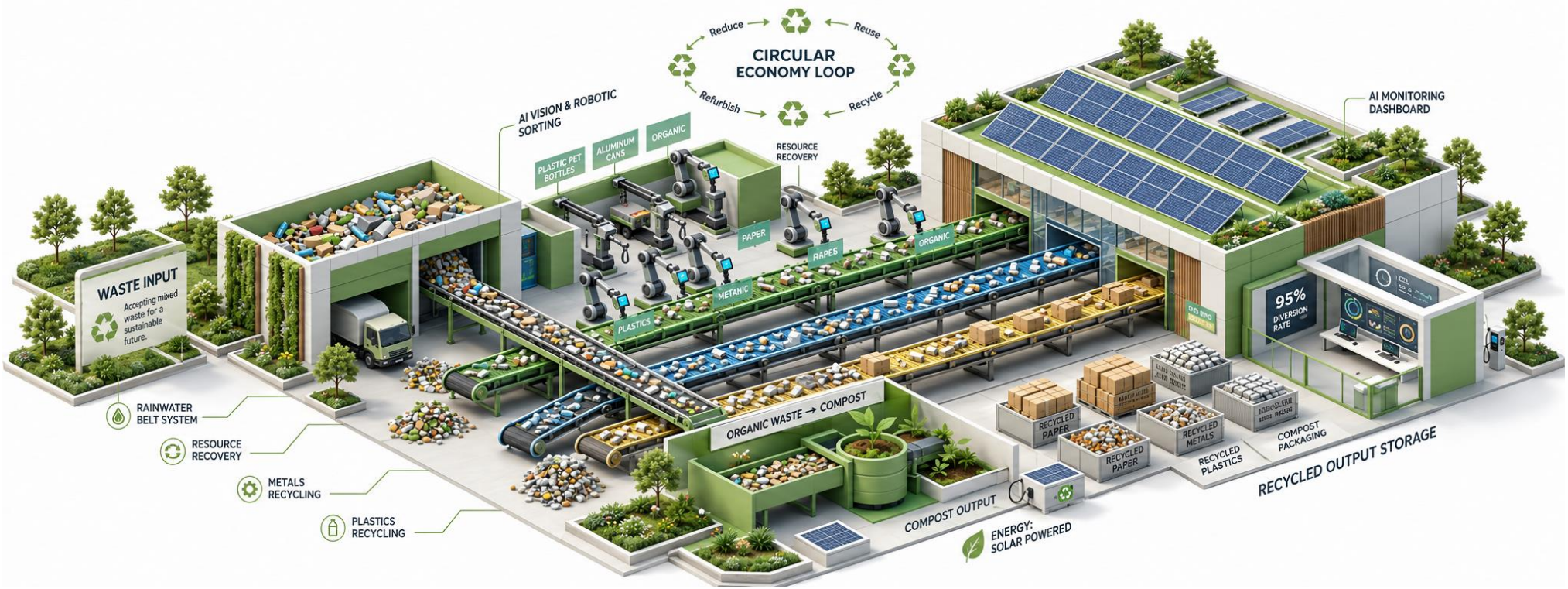
AI SORTING

WASTE RECEPTION & SMART SORTING SYSTEM – DETAILED TECHNOLOGY FRAMEWORK



Reference indicators concept-level: 1,250+ t/day capacity, 92% sorting accuracy, 98% material recovery, 40+ material categories, 24/7 smart operations, 678,540 t CO2 avoided reference, 95.8% operational efficiency reference – all require validation through waste characterization, mass-balance modelling and vendor performance guarantees. Role in ADS ECO Complex: First operational conversion stage after waste reception, creates stable, traceable and marketable material streams. Combines mechanical feed conditioning, machine vision, optical sensing, robotics, conventional separation and digital quality assurance. Supplies clean fractions to circular manufacturing, biological treatment, fuel preparation and energy-conversion modules.

01 | EXECUTIVE OVERVIEW – DESIGN PRINCIPLES & PROCESS GATES

Design Principle	Implementation
Design for variable municipal, commercial and industrial feedstocks	Feedstock acceptance spec, blending, modular lines, recipe management
Prioritize safety, availability, modular expansion and maintainability	Redundant drives, bypass conveyors, quick-change grippers, condition monitoring
Use cascade separation	Low-cost mechanical removal first, advanced sensors for high-value decisions, robots for flexible quality control
Maintain full material genealogy	Unique load ID from weighbridge ticket to bale, bunker or downstream process, time-stamped sensor decisions

Process Control Gate	Purpose	Control Method
Gate 1 – acceptance	Contract, source, weight, radiation/gas screen and visual inspection	Weighbridge, ANPR, radiation/gas detectors, cameras, RFID
Gate 2 – feed conditioning	Remove bulky, hazardous and entangling items; regulate size and belt loading	Bag opener, screens, ballistic separator, manual/robotic bulky removal
Gate 3 – classification	Fuse RGB, spectral, shape and position data into class/confidence results	NIR/VIS, RGB, 3D, XRT/LIBS, AI inference pipeline
Gate 4 – separation	Execute robot picks, air-jet ejection, magnetic and density-based separation	Robots, optical sorters, magnets, eddy-current, air classifiers
Gate 5 – quality	Verify purity and redirect off-spec material for rework	Online quality cameras, laboratory sampling, mass-balance reconciliation

Material Genealogy: Unique load ID linked to supplier, route, source and contract; Mass balance by conveyor, bunker, container, bale and dispatch vehicle; Sensor and robot decisions stored as time-stamped events; Laboratory results and customer specifications linked to each production lot; ESG reporting connects recovered mass, landfill diversion and avoided virgin-material emissions.

02 | WASTE RECEPTION, INSPECTION & FEEDSTOCK CHARACTERIZATION

Subsystem	Primary Function	Key Controls
Weighbridge & ANPR	Gross/tare/net weight; vehicle and contract ID; route verification	Calibration control; duplicate-ticket prevention
Radiation / gas screening	Detect abnormal radiation and combustible/toxic gas	Automatic quarantine and emergency workflow
Visual inspection	Identify prohibited, bulky, wet, smouldering or abnormal loads	Camera evidence and non-conformance record
Sampling station	Representative composition, moisture, density and contamination checks	Supports shift planning and model tuning
Tipping floor / bunkers	Segregated unloading, blending and controlled buffering	Fire detection, ventilation, drainage and wash-down
Feed metering	Grab crane, walking floor or apron feeder regulates line loading	Stable tonnes/hour and even material depth

Feedstock Acceptance Logic: Accepted – standard processing route; Conditionally accepted – additional inspection, manual removal or segregated processing; Rejected – prohibited or unsafe load returned or transferred to authorized treatment; Quarantined – suspected hot load, hazardous item, battery concentration or radiation alarm. Characterization Data: Composition by principal material family and particle-size band; Bulk density, moisture, ash/inert content and calorific value; Flexible-film content, fines, batteries, textiles, wood, glass and metal shares; Seasonal and route variability used to build feedstock forecasts and operating recipes.

03 | MECHANICAL PRE-SORTING & FEED CONDITIONING

Equipment	Function	Engineering Notes
Bag opener / low-speed shredder	Open bags without excessive size reduction	Torque control, anti-wrapping design, reversible drive
Manual / robotic bulky removal	Remove large, hazardous and entangling objects	Ergonomic cabins, positive picking, camera support
Trommel or disc screen	Separate fines and define particle-size bands	Aperture selection based on waste study
Ballistic separator	Split 2D, 3D and fines fractions	Deck angle, frequency and airflow optimization
Air classifier	Separate light films and paper from heavy rigid materials	Adjustable air velocity and recirculation
Dosing and acceleration conveyors	Create singulated, stable presentation for sensors	Belt speed, bed depth and gap control
Dust extraction	Capture airborne dust at transfer points	Local extraction, filters and differential-pressure monitoring

Stable feed – controlled loading and particle spacing; Low contamination – early removal of hazardous and bulky items; High sensor confidence – clean field of view and repeatable illumination; reduced wear – protect downstream sensors and robots.

04 | AI & MACHINE VISION SYSTEM

AI Inference Pipeline Step	Description
1. Acquire	Synchronized RGB, spectral, depth and encoder data
2. Segment	Individual objects and estimate position, velocity, orientation and overlap
3. Classify	Material type, color, form factor and contamination risk with confidence scores
4. Apply business rules	Value, purity priority, downstream capacity and robot availability
5. Transmit	Target coordinates and timing to selected actuator
6. Learn	Use downstream quality feedback for model drift detection and retraining

Model Governance Element	Requirement
Version control	Training data, model, threshold and deployment history
Validation sets	Separate validation for seasons, routes, lighting and contamination conditions
Human review	Low-confidence detections and false-positive/false-negative trends
Rollback capability	Cybersecurity approval and controlled production release
Performance reporting	By class, line, shift and feedstock source

05 | OPTICAL SORTING TECHNOLOGY

Sensor	Information Produced	Representative Use
RGB / line-scan camera	Color, shape, label, texture and object recognition	Glass color, package type, printed paper, object-level AI
NIR / hyperspectral	Polymer and organic molecular signature	PET, HDPE, PP, film, paper/organics discrimination
3D / laser profiling	Height, volume, shape and overlap	Position accuracy, object separation and robot guidance
XRT (optional)	Density / atomic-number contrast	Metals, PVC, stones, batteries and complex objects
LIBS (specialized)	Elemental composition from laser-induced plasma	Alloy sorting and selected high-value metals
Inductive sensor	Detect electrically conductive material	Small metal and non-ferrous detection

06 | ROBOTIC SORTING CELLS

Cell Engineering Aspect	Design Rule
Robot count	Selected from belt width, object density, target pick rate and class mix
Work envelopes	Minimize blind zones and allow bypass operation during maintenance
End effectors	Vacuum, adaptive fingers, magnets or hybrid gripping by material
Robot scheduler	Assigns objects using value, urgency, confidence, travel time and collision constraints
Reject verification	Downstream cameras for missed-pick analysis
Safety & Maintainability	Guarding, safety-rated scanners, interlocked doors, e-stop, safe torque off, quick-change grippers, centralized vacuum, auto cleaning, condition monitoring for gearboxes, vacuum performance, cycle time and motor temperature

07 | METALS, GLASS, FINES & DENSITY SEPARATION

Technology	Application	Design / Control Considerations
Overband magnet	Ferrous recovery above conveyor	Self-cleaning belt, adjustable height, metal burden monitoring
Drum magnet	Ferrous recovery from fines or controlled feed	High capture efficiency for small particles
Eddy-current separator	Non-ferrous recovery from sized dry fraction	Rotor speed, belt speed and splitter position
Air knife / zig-zag classifier	Light-heavy separation	Films, paper, labels and dust from rigid fractions
Glass cleanup line	Screening, aspiration, metal removal, optical color sorting	Protect cullet quality and remove ceramics/stones
Density separation	Wet or dry separation by specific gravity	Selected plastic and composite fractions
Fines management	Recover metals, organics or mineral fraction based on quality	Avoid uncontrolled dust and cross-contamination

Cascade Separation Strategy: Use least complex, lowest-cost separation step that can reliably remove a fraction, then reserve advanced sensor and robotic capacity for decisions that require higher selectivity, flexibility or value optimization. Recirculation Philosophy: Off-spec material not automatically rejected. Controlled recirculation loops allow second pass, alternative sensor recipe or manual QC route while preventing line overload and repeated contamination.

08 | MATERIAL-SPECIFIC RECOVERY LINES & QUALITY CONTROL

Stream	Critical Quality Controls	Typical Products
PLASTICS	Polymer and color purity, moisture, prohibited contaminants	rPET, rHDPE, PP flakes/pellets, film bales
FIBER	Moisture and contamination control, grade and bale density	OCC, mixed paper, recovered fiber pulp
METALS	Ferrous / non-ferrous and alloy separation, residual contamination	Steel scrap, aluminum, copper, brass concentrates
GLASS	Color and ceramic-stone removal, particle size	Clear/green/amber cullet, glass aggregate
SPECIAL STREAMS	Textiles, wood, batteries and mixed recyclables, hazardous removal	Sorted textiles, wood chips, battery fractions, RDF/SRF

Control Point	Method	Release Decision
Incoming control	Route/source profile, moisture, composition, prohibited items	Shift recipe and feed blending decision
Online quality camera	Residual contamination and missed target objects	Automatic recirculation or threshold adjustment
Bale sampling	Representative sample from production lot	Purity, moisture, color and prohibited-material test
Polymer verification	Portable NIR / FTIR or lab method	Confirm polymer grade and cross-polymer contamination
Metal analysis	Magnetic check, conductivity, XRF/LIBS where required	Confirm alloy or metal-family specification
Mass-balance reconciliation	Input, outputs, rejects, storage and dispatch	Detect losses, sensor drift and inventory errors
Certificate of analysis	Customer specification and traceability record	Release, hold, rework or downgrade decision

09 | CONVEYING, BALING, STORAGE & LOGISTICS – SCADA MES IoT

Subsystem	Function	Key Requirements
Conveyor network	Transfer materials between process stages	VSD, belt tracking, pull cords, blockage and speed sensors
Buffer bunkers	Decouple stages and stabilize downstream demand	Level measurement, FIFO logic, fire detection
Balers / compactors	Create transport-efficient market products	Automatic tying, density control, bale ID printing
Container loading	Direct loading for loose or densified products	Weight control, contamination prevention, dispatch confirmation
AGV / forklift logistics	Move bales, bins and maintenance materials	Traffic zoning, charging, collision avoidance and WMS integration
Storage management	Assign location, age and customer order	RFID/QR, inventory reconciliation and quarantine zones
Fire protection	Early detection and rapid isolation	Thermal cameras, spark detection, hydrants/sprinklers and response plan

Layer	Primary Responsibility	Examples
PLC / Safety PLC	Deterministic machine and safety control	Conveyors, robots, valves, drives, interlocks and emergency stops
SCADA / HMI	Operator visualization, alarms, trends and recipes	Line control room and local panels
Historian	High-frequency time-series data and event storage	Performance analysis and troubleshooting
MES	Production orders, genealogy, quality and OEE	Material lots, balances, downtime and product release
IoT / Edge gateway	Condition monitoring and protocol normalization	Vibration, energy, temperature and equipment health
Data platform	Cross-zone analytics and reporting	Enterprise dashboards, AI training and ESG indicators
Integration layer	Secure API / message bus	ERP, WMS, TMS, laboratory, maintenance and investor dashboard

10 | DIGITAL TWIN, ANALYTICS & INTELLIGENT OPTIMIZATION

Digital Twin Scope	Description
Dynamic mass-balance model	By feedstock, process stage and material class
Conveyor and equipment-state model	Linked to real-time tags
Robot cycle, queue and target-allocation simulation	Queue optimization and bottleneck detection
Storage, bale and dispatch inventory model	Inventory and dispatch planning
Energy, emissions and maintenance state representation	Energy optimizer and maintenance predictor
Scenario comparison	Throughput, recovery, purity and operating cost scenarios

Analytics Module	Inputs	Output / Action
Throughput optimizer	Feed rate, belt loading, downstream capacity	Setpoint recommendations within safe operating envelope
Purity optimizer	Sensor confidence, quality camera, lab results	Threshold and recirculation tuning
Maintenance predictor	Vibration, temperature, current, cycle count	Remaining-useful-life and work-order priority
Market optimizer	Inventory, quality, price and order data	Product routing, blending and dispatch plan
Energy optimizer	Power demand, tariff, equipment state	Load scheduling and peak-demand control

11 | SAFETY, ENVIRONMENTAL & ESG CONTROLS – KPIs

Risk Area	Primary Hazard	Core Controls
Fire and thermal risk	Batteries, hot loads, friction, stored combustible	Thermal cameras, spark detection, segregation, automatic suppression and emergency bunkers
Dust and air quality	Transfer points, fines, dry paper and plastics	Enclosures, local extraction, filtration and housekeeping
Noise and vibration	Screens, shredders, balers, compressors	Acoustic enclosures, isolation and exposure monitoring
Hazardous materials	Batteries, chemicals, medical or unknown items	Early removal, sealed containers, quarantine and authorized disposal
Machine safety	Moving conveyors, robots, balers and compactors	Guarding, interlocks, lockout/tagout and safety-rated controls
Water and drainage	Wash-down, firefighting and contaminated runoff	Segregated drains, oil/silt traps, collection and treatment
Cybersecurity	Remote access, malware and unauthorized control	Network segmentation, MFA, backups, allowlisting and incident response

ESG Dimension	Implementation
LANDFILL DIVERSION	Recovered materials routed to productive use, >95% diversion indicative
CARBON ACCOUNTING	Mass-balance-based avoided disposal and virgin-material substitution, 678k tCO2 reference
WORKER PROTECTION	Engineering controls before administrative controls and PPE, TRIR <1.0 target
AUDITABILITY	Time-stamped evidence for ESG reporting, traceable from weighbridge to bale

12 | EQUIPMENT SCHEDULE & IMPLEMENTATION

System Block	Indicative Equipment	Key Tender Parameters
Reception	Weighbridges, ANPR, radiation/gas screen, tipping floor, bunkers	Capacity, axle config, detection thresholds, fire and drainage design
Feed conditioning	Bag opener, screens, ballistic separator, air classifier, dosing conveyors	Particle-size range, feed density, wrapping resistance, bypass and redundancy
Optical sorting	RGB/NIR/3D sensor units, illumination, air manifolds	Belt width/speed, pixel resolution, spectral range, valve pitch and air demand
Robotic sorting	Industrial robots, grippers, vision interface, safety cells	Reach, payload, picks/min, success rate, class count and availability
Metals recovery	Magnets, eddy-current, inductive and optional sensor sorters	Particle-size band, throughput, recovery and product purity

Quality control	Online cameras, laboratory instruments, sampling equipment	Methods, calibration, sampling frequency and release criteria
Baling / storage	Balers, compactors, conveyors, WMS/RFID	Bale density, dimensions, tying system, storage capacity and fire controls
Utilities	Compressed air, power distribution, extraction, fire water, drainage	Demand profile, redundancy, efficiency and monitoring
Automation	PLC, safety PLC, SCADA, historian, MES, network, servers	Architecture, protocols, cybersecurity, retention and disaster recovery

Phase	FEED Inputs / Activities	Deliverables
Concept validation	Representative waste composition by season, route and source; Daily/weekly tonnage profile, peak loads and operating hours	Basis of Design and preferred configuration
Basic engineering	Process flow diagrams, mass balance, equipment datasheets, general arrangement	Basic engineering package and CAPEX/OPEX estimate
Permitting and procurement	Site survey, building envelope, utilities, fire strategy, environmental permit, interfaces with downstream	Approved permits and supplier packages
Detailed design and construction	Civil, mechanical, electrical, automation, quality lab and fire systems	Installed and inspected facilities
Commissioning	Mechanical completion, dry commissioning, hot commissioning with progressive feed rates and tuned sensor recipes	Commissioning records and acceptance tests
Ramp-up	Performance test under agreed reference feedstock, operator competence, maintenance readiness	Stable recovery, purity and traceability