leaves the layer between the nations unbuilt.

2. The mechanism

The mechanism deserves to be stated before the map, because Europe ran the experiment twice in the same language area and the results agree. On 1 January 2025, Austria attached twenty-five cents to every single-use bottle and can sold in the country. Twelve months later roughly two billion deposit containers had been placed on the market and 1.4 billion had come back, a first-year collection quota the operator puts at 81.5 per cent once container weights and time in circulation are accounted for. What no awareness campaign achieved in decades, twenty-five cents achieved in twelve months.

The second run of the experiment charges nothing at all. Vytal, a Cologne-based reuse platform for takeaway food containers, operates without any deposit: each container carries a QR code bound to a customer account, return within two weeks costs nothing, and a container that never comes back is charged to the account that kept it. Its return rate is 99.3 per cent, verified through the Blue Angel ecolabel, with the average container back in under four days, higher and faster than the German bottle system itself. I will call this instrument the quiet deposit: an obligation that stands at zero at checkout and settles only on non-return.

Between the Austrian counter and the Cologne app the mechanism is identical, and the record around them closes the case. Germany's national system returns 94 to 98 per cent of eighteen to twenty billion containers a year; the European deposit-system median stands near 90; Hungary's new system reached 88.8 per cent on more than three billion containers in its second year; a Danish city scheme holds 88 on a five-krone token. Wherever a binding consequence attaches to non-return, returns run between 85 and 99 per cent; wherever none does, no level of goodwill makes them reliable. The voluntary record reads accordingly, and Section 4 shows what it cost the ventures that relied on it.

The claim matters beyond packaging, because European policy has just changed rungs. The waste hierarchy has stood in EU law since 2008: prevention above reuse, reuse above recycling, recycling above disposal. For thirty years policy climbed the lower rungs, through collection targets, recycling quotas and recycled-content mandates. With the regulation now applying, it steps onto reuse: binding reuse targets for transport packaging from 2030, the deposit mandate from 2029. Reuse is a finance-hungry rung. A recycling target can be met with bins and sorting plants; a reuse target is met only when specific assets come back, which means only when someone keeps a ledger and enforces a

settlement. The circular economy has reached the part of the climb that cannot be done without a financial mechanism.

That mechanism is not hypothetical; it is already traded. Five families of instrument run settlements on returnable assets today, at scales from a city to a continent, and each is a position someone holds, with risks it moves and volumes it has proven. The next section prices them.

3. The positions

Five families of instrument currently occupy fragments of the settlement layer, and Exhibit E1 lays them side by side as term sheets: the position each one amounts to, the risk it moves, and the volume it has proven. The translation into finance is the point of the exercise. Stated as ecology, the instruments look interchangeable; stated as financial positions, they behave as differently as the balance sheets behind them.

The bearer deposit is the oldest and by far the largest position. It is an interest-free loan from the consumer to the system, redeemable by an anonymous bearer claim: whoever presents the container is owed the cash, no identity attached. Germany has run this loan at national scale for two decades; Austria opened its book in 2025. The float costs nothing and never sleeps, which is why the unredeemed residue is so often mistaken for a business model. The mistake dissolves on inspection: German breakage, estimated around €180 million a year and disputed down to the method, accrues as private windfall to fillers and first distributors; Danish breakage funds the system that generates it; Austrian breakage sits with the central operator by design. A revenue line that shrinks as the system improves, and that mostly belongs to somebody else, is a subsidy for the transition years, and Section 8 treats it as such.

The quiet deposit is the same obligation turned inside out. Nothing is lent at the counter; a collateralised obligation attaches to an identified account instead, a contingent receivable that crystallises only on non-return. The Cologne pure case of Section 2 runs it at 99.3 per cent, a figure no bearer system in Europe matches. On economics the comparison is one-sided. The bearer instrument taxes every honest customer with a cash loop and pays for its anonymity twice, in float handling and in fraud exposure; the quiet deposit touches only the fraction of a per cent who keep the asset, and charges them its replacement price.

Two further instruments prove that consumer deposits are one tool rather than the tool. The pooling contract is an operating lease on a shared fleet: the pool keeps the asset and its utilisation risk, charges rent by the trip, and never meets a consumer. On that instrument alone, one European crate pool moves more than two billion shipments a year and one open pallet exchange circulates roughly 670 million pallets, three decades of banked reuse without a deposit in sight. The city reuse token is the bearer deposit miniaturised: a small refundable float cleared inside a single city, currently returning 1.8 million cups at 88 per cent over two years in Aarhus on a five-kroner token.

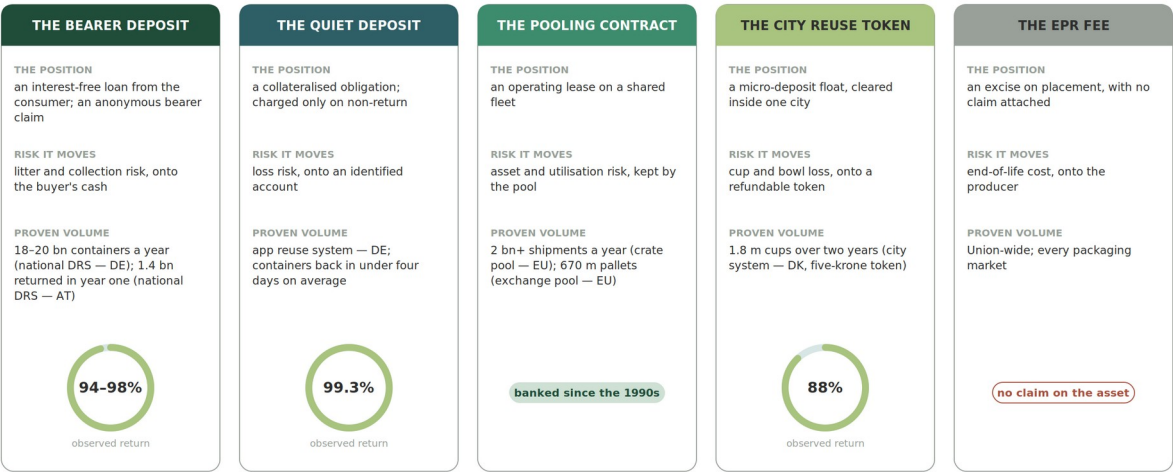
The producer-responsibility fee completes the set as the instructive exception. It is an excise on placement: it moves the end-of-life cost onto the producer and attaches no claim whatever to the asset itself. It has the widest scale of the five, every packaging market in the Union, and the least to show for it in returns, because money that carries no obligation moves no assets. The circular economy spent two decades learning that lesson at full price.

Each of the five is real, proven, and held: a loan here, a receivable there, a lease, a float, an excise. What none of them is, is the layer itself. Every position runs on a private ledger scoped to its own assets and its own counters, and the thing they all depend on, a shared register of identity, obligation and clearing that any claim could travel, sits on nobody's

balance sheet. The next section takes the system apart to show why that missing piece is the only part that cannot simply be bought.

E1 • Five positions on the layer

The instruments of return, read as term sheets



Money that carries no obligation moves no assets.

Source: operator and system reports 2024-2026; Appendix A. Graphics carry jurisdiction and mechanism only; operators are named in the text.

The Settlement Layer — working paper • E1

4. What no one sells

Strip any of the five positions to what it physically runs on and four layers appear. Exhibit E2 draws them as rings, because the layers nest: at the rim the container, inside it the return hardware, inside that the return network, and at the core the settlement layer, the register the whole system settles against. Reading inward is reading from the easily bought to the impossible to buy, and most debate about reusable packaging never leaves the rim.

The container is a commodity. A deposit bottle, a returnable cup, a durable shipping box rated for dozens of cycles: each is a purchase order and a lead time, sold by any packaging producer to anyone with a budget. It is worth stating bluntly, because the container is where attention gathers; it is the thing customers touch and photographs show. Yet nothing about a durable box constitutes a system. A reusable mailer without the rings inside it is single-use packaging in better materials, at a worse price.

The next two rings can be acquired, at rising cost in time. Return hardware (reverse-vending machines, counter scanners, smart locks) is sold by several equipment makers and installed in months; Austria fitted out the second-densest reverse-vending network in Europe inside a year, and those machines now take ninety-eight per cent of all Austrian returns. The return network is different in kind, because nobody sells one outright. It is assembled, contract by contract, from counters that already exist for other reasons: supermarkets, parcel shops, locker walls. The raw material is abundant, with more than 390,000 parcel lockers and pickup points across Europe and over 15,000 automated lockers in Germany alone, on plans approaching double that by 2030. Abundant is not the same as enrolled; assembly takes years, and the contracts are the moat.

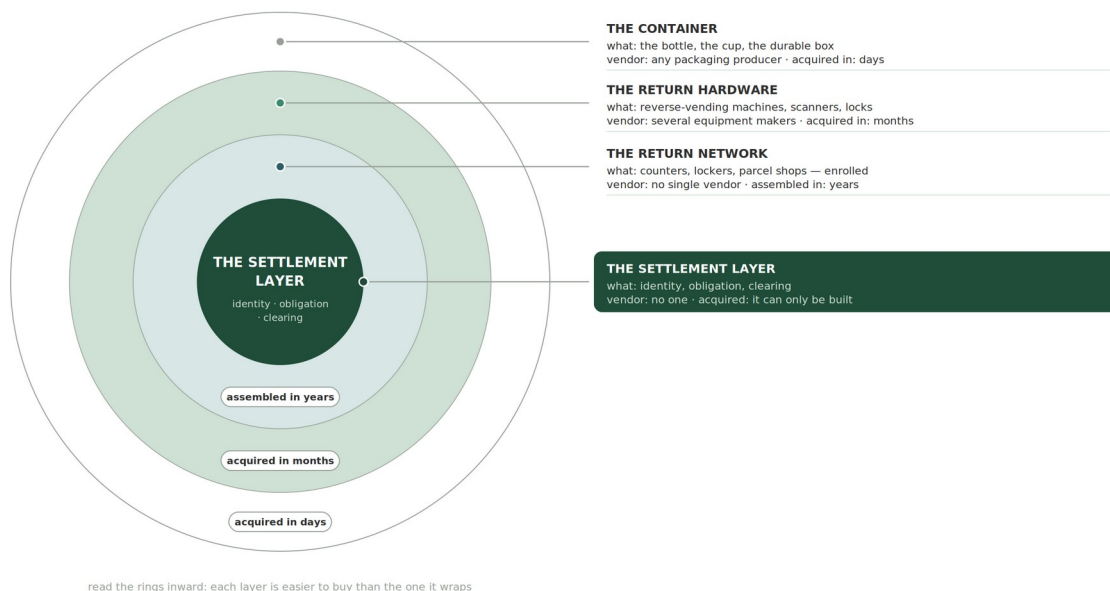
The core is made of three things: identity, obligation, and clearing. Identity is the register of which asset is out, and with whom. Obligation is what attaches at the moment of non-return: a forfeited deposit, a charge to an account, an invoice to a merchant. Clearing is the machinery that nets who owes whom across every counter that touched the asset, and honours the claim wherever it is presented. None of this is equipment, and no vendor sells

it. Germany makes the point almost by accident: the body behind the world's largest bottle-deposit market is a standards organisation rather than a clearing house, and settlement runs bilaterally between retailers and fillers through private agencies, with no central ledger anyone can audit. Austria, launching twenty-two years later, drew the opposite conclusion and put a single operator at the centre, holding every deposit and every claim. Two architectures, one lesson: the core can be organised more than one way, and it can only ever be organised. Three layers can be bought; the fourth can only be built.

The core's absence explains the record better than any cost curve. Zalando's Nordic pilots mailed reusable bags with a return label and a request; they had containers, hardware of a sort, and a network borrowed from the postal system, and their operator named getting customers to send the empty bags back as the defining challenge. RePack, the category's flagship, ran reuse without settlement across more than three hundred brand partnerships and exited fashion e-commerce in June 2026. Return ventures fail at the core far more often than at the rim. What remains is to see how far a claim travels once a core exists, and the answer, today, is: exactly to the edge of the loop that issued it.

E2 · The anatomy of return

Four layers; only three are for sale



Three rings have a vendor; the core has none.

Source: author's analysis; system evidence in Appendix A.

The Settlement Layer — working paper · E2

5. Where settlement stops

Every position in Section 3 is bankable inside its own loop and expires at its edge. Exhibit E3 draws the general case as a single journey: one returnable asset travelling a loop that should close, and three points at which, today, it cannot. The loop that does not close is not a metaphor; it is the operating condition of European return infrastructure in 2026.

The first gap is the country border, and Section 1's bottle is its formal case. The claim carried across at Freilassing was neither damaged nor expired; it was an orphaned deposit, because the deposit is a national instrument and the register that could honour it stops at the line. The regulation now applying leaves this exactly where it found it: it harmonises minimum requirements inside each national loop, and nothing in its deposit provisions or

their interpretive guidance reaches cross-border redemption. Retailers on both sides refuse foreign containers on precisely that ground, and every system the 2029 mandate calls into being will inherit the same edge.

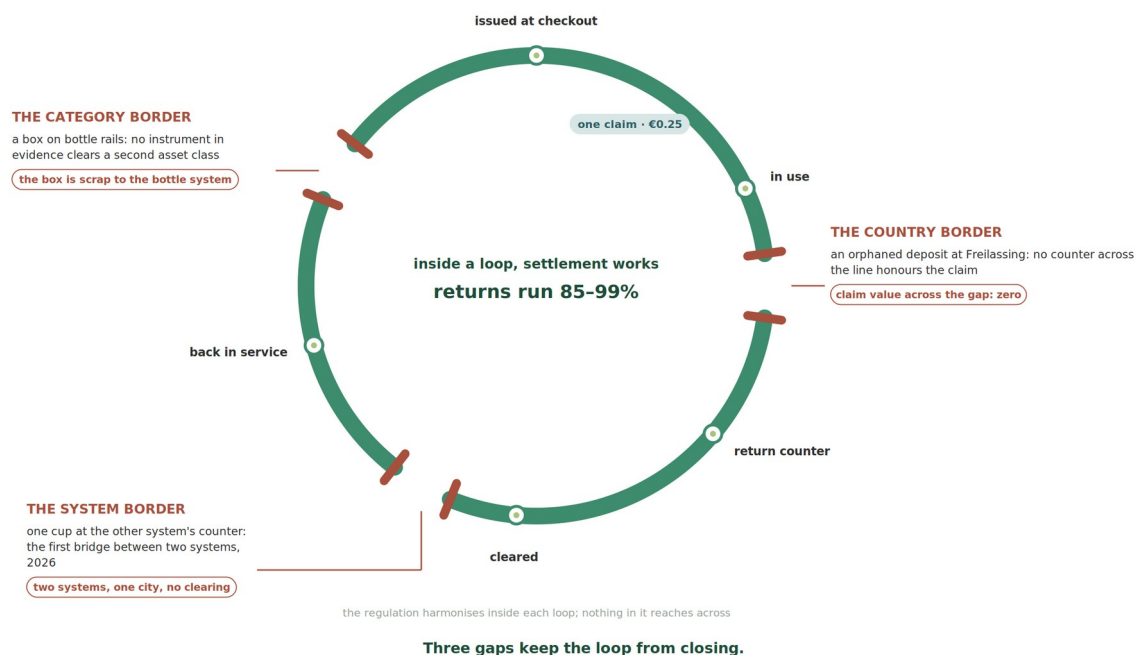
The second gap is the category border. Bottle rails clear bottles: one asset class, cleared superbly, at national scale. No instrument in evidence clears a second class on the same rails, and a box presented to a bottle system is scrap. The machinery is indifferent and the barcode readers are the same; the register behind them recognises only its own asset list.

The third gap is the narrowest and the most telling: the system border. Two reuse schemes can operate in the same city, each returning 85 to 99 per cent, and fail to honour one another's tokens; a cup issued by one is, at the other's counter, exactly as foreign as the German bottle in Austria. The first automated bridge between two such systems, at Freiburg's central station, dates from 2026, and it made the trade press precisely because nothing like it had existed.

Three gaps, one missing counterparty behind all of them. The regulation will multiply the loops: twenty-seven national deposit systems by mandate, city schemes by procurement, category rails by statute, each clearing perfectly inside its own edge. What it will not build is anything between them, and the sum is bordered loops. The settlement layer's job description is written at the three gaps where every existing position stops; until someone takes the job, the map of European return is a set of circles that do not touch.

E3 • Where settlement stops

One return loop, three gaps: the borders no claim can cross



Source: Regulation (EU) 2025/40, Arts 29 and 50; system evidence, Appendix A.

The Settlement Layer — working paper • E3

6. The admission order

Not every category deserves the settlement layer, and none deserves it by acclaim. Exhibit E4 arranges the candidates as an admission order around the layer itself, judged on two questions: what stands behind demand (a statutory mandate, a proven commercial

willingness, or a hope), and what must be committed before the answer arrives, in fleet, washing capacity and changeover, and how much of it can be recovered if the answer is no.

Two candidates sit outside the admission question entirely, because their certainty is already spoken for. Beverage containers hold maximum certainty, which is exactly why the position is occupied: statutory operators, national law, machinery installed and amortising. B2B transport packaging is certain for the opposite reason: no mandate was ever needed, the pooling contracts of Section 3 have banked that reuse since the early 1990s, and a consumer deposit appears nowhere in it. The exhibit parks both in the outer band, occupied and served. Certainty, it turns out, is the least scarce thing on the map.

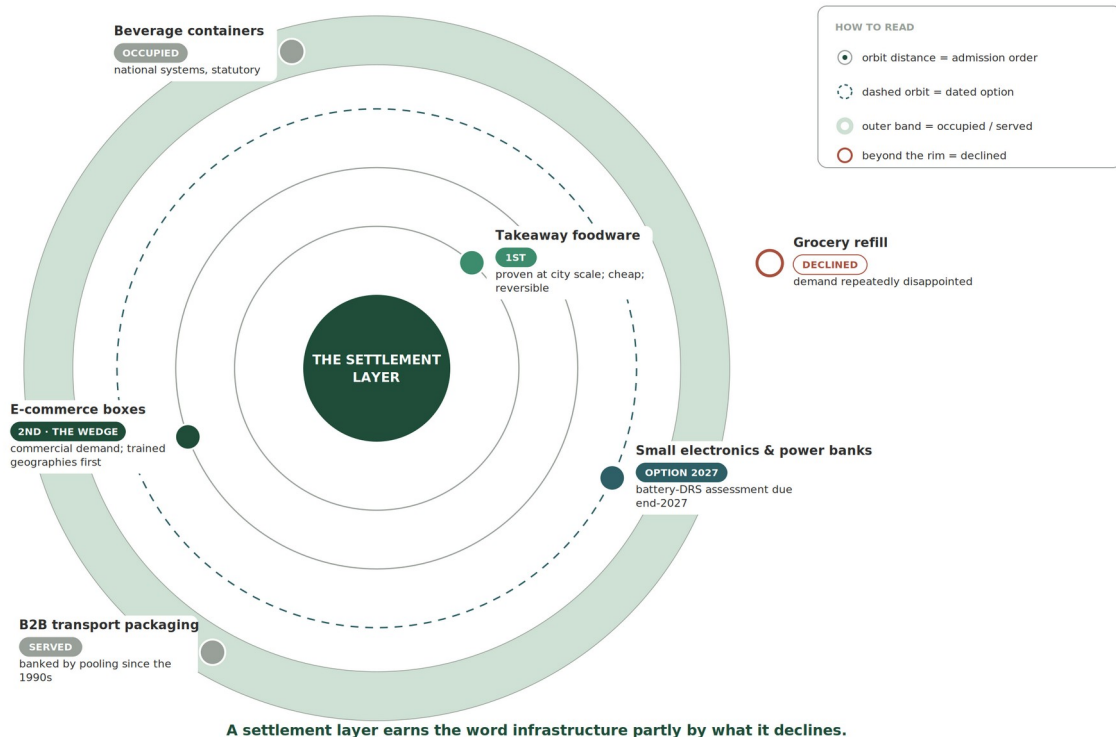
The genuine uncertainties divide by their price. Grocery refill combines demand that has repeatedly disappointed with changeover costs that reach into store layouts and supply chains; the exhibit places it beyond the rim, declined, a costly bet by any reading. Small electronics and power banks are the opposite case: an option with a date on it. The Batteries Regulation obliges the Commission to assess, by the end of 2027, whether deposit-return should apply to portable batteries, and the pressure is no longer theoretical: last December, Austria, supported by Germany and Lithuania, formally asked the Commission to accelerate that assessment, citing lithium-battery fires. An assessment is not a mandate, and the honest position treats it as one: the cost of being ready is small, since a layer built category-agnostic can admit power banks the week the assessment lands, while building ahead of it would be carried for years. The exhibit gives electronics a dashed orbit marked 2027.

E-commerce boxes hold the contested middle, and they arrived there by legislation. The Commission's original proposal carried dedicated reuse targets for e-commerce packaging; the adopted regulation carries none. What survived is a general transport-packaging target from which cardboard boxes are exempt, an empty-space cap from 2030, and minimisation duties from 2028. A mandate is not a market, and the mandate for reusable e-commerce boxes went missing in trilogue. The commercial record reads accordingly: the flagship exit of Section 4 cited precisely those exemptions, and the French operator Hipli, running a fleet of a million reusable mailers, was placed in liquidation in December 2025. Demand certainty for boxes is therefore commercial rather than statutory, resting on what merchants will pay per cycle, which Section 8 prices without sentiment. The cost side is moderate: box fleets cost less than store refits and more than cups, and outside food, inspection substitutes for washing.

The first admissions follow. Takeaway foodware enters first: returns between 85 and 99 per cent across deposit-based and deposit-free systems, fleets that cost little, commitments that reverse within a season, and counters that already exist wherever the food is sold. E-commerce boxes enter second, as the wedge, and only in trained geographies. This is the reflex dividend: a population already returning millions of containers a day does not need to be retrained to return a box, and the parcel networks of the German-speaking market put a counter within minutes of most doors. Everything else is occupied, served, held as a dated option, or declined. A settlement layer earns the word infrastructure partly by what it declines.

E4 • The admission order

What the settlement layer carries first — and what it declines



Source: regulatory dates, EUR-Lex; category evidence, operator reports 2025–2026; Appendix A.

The Settlement Layer — working paper • E4

7. The layer beyond its cargo

The strongest argument for the settlement layer is the one that survives the failure of any single use for it. Section 6 chose an admission order; this section states why the layer outlives every admission on the list, because infrastructure justified by one application is a project, while infrastructure that serves whatever crosses it is an asset. The distinction carries the weight of the record: fleets die with their category, as the liquidations of Sections 4 and 6 showed, yet nothing that failed in those ventures discredited identity, obligation, or clearing. A loop is a bet on one category; the layer is an option on all of them.

The first cross-cutting value is evidentiary. A layer that binds every asset to an identity produces, as exhaust, the dataset the circular economy has always lacked: cycle counts, dwell times, loss rates, and flows, per asset and audited by settlement rather than by survey. The regulation makes this valuable on a date. Reuse targets count only packaging that is reusable within a re-use system, a delegated act defining minimum rotations is due by February 2027, and a merchant claiming compliance will need proof of rotations that survives an auditor. Environmental claims need the same ledger: the measured benefit of reusable packaging swings between thirty-nine and eighty-two per cent depending on realised return rates, so the return data is the difference between a verified claim and a brochure. The market has noticed; the largest food-crate pool began selling asset tracking as a service in 2025, three decades after it began selling crates.

The second value is fraud resistance, and it is native rather than added. Anonymous bearer systems invite industrial redemption fraud: Michigan's ten-cent deposit draws an estimated ten to thirteen million dollars a year in out-of-state and falsified redemptions, and enforcement there has watched fraud migrate from smuggled cans to faked return records as scanning improved. An identity-bound settlement inverts the exposure. Every

redemption has a counterparty, every serial number a history, and a claim presented twice is a database event rather than a loss. The bottle systems pay for anonymity because cash at a counter demands it; a layer built on accounts never owes that tax.

The third value sits in the returned material itself. A settlement layer knows whose asset came back, which makes ownership of the return stream unambiguous, and unambiguous ownership is what turns collected material into a tradable position. Austria wrote the precedent into its system: producers hold first refusal on the sorted material their containers become, so a bottler's feedstock loop closes by right rather than by auction. Germany showed the same value from the other side, where sorted clear PET fetched over seven hundred euros a tonne at peak and the material income accrued to whoever held the containers. Multiply the principle beyond bottles and it compounds: a box fleet is a rolling inventory of known-grade polymer, and the ledger is its title register.

The fourth value is the standing option. A layer built category-agnostic from the first asset admits the next category at the marginal cost of onboarding it, which converts every future mandate into an opportunity that requires no forecasting. The battery assessment of Section 6 is the nearest dated example, and it is not novel: remanufacturers have charged refundable core deposits on alternators and gearboxes for half a century, which is settlement infrastructure by another name, run bilaterally because no shared layer existed to run it. Reuse, refill, return, remanufacture: every R-strategy in the circular economy's alphabet shares the same dependency on identity, obligation, and clearing, and none of them needs to be predicted correctly for the layer to pay. If a category fails, the layer holds.

That is the asset side of the ledger, stated in full. Honesty requires the other side at the same strength, and the next section supplies it.

8. The case against building it

An argument for infrastructure owes its readers the case against it, stated at the strength its opponents would give it. Six objections survive contact with the evidence, and one of them carries the condition under which this paper's own framework concludes against building at all.

The first objection is that the advertised funding taxes its own success. Unredeemed deposits shrink as a system improves: Austria banked 81.5 per cent in year one on its way to a 90 per cent target, Germany runs between 94 and 98, and every point of progress removes revenue. The residue is rarely the operator's to keep: German breakage accrues to fillers and first distributors as private windfall, Danish breakage funds the system by statute, and the regulation's minimum requirements for new systems point unredeemed refunds back into the system itself. The objection stands, and the honest answer concedes it. Breakage is bridge financing for the training years; a durable model earns its keep from per-cycle clearing fees and the charges collected on non-return. What the concession leaves open is whether those fees clear the system's true costs, which is the next objection's territory.

The honest counter-case lives in the empty mile, the leg from the parcel shop back to the hub that nobody has priced at box scale. No public benchmark exists for that leg; the indicative figures are unfriendly, on the order of twelve euros a trip for a returnable container against three to six for a single-use carton, with an environmental case that collapses below roughly four cycles. The record supplies the corpse: Hipli ran a fleet of a million reusable mailers for 350 brands and was liquidated in December 2025, and the category's flagship exited six months later. The answer is partial and must say so. Outside food, inspection substitutes for washing; pooling operators have run collection, washing and reinjection profitably for three decades at industrial volume; and every per-cycle figure

improves steeply with the return rate, the one variable settlement demonstrably moves. The consumer leg at box scale nonetheless remains unpriced by anyone, and this is where the framework's stop-rule sits: if the empty mile's cost floor exceeds what merchants will pay per cycle, and no mandate arrives to change their minds, the correct disposition is not to build. That is the condition that liquidated Hipli, and no reader should assume it has lapsed.

The third objection holds that the position is already occupied. The reverse-vending market leader runs an open managed system accepting any serialised reusable packaging against a central database, live in two cities and behind the Freiburg bridge that Section 5 called the first of its kind; national operators carry statutory legitimacy, and Member States have already shown they can widen a system's scope by national law. The answer draws the line finely. What exists is hardware-led and city-scale, the national operators are beverage-bound by governance and mandate, and no player in evidence clears claims across borders, categories, or rival systems at network scale. The open seat is the neutral one, and neutrality is structurally hard for an equipment vendor or a national monopoly to claim. What the answer cannot rule out is the leader taking the seat once it looks valuable; part of Section 10's timing argument rests on that clock.

The fourth objection is checkout friction, and its record is unambiguous. The one multi-category deposit platform attempted at consumer scale attached deposits of fifteen cents to ten dollars per item, plus a tote and shipping, drew sticker-shock coverage in its first week, and closed its e-commerce arm within four years. A deposit added at an online checkout is a price rise at the moment of maximum abandonment. The quiet deposit is the structural answer, standing at zero at checkout and touching only the accounts that keep assets. The residue is genuine: nobody has run charge-on-non-return for packaging at e-commerce scale, and the consumer-law treatment of automatic charges differs by market.

The fifth objection arrives with interoperability itself. A layer that lifts per-asset value from twenty-five cents to several euros, and clears claims between systems, raises the fraudster's prize in proportion; the Michigan record of Section 7 shows deposit fraud industrialising at a dime and migrating into falsified records as scanning improved. Identity is the answer as far as it goes: accounts, serial histories and velocity checks make anonymous redemption structurally harder than any bearer counter. How fraud behaves once several issuers clear across one layer has no precedent to consult, and European cross-border loss figures remain unverified. The exposure is real, and it is unmeasured.

The sixth objection is the honest breadth of the ambition. Deposit-return for everything is, on the evidence, three categories: foodware, which works at city scale; boxes, whose record includes a liquidation, an exit, and voluntary return rates as low as fifteen per cent; and small electronics, which are a study due at the end of 2027 rather than a market. The one platform that claimed everything ended at coffee cups. The answer is to claim sequencing rather than universality, and to build the layer category-agnostic so that each admission costs little. What sequencing cannot settle in advance is whether the categories share enough logistics to be one business rather than several wearing one brand; only the wedge will answer that.

Six objections, two standing concessions, one stop-rule. The framework that follows is built to hold them rather than to outrun them.

9. Four tests, four dispositions

The argument now reduces to four questions, and Exhibit E5 sets them as gates. They are addressed to the three readers a framework like this must serve at once: the operator weighing a category, the merchant weighing a commitment, the investor weighing both.

Each question names a test with an observable answer; each answer routes to one of four dispositions: run a loop, join the layer, hold the option, or don't build; and every disposition is entered at a scale that can be unwound.

The first question is the mechanism test: does a binding settlement attach at the moment of non-return? If nothing enforceable happens when the asset stays out, neither a forfeited float nor a charge to an identified account, then the experiment has been run at scale and its result is in: returns become unreliable at any level of goodwill, and the disposition is don't build. The bearer deposit passes the test; the quiet deposit passes it more cheaply; a return label and a request do not.

The second question is the economics test: does the category clear its break-even cycles at the return rate actually observed, in systems comparable to the one proposed? The floor is unforgiving. A reusable asset starts beating single-use somewhere above four cycles, with one peer-reviewed estimate near eight, and the return rate sets the cycles an average asset will ever see: at 75 per cent, about four trips; at 95, about twenty. A category that clears only at projected rates is early rather than failed, and early has a disposition of its own. Hold the option, at the cost of readiness rather than fleet: small electronics wait exactly there until the battery assessment reports at the end of 2027.

The third question is the network test: can returns ride counters that already exist? Europe's supermarkets, parcel shops and locker walls put a potential counter within minutes of most urban doors, and a counter enrolled by contract converts the heaviest buildable ring of Exhibit E2 into rent. A fleet that instead requires its own collection leg walks into the empty mile, and the record of ventures that priced that walk optimistically is a list of liquidations. The disposition on a failed network test is don't build, and it is the framework's least negotiable exit.

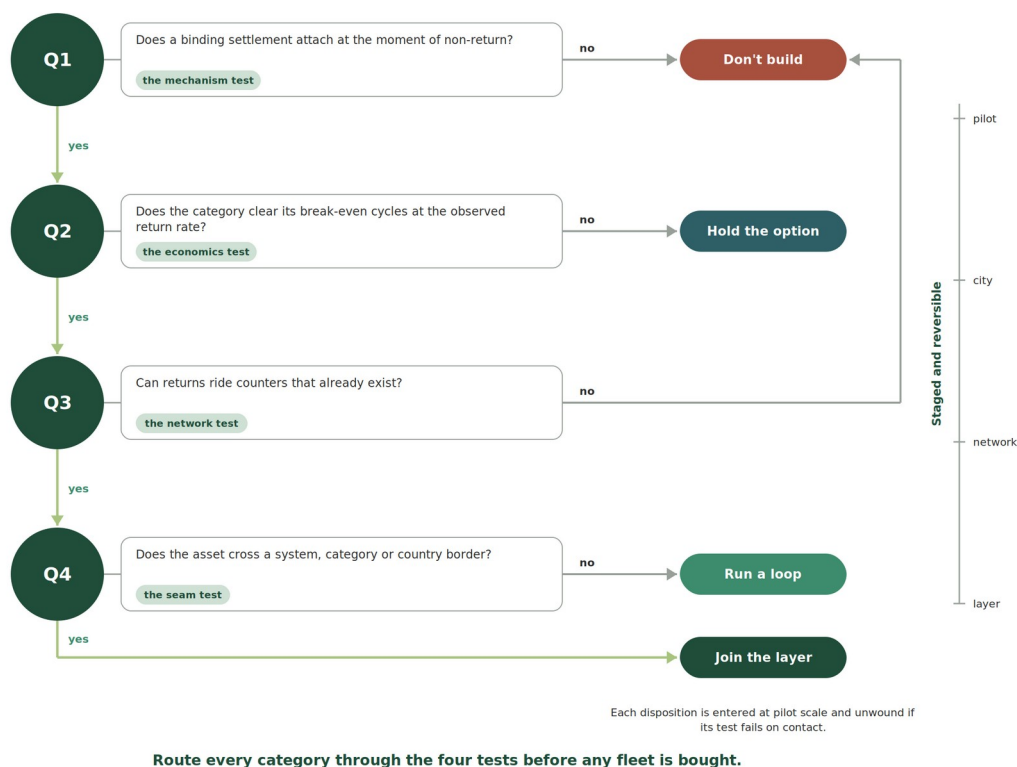
The fourth question is the seam test: does the asset cross a system, category or country border in its working life? An asset that lives and dies inside one loop needs no layer at all; a stadium cup or a single city's foodware can be run as a loop, profitably and without apology. The moment the asset crosses, sold in one system and returned in another, carried over a border, presented at a rival's counter, the loop inherits the gaps of Section 5, and every unrecognised claim it strands is an orphaned deposit in miniature. That is the case for joining the settlement layer, or, while it does not yet exist, for building it category-agnostic from the first asset.

The right-hand edge of Exhibit E5 carries the staging that keeps every answer revisable: pilot, city, network, layer, each increment reversible until the next contract is signed. Foodware enters at pilot scale on counters that already sell the food. Boxes enter second, in trained geographies where the reflex dividend is waiting to be collected, and only after foodware has proven the clearing machinery on cheap assets. Nothing proceeds past a failed test, and no fleet is bought ahead of its network. The framework exists to make the expensive error impossible and the cheap one survivable.

What the four questions cannot decide is how urgently to act on their answers. That depends on the cost of being wrong in each direction, and the closing section weighs the two against the clock the regulation has set running.

E5 · Four tests, four dispositions

Route every category through the gates; every increment can be unwound



Source: author's framework; thresholds in §9; Appendix A.

The Settlement Layer — working paper · E5

10. The return decade

This paper set out to name the circular economy's missing rail, and the vocabulary it built along the way carries the argument in miniature. Return is a settlement, not a virtue: that is what Austria's first year and a Cologne app's 99.3 per cent jointly prove, and everything else follows from taking it seriously. Beneath every container and counter sits the settlement layer, the register of identity, obligation and clearing that no vendor sells. Its modern instrument is the quiet deposit, which stands at zero at checkout and touches only the account that keeps the asset. Its launch geography is wherever the reflex dividend waits to be collected. Its honest risk is the empty mile, the unpriced leg between the return counter and the hub. And its reason for existing is written at the gaps, where a claim that crosses a border becomes an orphaned deposit and the map of national successes hardens into bordered loops.

The cost of building too early has a name in the record. Hipli entered the empty mile with a fleet of a million reusable mailers and no mandate behind its demand, and the tribunal closed its book in December 2025; the category's flagship followed it out within six months. Early capital in this landscape dies of per-cycle costs at return rates it cannot yet command, and it dies quietly. The framework of Section 9 exists against exactly that death: no fleet before its network, no category before its cycles clear, every increment reversible until the next contract is signed. Whoever builds the layer should spend contracts first and fleet second.

The cost of waiting is larger and quieter, which is why it is the likelier error. The dates are already set: the regulation applies from 12 August 2026, the deposit mandate bites in January 2029, the reuse targets follow in 2030, and the battery assessment reports by the

end of 2027. Every year of waiting entrenches the bordered loops more deeply: twenty-seven national systems, each clearing perfectly inside its own border, none recognising a neighbour's claim, fixed for a generation by the same regulation that proves the mechanism. The neutral seat does not stay empty on a schedule either; the equipment leader already operates the nearest thing to it in two cities. Waiting has cost nobody anything yet, which is precisely how infrastructure gaps persist. Without settlement rails, the circular economy remains a recycling economy.

Europe has entered the return decade with the mechanism proven, the counters built and the reflex trained; the layer that lets a claim travel is the one thing still missing. For operators, the disposition is to run their loops and open them at the gaps. For merchants, it is to buy cycles rather than fleets. For investors, it is to fund the ledger before the hardware. The work is unglamorous, as rails always are, and the increments are small enough to abandon, which is the point. The loops are closing one by one; whether they close into a circle is a question of settlement, and it stays open exactly as long as the layer stays unbuilt.

Appendix A — Source map

Every figure in the paper traced to source and date. Web sources accessed 29–30 July 2026; regulatory texts cited from EUR-Lex and Commission documents; operator figures from the operators' own published releases. The two mandated EUR-Lex pulls are recorded first.

A.1 The two EUR-Lex pulls (completed 29 July 2026)

Pull 1 — Article 29 and the e-commerce scope. Regulation (EU) 2025/40 (OJ L, 22.1.2025). Article 29(1), first subparagraph, verified against the OJ text on EUR-Lex: from 1 January 2030, economic operators using transport packaging or sales packaging used for transporting products — the provision's own words are “including for products distributed via e-commerce” — in the form of pallets, foldable-plastic boxes, boxes, trays, plastic crates, intermediate bulk containers, pails, drums and canisters of any size or material, including flexible formats and pallet wrappings or straps, must ensure at least 40 per cent of such packaging in total is reusable packaging within a re-use system. The second subparagraph sets 1 January 2040 as the date from which operators shall endeavour to reach 70 per cent — aspiration, not obligation. Article 29(2) requires 100 per cent reuse from 2030 for the listed formats moved between an operator's own sites or with linked or partner enterprises within the Union; Article 29(3) requires the same for deliveries to another economic operator within the same Member State, again including e-commerce distribution. The reuse quotas do not apply to packaging for dangerous goods, large-scale machinery, flexible formats in direct contact with food or feed, or cardboard boxes — the cardboard exemption on which §6 rests, confirmed across the coverage of the Commission's own delegated decision and multiple regulatory analyses. Delegated Decision (EU) 2026/429 (25 February 2026) exempts pallet wrappings and straps from Articles 29(2) and (3), issued under the Article 29(18)(a) empowerment — proof the exemption machinery is live. No dedicated e-commerce reuse percentage exists anywhere in the adopted text; e-commerce packaging is defined in Article 3 as transport packaging for distance sales to the end user and is carried by the general Article 29 targets only. Related dates verified: the delegated act defining minimum reuse rotations is due by 12 February 2027, and the standardised methodology for calculating the Article 29 targets by 30 June 2027.

Pull 2 — Article 50 and Annex X. By 1 January 2029, Member States must ensure deposit return schemes are established for single-use plastic beverage bottles up to 3 litres and single-use metal containers up to 3 litres; glass is outside the mandate. The PPWR retains the Single-Use Plastics Directive's separate-collection trajectory (77 per cent by 2025, 90 per cent by 2029), adds metal cans to the 2029 target, and adds the deposit-system

requirement as the instrument for reaching it. The exemption route requires separate collection of 80 per cent of the relevant containers made available in 2026, reported to the Commission by 1 July 2028; the exemption lapses if the Member State misses 90 per cent for three consecutive years, and deposit systems must meet the Annex X minimum requirements by 1 January 2029. Systems that do not reach the 90 per cent collection level have until 1 January 2035 to comply with the minimum requirements. Nothing in Article 50, Annex X, or the Commission's interpretive guidance provides for cross-border redemption or inter-system clearing of deposits — the absence on which §5 and Exhibit E3 rest. Verified in the same pass: the 50 per cent maximum empty-space ratio applies to grouped, transport and e-commerce packaging.

A.2 Figure-by-figure map

§	Figure or claim	Source (date)
1	PPWR in force 11 Feb 2025; applies 12 Aug 2026	Reg. (EU) 2025/40, OJ 22.1.2025; Commission packaging-waste page; Baker McKenzie (2025)
1	2029 deposit mandate; 90% collection	Art. 50 + Annex X (Pull 2)
1	Munich deposit worthless in Salzburg; foreign containers refused	Weser-Kurier Jan 2025; AT/DE system scope rules
1	DE cycles 18–20 bn containers a year	NABU (2015 basis); DPG via Euronews 17 Jun 2026
2	Waste hierarchy in EU law since 2008	Directive 2008/98/EC, Art. 4 (OJ L 312, 22.11.2008)
2	2030 transport reuse targets	Art. 29(1) (Pull 1)
2	Austria: launch 1 Jan 2025; €0.25; 0.1–3.0 L	Einwegpfandverordnung, BGBl. II Nr. 283/2023; Recycling Pfand Österreich (RPÖ) releases 2025–26
2	~2.0 bn placed; 1.4 bn returned; 81.5% on weight and 51-day dwell basis	RPÖ release 28 Jan 2026; EUWID 2 Feb 2026; profil 30 Jan 2026 (method critique)
2	Vital: QR-to-account; free return window; charge on non-return; 99.3%; under four days	Blue Angel ecolabel listing; vital.org
2	The 85–99% band	DE 94–98% (NABU; UBA Apr 2026); EU DRS median 90% (Reloop Dec 2025); Hungary 88.8% in 2025 on 3 bn+ containers (Sensoneo, May 2026); Aarhus 88% (TOMRA 2026); Vital 99.3% (Blue Angel). AT year one (81.5%) quoted separately as a transition year
3	Breakage ~€180 m/yr, disputed; to fillers and first distributors	NABU Feb 2017; supermarkt-nachrichten Apr 2026
3	Danish breakage funds the non-profit system; 2013 Finance Act transfers	danskretursystem.dk
3	Austrian deposits held by the central operator	RPÖ system publications; § 14c AWG 2002; BGBl. II Nr. 283/2023 (A.3)
3	EPAL ~670 m pallets (pool since 1991); IFCO >2 bn shipments a year (since 1992)	epal-pallets.org; ifco.com
3	Aarhus 1.8 m cups; 88%; two years; DKK 5	TOMRA feature 2026 (supersedes 27 May 2025 release: 85% at 17 months)
4	98% of AT returns via machines; second-densest RVM network	RPÖ release 16 Jul 2025
4	390,000+ lockers and pickup points in Europe	ParcelSelector network data, Q1 2026
4	DE 15,000+ Packstations; ~30,000 by 2030	DHL statements 2024–25
4	DPG a standards body; bilateral clearing; no auditable central data	NABU information paper, Feb 2017
4	Zalando pilots; return engagement the key challenge	Zalando corporate sustainability page (2021); ecommercenews.eu 2019/2022
4	RePack: 300+ brands; June 2026 exit citing the exemptions	packaging journal 22 Jun 2026; Sustainable Packaging News Jun 2026
5	No cross-border redemption in PPWR; retailers refuse foreign containers	Pull 2; Weser-Kurier Jan 2025
5	Freiburg: first automated cross-system bridge, 2026	Trade coverage of the Rotake-RECUP integration, 2026

§	Figure or claim	Source (date)
6	Battery-DRS assessment due 31 Dec 2027	Reg. (EU) 2023/1542, Art. 63; EP Legislative Train
6	Council request to expedite the battery-DRS assessment (AT, supported by DE and LT), citing lithium-battery fires	Council Environment AOB, ST 16339/25 (16 Dec 2025)
6	Proposal carried e-commerce reuse targets; adopted text carries none	COM(2022) 677 final vs. Art. 29 (Pull 1); RePack exit coverage
6	Cardboard exempt from transport targets	Pull 1
6	Empty-space cap from 2030; minimisation from 2028	EP press release 24 Apr 2024; Fieldfisher Jun 2026; Ropes & Gray Apr 2026
6	Hipli: ~1 m mailer fleet; 350 brands; liquidation 5 Dec 2025; assets to Movopack	French trade press Dec 2025; Veolia UpToUs profile; Amazon accelerator coverage 2024
7	Rotations act 12 Feb 2027; methodology 30 Jun 2027	Pull 1; Corplex Feb 2025
7	Emissions benefit 39–82% by return rate; –87% plastic	Fashion for Good reusable-packaging pilot (2021)
7	Crate pool selling tracking-as-a-service (2025)	Fruitnet 12 Nov 2025
7	Michigan fraud \$10–13 m/yr; falsified-record migration	Michigan legislature bill analysis 2007–08; state police estimates via press; Michigan Environmental Council
7	Austrian producer first refusal on sorted material	RPÖ releases; ministry joint bilanz Jan 2026; Pfandverordnung Vorkaufsrecht (WKO)
7	Clear PET to €710/t; retail material income >€230 m (2011), ~€50 m (2015)	NABU Feb 2017
8	~€12/trip vs €3–6 single-use (indicative)	FLEX Fulfillment (flagged indicative)
8	Break-even above ~4 cycles; ~8 in one LCA	Fashion for Good 2021; Park et al., J. Industrial Ecology 2024
8	Scope widened by national law	German deposit-scope extensions 2022 and 2024 under VerpackG; BMUV
8	Loop: \$0.15–\$10 deposits; \$15 tote; e-commerce sunset end-2022; ~150 stores; £1 QSR cup	Waste Dive 28 Sep 2021 and 10 Jan 2023; WHYY 10 Jun 2019; Trellis; foodnavigator 30 Aug 2023
8	Boox voluntary returns 15–65%	Modern Retail
9	Expected trips $\approx 1/(1-r)$: four at 75%, twenty at 95%	Author's calculation; consistent with Returnity's published rule of thumb
9	Counter density (90% of Germans within 10 minutes of a locker)	DHL 2024–25; ParcelSelector Q1 2026
10	All dates restated	Pulls 1 and 2; Reg. (EU) 2023/1542, Art. 63

A.3 Residual verification items (closed in the P7 pre-upload checks, 30 July 2026)

The five items carried out of the P6 build were closed on 30 July 2026; the two letter-level sightings were completed against the EUR-Lex text on 31 July 2026.

1. Article 29 exemption list. Closed. The lettered carve-out from the reuse quotas — dangerous goods; large-scale machinery, equipment and commodities for which packaging is custom-designed; flexible formats in direct contact with food and feed; and cardboard boxes — sits at Article 29(4), with cardboard at point (d). Established by the verbatim list in the EUROPEN PPWR guidebook and by the delegated decision's recitation of Article 29's targets as paragraphs 1, 2, 3, 5 and 6 (C(2026) 511 final). Sighted on EUR-Lex, 31 July 2026: Article 29(4), point (d), confirmed in the operative text.

2. Battery-DRS assessment clause. Closed. Article 63 of Regulation (EU) 2023/1542: the Commission is to assess, by 31 December 2027, the feasibility and potential benefits of deposit-return systems for batteries, in particular portable batteries of general use. Sources: Council document ST 16339/25 (16 December 2025), citing Article 63 directly; concordant legal analyses.

3. BGBl. citation of the Austrian ordinance. Closed. Pfandverordnung für Einweggetränkeverpackungen, BGBl. II Nr. 283/2023, in force 26 September 2023 and applicable from 1 January 2025, issued under §§ 12b, 14, 14c, 23 and 28c AWG 2002 (RIS, BGBLA_2023_II_283).

4. Statutory basis for the retention of unredeemed deposits. Closed. § 14c Abs. 2 AWG 2002 expressly makes the use of unredeemed deposit amounts (Pfandschlupf) a subject of the ordinance; Abs. 2a requires the central body to be organised as a non-profit GmbH; Abs. 3 directs 0.5 per cent of producer contributions and 0.5 per cent of the annual Pfandschlupf to waste-prevention projects (parliamentary answer 1168/AB, XXVIII. GP). The ordinance's explanatory notes confirm that revenues remain within the deposit system and that no payout of unredeemed deposits or material gains to producers occurs.

5. Article 3 definition of e-commerce packaging. Closed. Sighted on EUR-Lex, 31 July 2026: Article 3(1), point (8) — 'e-commerce packaging' means transport packaging used to deliver products in the context of sale online or through other means of distance sales to the end user. The Commission proposal's point (5) did not survive the final renumbering; the paper cites Article 3 without a point number in the body, so the correction is confined to this appendix.