INPAC LIVING LEARNING LAB

Living Learning Lab

Understanding Waste, Technology & Resource Recovery

University, Professional & Institutional Visitor Handbook



TOSS Center, Klungkung, Bali, Indonesia

PT INPAC SOLUTION INDO (INPAC Solutions) and W.E. (Waste Education)

For a Cleaner Tomorrow

LIVING LEARNING LAB · VISITOR HANDBOOK

Contents

CONTEXT

01 Introduction to the Living Learning Lab 3

02 Understanding the Waste Challenge 6

THE FACILITY

03 Introduction to INPAC's Processing Facility 9

04 Waste Sorting and Material Preparation 11

SCIENCE & TECHNOLOGY

05 The Science of Pyrolysis 14

06 Understanding the Pyrolysis Reactors 17

07 Resource Recovery and Products 20

ANALYSIS

08 Mass Balance and Energy Balance 22

09 Environmental Management and Safety 25

10 Operational Efficiency and System Performance 28

APPLICATION

11 Implementing Similar Systems at Other Sites 29

12 Research Opportunities for Universities 30

LEARNING

13 The Role of W.E. (Waste Education) 31

14 The Visitor Learning Experience 32

15 Discussion Questions and Activities 33

REFERENCE

16 Glossary and References 35

PRACTICAL WORKSHEETS

A Waste Characterisation 37

B Technology Observation 38

C Mass Balance 39

D Site Implementation Assessment 40

E Research Proposal 41

About this handbook

This handbook supports educational visits to the INPAC Living Learning Lab at TOSS Center, Klungkung. It is written for university students and lecturers, professionals, government delegations and community organisations, and can be read before, during and after a visit.

It is an educational resource. It does not replace the facility's operating procedures, safety documentation or engineering manuals.

How to read the information boxes

FACILITY INFORMATION
INPAC equipment, nominal capacities and technical observations.

HYPOTHETICAL EXAMPLE
Invented numbers for teaching. Never INPAC operating data.

SAFETY
Rules and precautions. Site instructions always take precedence.

KEY CONCEPT
Core scientific or engineering idea to remember.

ACTIVITY
Something to observe, discuss or record on a worksheet.

PART I · CONTEXT

01 Introduction to the Living Learning Lab

LEARNING OBJECTIVES

- Explain what a Living Learning Lab is and why it is located inside a working facility.
- Contrast classroom learning with structured industrial observation.
- Describe the respective roles of INPAC Solutions and W.E.
- Identify how education, processing and research can reinforce each other.

> "Turning real-world environmental challenges into opportunities for education, innovation, and sustainable solutions."

What is a Living Learning Lab?

A Living Learning Lab is a place where learning happens inside a real operating system rather than in a simulated one. Instead of studying waste management only through textbooks and lecture slides, visitors observe the actual materials, machines, people and decisions that shape how waste is received, prepared and processed. The facility is not modified to look like a classroom; instead, the visit is designed so that the working facility itself becomes the teaching material.

The concept draws on experiential learning: people understand complex systems more deeply when they can connect abstract principles, such as heat transfer or mass conservation, to something they have seen, heard and questioned in person.

Classroom learning and industrial observation

A classroom explains ideal behaviour: a clean feedstock, a steady temperature, a balanced equation. A working facility shows real variability: wet material after rain, mixed bags that must be opened and sorted, maintenance that interrupts a schedule, and judgement calls made by trained operators. Both views are necessary. Theory provides the vocabulary to describe what is observed, and observation reveals which assumptions in the theory matter most in practice.

Why TOSS Center Klungkung?

TOSS Center in Klungkung, Bali, brings several stages of a waste-to-resource chain onto one site: screening, material preparation and thermal processing by pyrolysis. This allows visitors to follow material along a sequence of operations within a single visit and to discuss the connections between them, which is rarely possible in a lecture theatre.



SITE PHOTOGRAPH · TOSS CENTER

Two organisations, complementary roles

INPAC SOLUTIONS

PT INPAC SOLUTION INDO operates the processing equipment at the site. Its role in the Lab is to provide access to real operations, share technical knowledge about its systems, and ensure that every educational activity respects operational and safety requirements.

W.E. (WASTE EDUCATION)

W.E. focuses on public understanding of waste. Its role is to translate technical subjects into learning experiences for schools, communities and the wider public, and to connect the facility with educational audiences.

Education, processing and research working together

INPAC Solutions and W.E. bring technical practice and waste education together through the Living Learning Lab. A working facility generates valuable questions: why do batches behave differently, how does moisture affect energy use, and what does condensate contain? These questions connect engineering observation with classroom learning and structured investigation. The Lab gives students, professionals and communities a shared framework for understanding waste systems and identifying practical improvements.

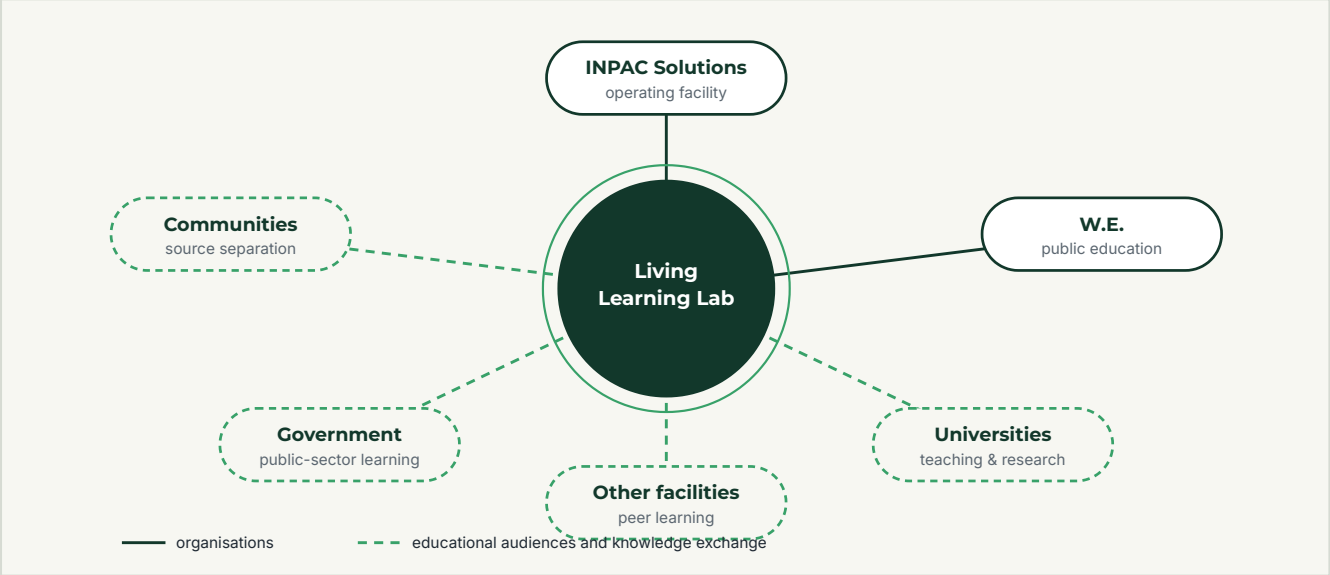


Figure 1.1 INPAC and W.E. connect technical practice with education and public learning. *Dashed links identify educational audiences and areas of exchange.*

Benefits for Klungkung, Bali and Indonesia

For Klungkung, the Lab can help residents see what happens to waste after collection and why separation at home matters. For Bali, where tourism and daily life both depend on a clean environment, it offers a practical reference point for discussing waste-to-resource options. For other regions of Indonesia, it may serve as a place where planners and operators can study one approach in detail before deciding whether, and how, a similar approach suits their own conditions.

LEARNING OUTCOMES FOR THE FULL PROGRAMME

- Describe the waste management hierarchy and the place of waste-to-resource technologies within it.
- Explain the basic science of pyrolysis and how it differs from combustion.
- Identify the main output streams and why each requires testing and management.
- Apply a simple mass balance to observational data.
- Recognise the environmental, safety and operational factors that determine real performance.
- Evaluate what another site would need to assess before adopting a similar system.

PART I · CONTEXT

02 Understanding the Waste Challenge

LEARNING OBJECTIVES

- Define municipal solid waste and its main components.
- Distinguish organic, inorganic, plastic and rubber fractions.
- Explain why mixed and contaminated waste is hard to manage.
- Read published waste statistics with attention to scope and date.

Municipal solid waste

Municipal solid waste (MSW) is the everyday waste produced by households, shops, markets, offices, schools and similar sources, and usually collected or managed by, or on behalf of, local government. It excludes most industrial process waste, construction debris and hazardous waste, which are normally regulated separately, although in practice some of these materials still find their way into municipal streams.

Household waste composition

Composition describes what waste is made of, usually as percentages by mass: food and garden waste, paper and cardboard, plastics, textiles, glass, metals, rubber and leather, and "other" material. In many lower- and middle-income settings, food and other organic waste make up the largest single share. Composition varies with income, season, culture, tourism and collection practices, which is why it must be measured locally rather than assumed.

Organic and inorganic waste

Organic waste is biodegradable material of biological origin, such as food scraps, leaves and offerings. It is wet, decomposes quickly and, in landfills, can generate methane and leachate. Inorganic waste includes materials such as glass, metals and most plastics, which do not readily biodegrade. Separating the two keeps organics clean for composting or digestion and keeps dry materials clean for recycling or other recovery.

Plastics and rubber

Plastics are synthetic polymers, mostly derived from fossil hydrocarbons. Rigid, single-polymer items are often mechanically recyclable, while thin films, multilayer sachets and contaminated packaging frequently are not. Rubber, including end-of-life tyres, is a cross-linked polymer reinforced with fillers and steel or textile cords, which makes it durable in use and difficult to recycle at end of life.

Mixed and contaminated waste

When organics, plastics, sand, glass and liquids are collected together, every material contaminates the others. Wet food residue lowers the value of plastics, fine grit damages machinery, and small hazardous items such as batteries create fire and pollution risks. Most downstream technologies, including thermal processes, perform better and more safely with cleaner, better-characterised input.

VERIFIED GLOBAL CONTEXT, WITH SCOPE AND DATE

The World Bank's What a Waste 2.0 report estimated that the world generated 2.01 billion tonnes of municipal solid waste in 2016 (Kaza et al., 2018; hdl.handle.net/10986/30317). UNEP's Global Waste Management Outlook 2024 estimates global municipal solid waste at 2.1 billion tonnes in 2023 and projects 3.8 billion tonnes by 2050 if current trends continue (UNEP, 2024).

Both estimates refer to global municipal solid waste, not to Bali or Klungkung. They use different reference years and assessment methods and should not be treated as a directly comparable local time series.

Landfill dependence and improper dumping

Where collection and treatment capacity is limited, most waste ends up in landfills or open dumpsites. A dumpsite that lacks a liner, leachate collection, gas management and daily cover can pollute surrounding land and water for decades. Where collection does not reach a community at all, waste is often burned in the open, dumped in rivers and ravines, or buried informally.

Why separation at the source matters

Separating waste where it is generated, at home or at a market stall, is the cheapest and most effective point of intervention. A few seconds of separation at source avoids hours of sorting later, keeps recyclables saleable, keeps organics clean, and improves the quality and predictability of material arriving at any processing facility.

MEDIUM	TYPICAL PATHWAY OF HARM	EXAMPLES OF CONSEQUENCES
Soil	Leachate, ash and fragments from dumped or burned waste	Contamination by metals and persistent pollutants; degraded agricultural land
Water	Leachate migration, waste in drainage channels and rivers	Polluted groundwater and surface water; flooding from blocked drains; marine litter
Air	Open burning, decomposing organics, uncontrolled fires	Smoke and particulate exposure; methane, a potent greenhouse gas; odour

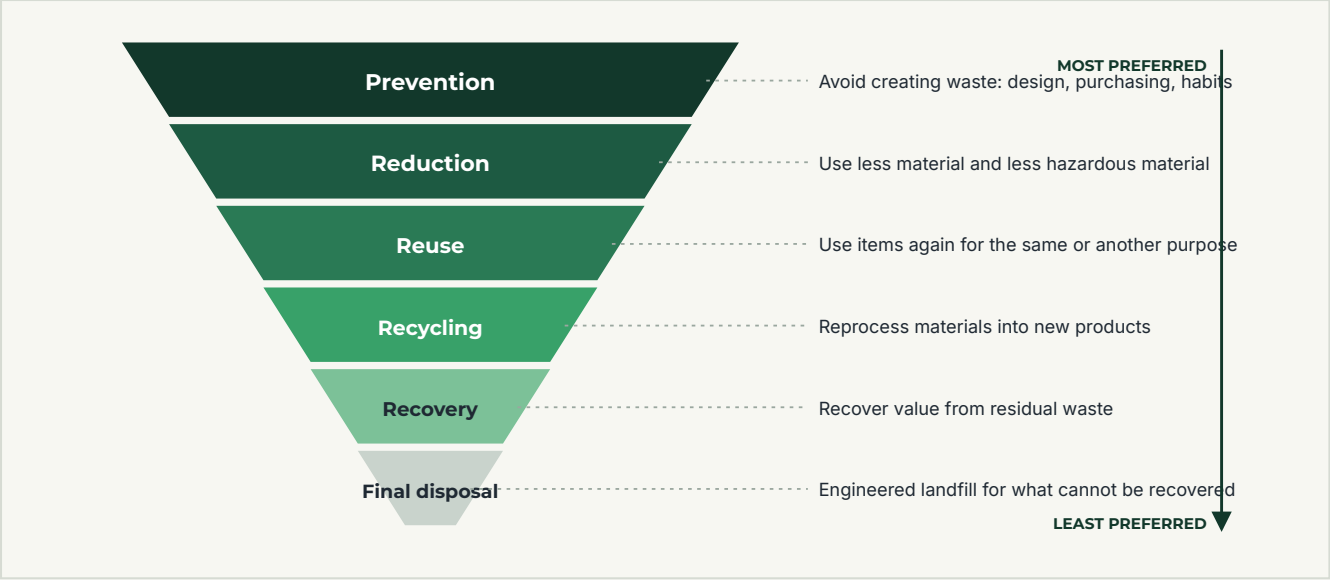


Figure 2.1 The waste management hierarchy: options higher up are generally preferred where they are practical. *Classification of thermal conversion as recycling or recovery depends on jurisdiction and on how outputs are used.*

Where waste-to-resource fits

The hierarchy ranks Prevention, Reduction, Reuse, Recycling, Recovery and Final Disposal. Waste-to-resource technologies such as pyrolysis address material that remains after prevention, reuse and conventional mechanical recycling. They complement those options; they do not replace them. A community that skips separation and recycling in favour of a single technology usually ends up with poorer feedstock, higher costs and weaker environmental outcomes.

The circular economy, explained

A linear economy follows "take, make, use, discard". A circular economy tries to keep materials in use at their highest value for as long as possible, through durable design, repair, reuse, recycling and, last, recovery. Physically, materials cannot circulate forever: each cycle loses some quality and requires energy. The scientific aim is therefore to slow, narrow and close material loops while accounting honestly for energy use and emissions at each stage.

PART II · THE FACILITY

03 Introduction to INPAC's Processing Facility

INPAC's processing facility at TOSS Center combines waste sorting, material preparation and batch pyrolysis. The equipment includes an 8-tonne/hour trommel, two horizontal reactors with nominal batch capacities of 4 tonnes each, and one smaller 750-kg reactor. Prepared, suitable material proceeds to thermal processing; separated recyclables and unsuitable fractions follow appropriate alternative routes.

AREA	EQUIPMENT	CAPACITY OR PROCESSING ROLE	FUNCTION
Waste sorting	Trommel screening system	Nominal capacity 8 tonnes/hour	Separates material by size; prepares fractions for further handling
Material preparation	Shredding equipment	Feed size reduction	Reduces particle size for more uniform feed
Material preparation	Baling and storage equipment	Material consolidation and storage	Compacts and stores prepared material
Material preparation	Material handling and feed preparation	Feed conditioning and transfer	Moves and conditions material ahead of processing
Pyrolysis	Horizontal reactors (2 units)	Nominal batch feed 4 tonnes each	Thermal decomposition of suitable feedstock
Pyrolysis	Smaller reactor (1 unit)	Nominal batch feed 750 kg	Thermal decomposition at smaller batch scale
Pyrolysis	Condensation and recovered-liquid collection; gas handling; cooling	Product recovery and heat removal	Recover condensable vapours; route gases; cool equipment and products

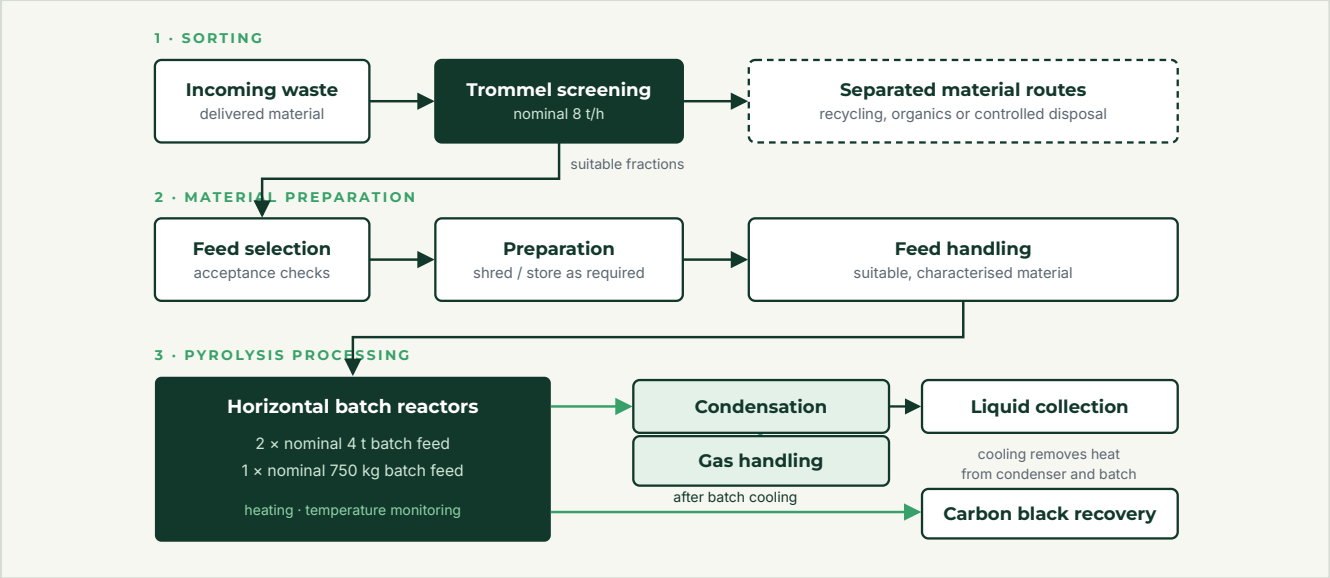


Figure 3.1 From screening and material preparation to pyrolysis and resource recovery. *Process relationships rather than equipment placement; preparation follows feed requirements.*

NOMINAL CAPACITY IS NOT DAILY THROUGHPUT

A nominal batch capacity describes how much material a reactor is designed to receive in one batch. It does not state how many batches are completed per day. Actual throughput depends on feedstock characteristics such as moisture and density, heating and cooling time, maintenance, staffing and operational scheduling. Likewise, a trommel's nominal hourly rating assumes suitable material and continuous feeding.



PART II · THE FACILITY

04 Waste Sorting and Material Preparation

LEARNING OBJECTIVES

- Explain why preparation determines downstream performance.
- List the material properties that are characterised before processing.
- Describe how a trommel separates material by size.
- Explain why unsuitable and hazardous items must be removed.

Thermal processes are sensitive to what goes into them. Preparation turns an unpredictable mixture into a feed whose behaviour can be anticipated, monitored and managed.

Waste characterisation

Characterisation is the systematic measurement of what a waste stream contains. A typical study takes representative samples over several days, sorts them by category and weighs each fraction. It may also measure moisture, ash and calorific value. Without characterisation, operators and planners are guessing.

Material identification

Different plastics behave differently when heated. Polyolefins such as polyethylene (PE) and polypropylene (PP) consist mainly of carbon and hydrogen. Polyvinyl chloride (PVC) contains chlorine, and polyethylene terephthalate (PET) contains oxygen; both can create corrosive or undesirable products in pyrolysis and are commonly kept out of feed. Resin identification codes help, but many items are unlabelled.

Moisture content

Water entering a reactor must be heated and evaporated before the material itself decomposes. This consumes energy, lengthens batch time and can add water to the recovered liquid. Covered, ventilated storage and the removal of wet organic contamination reduce moisture.

Contamination

Sand, glass, metals, food residue and labels add mass that does not convert into useful products. Inorganic contaminants largely remain in the solid residue, increasing its quantity and complicating its management. Abrasive grit also accelerates equipment wear.

Particle size and consistency

Smaller, more uniform pieces heat more evenly because heat must travel a shorter distance into each piece. Consistent material also packs more predictably, so batch loading and batch duration are easier to plan. Large variations in size or composition between batches make outcomes harder to compare.

Handling and storage

Prepared material should be stored in an organised way that limits rain exposure, fire risk and mixing between grades. Baling compacts loose material, saves space and makes stock easier to count, move and record. Good housekeeping in storage areas is also a core fire-prevention measure.

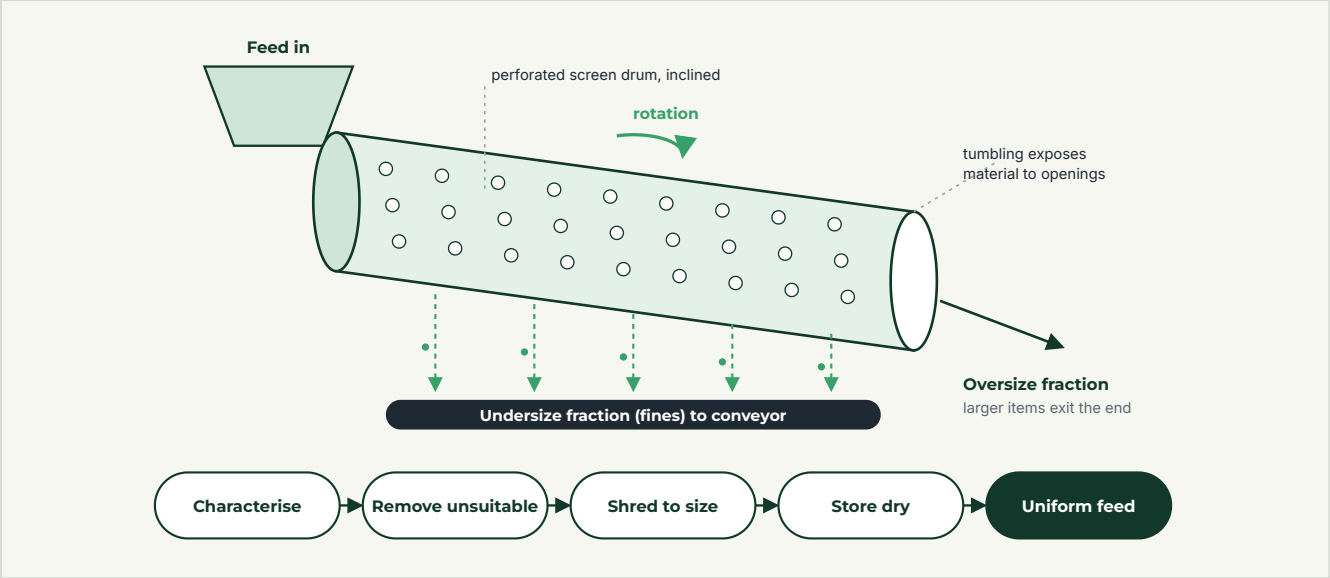


Figure 4.1 How a trommel screen separates material, and the preparation sequence that follows. *Educational schematic. Not an engineering drawing or site layout.*

How a trommel works

A trommel is a rotating cylindrical screen that separates material primarily by size. Rotation tumbles the material and exposes it to the screen openings. Smaller pieces fall through as the undersize fraction; larger pieces travel along the drum and leave as the oversize fraction. Separation depends on opening size, feed rate, moisture, rotation and inclination. Size fractions are not pure material categories: plastics, organics and grit can occur in either. A trommel is not a bag opener; closed bags require separate preparation where necessary.


SITE PHOTOGRAPH · TROMMEL

Shredding and uniform feed size

Shredders cut or tear material into smaller pieces. Uniform particle size supports even heating, more predictable loading density and steadier batch behaviour. Shredding is not a cleaning step: contaminants that enter the shredder remain in the material.

⚠ SEPARATING UNSUITABLE AND HAZARDOUS MATERIALS

Batteries, gas canisters, aerosol cans, medical waste, chemical containers and electronic waste must never enter thermal processing. They can cause fires, explosions or toxic releases. Material acceptance must follow the facility's site-specific operating requirements, which take precedence over any general guidance in this handbook.

OBSERVATION ACTIVITY

Observe the incoming material and identify how preparation could influence downstream processing. Note one example each of moisture, contamination and size variation, and suggest which preparation step would address it. Record your notes on Worksheet A.

PART III · SCIENCE & TECHNOLOGY

05 The Science of Pyrolysis

Pyrolysis is thermal decomposition in the absence of oxygen in the reaction zone. Heat drives chemical bond breaking and rearrangement, producing gases, condensable vapours and solid residue rather than burning the feedstock.

Thermal decomposition

Heat breaks bonds in polymers and other organic molecules. Cracking, rearrangement and secondary reactions form a range of products: gases, vapours that condense on cooling, and carbon-rich solids. Inorganic fillers and contaminants also contribute to the residue. These reactions differ from oxidation by oxygen during combustion [4].

Heat transfer

In an indirectly heated system, heat crosses the vessel wall into the feed. Conduction, convection and radiation influence the temperature distribution. Particle size, loading density and heat-transfer conditions affect how uniformly a charge heats. A temperature measured at one point does not describe the entire batch.

Temperature and residence time

Temperature affects reaction rates and product distribution. Solid residence time and vapour residence time are different: longer exposure of hot vapours can promote secondary cracking, gas formation or carbon deposition. Higher temperature often increases lighter products, but the outcome depends on feed chemistry and reactor conditions.

Composition and moisture

Polymer structure, oxygen content, additives and contamination influence products. Chlorine and sulphur can form corrosive or undesirable compounds. Moisture consumes heat during warming and evaporation, alters the thermal profile and adds water to condensate. Its effects must be separated from changes in dry-feed composition.

Vapours, gases and condensation

Cooling the vapour stream condenses compounds according to their volatility and the collection conditions. Hydrocarbon-rich liquid, wax and aqueous condensate can form. Hydrogen, methane and other light species remain gaseous at collection conditions. Condenser performance therefore affects the apparent liquid and gas yields.

Solid residue formation

Carbonisation and secondary reactions produce a carbon-rich solid, commonly called char. INPAC recovers this solid as carbon black; laboratory results show a calorific value of 4,200–7,200 kcal/kg. Feedstock, ash and moisture affect the properties of the solid product, so sample characterisation remains important.

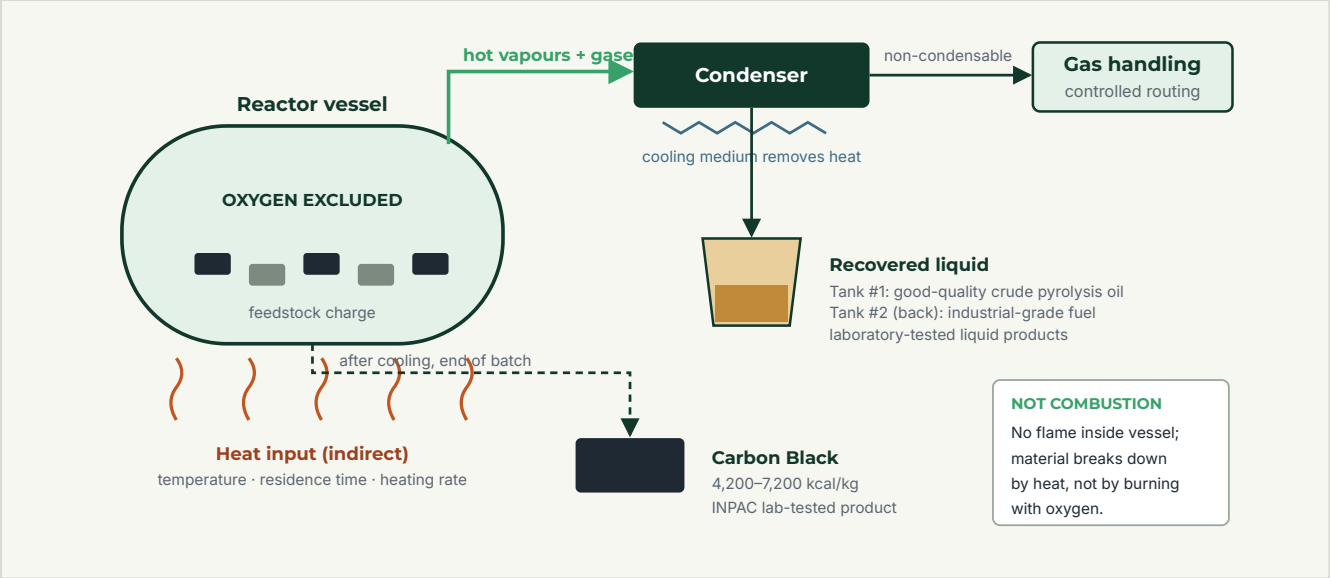


Figure 5.1 Simplified pyrolysis process showing INPAC's carbon black and recovered-liquid products. *Educational schematic. Not an engineering drawing or site layout.*

How conditions and materials influence product yields

Product distribution, meaning the share of liquid, gas and solid produced, is not a fixed property of a technology. It changes with feedstock, temperature, heating rate, residence time, reactor design and how efficiently vapours are condensed. The scientific literature on plastic pyrolysis, reviewed for example by Al-Salem et al. (2017), reports wide ranges for these reasons. Results from one facility or one study should not be transferred to another without care.

FEEDSTOCK	MAIN COMPOSITION	GENERAL BEHAVIOUR IN PYROLYSIS	POINTS OF ATTENTION
Plastics (PE / PP)	Mainly carbon and hydrogen; additives vary	Can yield hydrocarbon liquids, waxes and gases; the split changes with conditions	Not all plastics behave alike; PVC releases acid gas and PET forms oxygenated products
Rubber / tyres	Cross-linked polymers, filler carbon, sulphur, steel and textiles	Yield liquids, gases and carbon-rich residue; steel remains a separate solid fraction	Sulphur, additives and residue quality require testing
Suitable organic materials	Biomass polymers, oxygen, minerals and variable moisture	Form oxygenated vapours, water, gases and char; yields depend on material and conditions	Wet organics are not equivalent to dry biomass; aqueous phases and acidity need management

Why mixed feedstocks behave differently

Mixed feeds combine different decomposition behaviours, moisture levels and additives. Vapour interactions and heat-transfer changes mean their yields need not equal a weighted average of separate feeds. Organic material can contribute water, oxygenated compounds and char; the extent depends on its composition and conditions. Comparisons should use consistent mass and moisture bases.

INPAC TRIALS AND PRODUCT RESULTS

Mixed plastic and organic feedstock trials showed lower recovered-liquid yield and changes in solid-product energy characteristics. INPAC's carbon black has a laboratory-tested calorific value of 4,200–7,200 kcal/kg. The calorific range describes tested carbon-black samples, not a fixed yield or a guarantee for every feed mixture.

Pyrolysis is not combustion

ASPECT	PYROLYSIS	COMBUSTION
Oxygen	Excluded from the reaction zone	Participates in oxidation; supply affects completeness
Main purpose	Break material into liquid, gas and solid products	Release heat by oxidation
Primary products	Condensable vapours, non-condensable gas, char	Mainly carbon dioxide and water when complete; pollutants can also form
Energy	Heat is supplied to maintain decomposition	Oxidation releases heat
Heating and flame	A separate burner can supply heat without burning the feed	Can be flaming or flameless; flame is not the defining test

SCOPE OF THIS CHAPTER

This handbook explains principles only. It intentionally contains no operating setpoints, pressure limits, valve sequences or step-by-step instructions for industrial operation. Those belong in the facility's approved procedures and are used only by trained, authorised operators.

PART III · SCIENCE & TECHNOLOGY

06 Understanding the Pyrolysis Reactors

LEARNING OBJECTIVES

- Name the functional parts of a horizontal batch pyrolysis system.
- Explain what each part contributes to the process.
- Describe the stages of a batch cycle conceptually.
- Compare the nominal 4-tonne and 750-kg reactor sizes.

INPAC uses horizontal batch reactors to process prepared feedstock. Each charge is loaded, heated and cooled before residue removal and the next cycle. The reactor vessel contains the reaction; the surrounding assembly supports heating, vapour recovery, cooling and controlled handling. The flow below explains these functions without assigning component positions or dimensions.

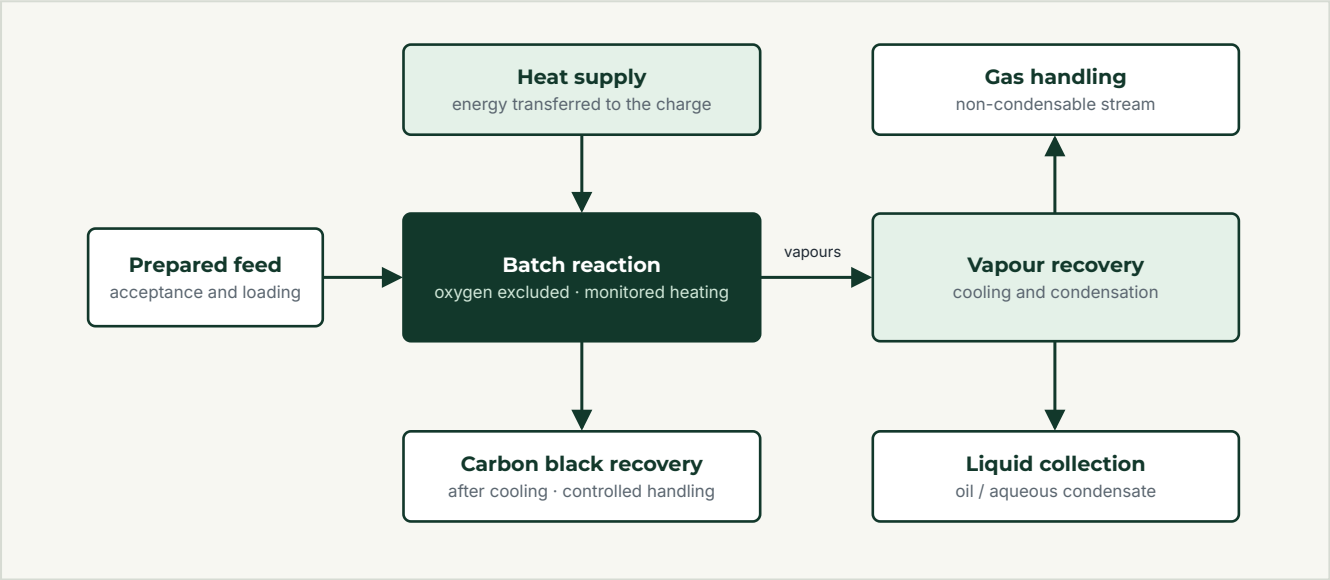


Figure 6.1 Functions of a batch pyrolysis system and its recovery streams. *Functional relationships, not a machinery blueprint.*

PROCESS FUNCTION	ENGINEERING PURPOSE
Feed loading	Prepared feed enters the vessel before the batch is sealed for processing.
Reaction vessel	Contains the feed during thermal decomposition with oxygen excluded from the reaction zone.
Heat supply	Transfers energy into the charge to warm the material and sustain decomposition.
Temperature monitoring	Provides readings for trained operators to assess thermal progress within the approved procedure.
Vapour transfer	Carries volatile products from the reaction zone towards recovery.
Condensation and collection	Removes heat from vapours and collects condensable liquids for testing and management.
Gas handling	Controls the non-condensable stream through engineered containment and routing.
Cooling and solid-product recovery	Removes heat and enables controlled handling of INPAC carbon black and other cooled solid material.



INPAC · GREEN REACTOR ASSEMBLY



INPAC · SILVER REACTOR ASSEMBLY

Actual INPAC equipment at TOSS Center. Both photographs show the horizontal cylindrical outer enclosure and metal frame. Exterior views do not show the internal reaction chamber or its instruments.

The batch cycle, conceptually

1	2	3	4	5	6
Preparation	Loading	Thermal processing	Vapour recovery	Cooling	Residue management

Each batch begins with prepared, characterised material. After loading and sealing, the charge is heated; volatile products leave as vapour and are condensed or routed as gas. When decomposition is complete, the system is cooled before the residue is removed and contained. Because heating and cooling are part of every cycle, batch duration is strongly influenced by charge size, moisture and the time needed to cool safely.

CHARACTERISTIC	HORIZONTAL REACTORS	SMALLER REACTOR
Number at site	2	1
Nominal batch feed	4 tonnes each	750 kg
Relative scale	Production-scale batches	Roughly one-fifth of a large batch by nominal feed
Educational relevance	Shows full-scale handling, heating and cooling demands	Illustrates how batch size influences handling and thermal requirements
Daily throughput	Depends on full cycle time and scheduling	Depends on full cycle time and scheduling

⚠ **OPERATION IS RESTRICTED**

Industrial operation of the reactors is restricted to trained and authorised operators following the facility's approved standard operating procedures (SOPs). Visitors observe from designated areas only and must not touch controls, valves, hatches or hot surfaces.

PART III · SCIENCE & TECHNOLOGY

07 Resource Recovery and Products

INPAC recovers carbon black, crude pyrolysis oil and industrial-grade fuel. Laboratory testing establishes product properties and supports appropriate use. Non-condensable gas and aqueous condensate remain separate streams requiring controlled handling.

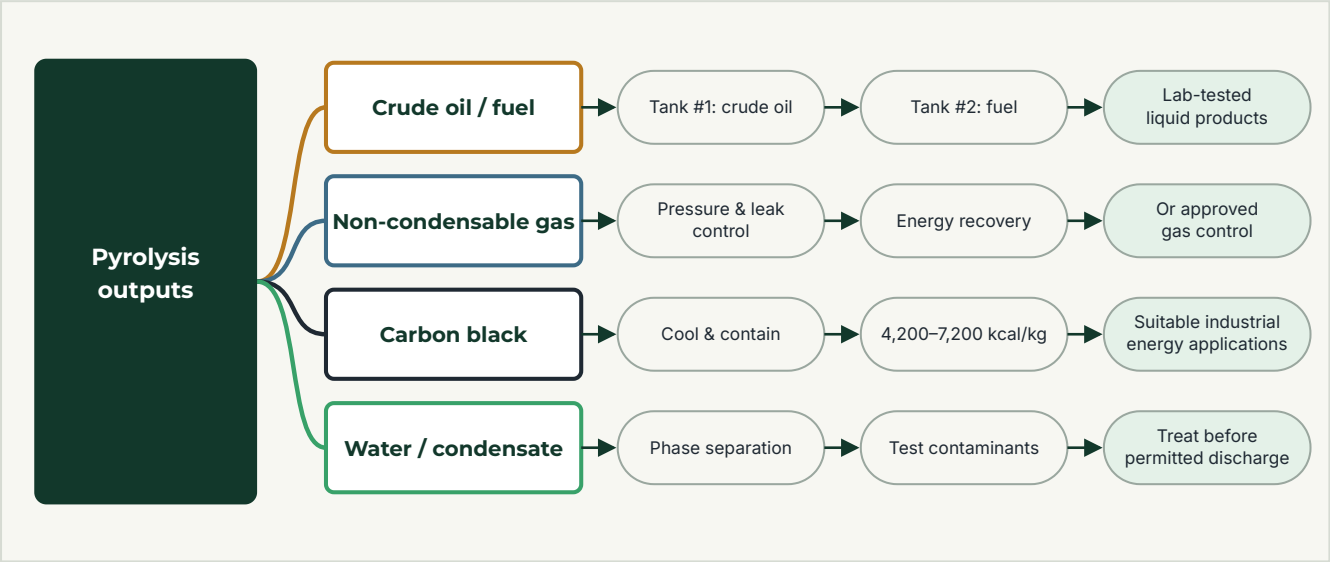


Figure 7.1 INPAC product streams and responsible handling pathways. *Educational schematic. Not an engineering drawing or site layout.*

Recovered liquids

INPAC's laboratory results identify the liquid collected in Tank #2, the back tank following condensation, as industrial-grade fuel. Tank #1 contains good-quality crude pyrolysis oil. These are distinct collection points and product descriptions. Pyrolysis oil is derived from thermal decomposition, not extracted petroleum. Industrial-grade fuel does not automatically mean automotive diesel: its intended use determines the applicable specification and handling requirements.

Non-condensable gases

These gases do not condense under collection conditions and typically include hydrogen, methane and other light hydrocarbons, together with carbon oxides. They are flammable. With proper design they may be used for controlled energy recovery, for example to supply part of the process heat. Pressure control, leak prevention and safe routing are essential.

Carbon black

INPAC's recovered carbon black has a laboratory-tested calorific value of 4,200–7,200 kcal/kg. This demonstrates its energy content and supports evaluation for suitable industrial energy applications. Calorific value measures energy released during combustion; it does not describe every material property. Ash, moisture, sulphur, metals and particle characteristics also matter when selecting an application. General pyrolysis science uses “char” or “solid residue” for the wider category; this handbook identifies INPAC's recovered product as carbon black.

Water and contaminated condensate

Water enters with moisture and can form during decomposition of oxygen-containing feed. An aqueous layer may separate from the oil but still contain dissolved organics, suspended solids and other contaminants. Visible separation is not treatment or proof of safety. Characterisation, including pH, organic load and relevant feed-specific contaminants, guides storage, treatment and any permitted discharge. Keep oil, aqueous condensate and residues in controlled, identified streams.

INPAC LABORATORY-TESTED PRODUCTS

Carbon black: 4,200–7,200 kcal/kg. Tank #1: good-quality crude pyrolysis oil. Tank #2 (back tank, following condensation): industrial-grade fuel. Keep product identity and collection point attached to each sample and laboratory record.

PART IV · ANALYSIS

08 Mass Balance and Energy Balance

LEARNING OBJECTIVES

- Write the general mass-balance equation for a batch.
- Calculate liquid, solid and gas yields from data.
- Explain specific energy consumption.
- Recognise why unaccounted differences matter.

Mass cannot be created or destroyed in a process. Everything that enters a reactor must leave as a product, a residue, a gas or a loss, or remain inside the equipment. A mass balance uses this principle to check whether measurements are complete and to quantify how input is distributed between outputs.

Input = Liquid + Separated water + Residue + Gas + Other accounted material + Unaccounted difference

HYPOTHETICAL TEACHING EXAMPLE: NOT INPAC OPERATING DATA

Assume a 1,000 kg feed input, 438 kg recovered liquid (excluding separated water), 41 kg separated water, 297 kg residue, 176 kg estimated gas and 48 kg assumed other accounted material. The final category represents identified hold-up or other separately accounted material, not unexplained measurement error. These invented figures are for teaching only, not INPAC operating results.

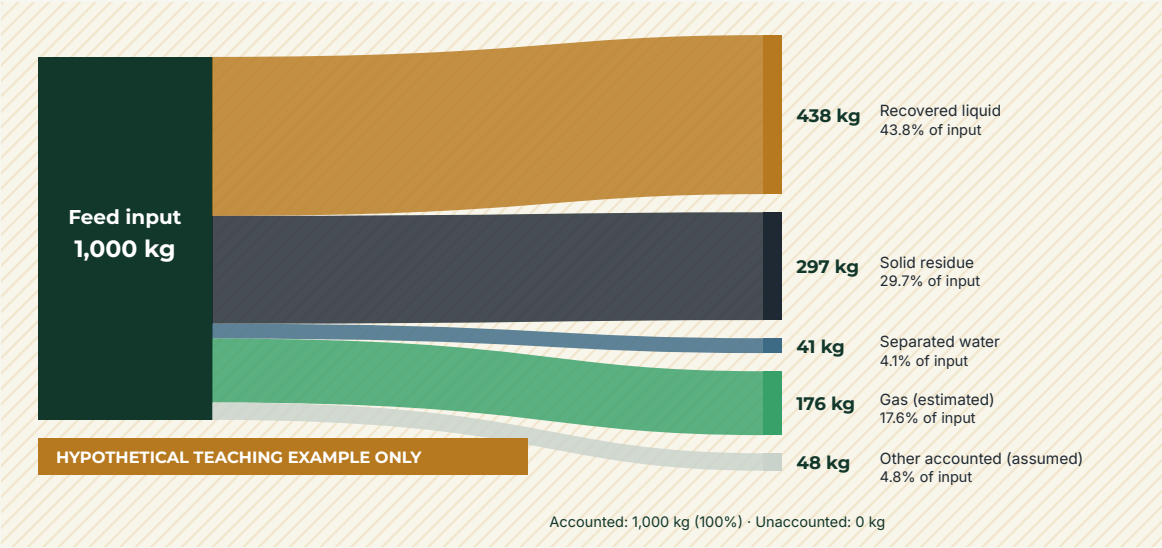


Figure 8.1 Example mass balance using hypothetical values. *Illustrative assumptions only.*

INDICATOR	FORMULA	HYPOTHETICAL RESULT
Liquid yield	liquid mass ÷ input mass × 100	438 ÷ 1,000 = 43.8%
Separated water	water mass ÷ input mass × 100	41 ÷ 1,000 = 4.1%
Solid residue yield	residue mass ÷ input mass × 100	297 ÷ 1,000 = 29.7%
Estimated gas yield	estimated gas mass ÷ input mass × 100	176 ÷ 1,000 = 17.6%
Other accounted material	assumed accounted mass ÷ input mass × 100	48 ÷ 1,000 = 4.8%
Total accounted	(438 + 41 + 297 + 176 + 48) ÷ 1,000 × 100	1,000 kg = 100.0%
Unaccounted difference	1,000 − (438 + 41 + 297 + 176 + 48)	0 kg = 0.0%
Collected liquid, water and residue	(438 + 41 + 297) ÷ 1,000 × 100	776 kg = 77.6%

Reading the example critically

The 48 kg is assumed accounted material: a defined category included in the balance. The unaccounted difference is the residual after all categories are included; here it is zero. Estimating gas as 1,000 − 438 − 41 − 297 − 48 = 176 kg forces closure and is not independent proof of accuracy. Errors in other categories enter that estimate. Measure streams directly where possible and record the method and uncertainty.

Energy requirements

Energy is needed to heat the feed and vessel, to evaporate moisture, to drive the decomposition reactions and to compensate for heat lost through insulation. Electricity is also used for motors, pumps, fans, shredders and conveyors. Energy may be supplied externally or partly from recovered gas.

Specific energy consumption

Specific energy consumption (SEC) is the energy used per unit of input processed, for example kilowatt-hours or megajoules per tonne. It allows comparison between batches of different size. All energy sources should be converted to a common unit and the system boundary stated.

Why complete balances matter

A balance tracks materials into products, water, gases and residues. Collected mass is not automatically a saleable product: water and contaminated residue still need management. Investigate unexplained differences rather than relabelling them as accounted material. State the boundary, period and whether each value is measured, estimated or assumed.

ENERGY TERM	WHAT IT REPRESENTS	TYPICAL MEASUREMENT APPROACH
External fuel input	Fuel used to heat the reactor	Fuel meter or weighed fuel use × heating value
Electricity	Motors, pumps, fans, instruments	kWh meter readings at start and end
Recovered-gas energy used	Gas routed back to heating	Gas flow and composition (requires metering)
Product energy content	Chemical energy in fuel oil and carbon black	Laboratory calorific-value testing
Losses	Heat lost to surroundings, cooling water	Estimated by difference or by heat-loss calculation

SPECIFIC ENERGY CONSUMPTION

SEC = total energy input during the batch ÷ mass of feed processed. Example units: kWh/tonne or MJ/tonne. Always state which energy inputs are included.

CARBON-BLACK ENERGY CONTENT

INPAC's laboratory-tested range is 4,200–7,200 kcal/kg. For a sample with a known calorific value, energy content = product mass × calorific value. This is chemical energy, not net usable heat or electricity; actual recovery depends on conversion efficiency. Keep this product result separate from the hypothetical mass-balance quantities.

APPLY IT

Use Worksheet C to record feedstock input, recovered-liquid mass, residue mass and estimated gas mass for an observed or explained batch, and to calculate the unaccounted difference. Record only figures you are authorised to note, and label each as measured, estimated or assumed.

PART IV · ANALYSIS

09 Environmental Management and Safety

Any industrial waste-processing facility interacts with air, water, land, workers and neighbours. Environmental management is the structured set of measures used to identify those interactions, control them and prove that controls work.

Emissions monitoring and air pollution control

Combustion of fuel or recovered gas for heating produces flue gases that may contain particulates, nitrogen oxides, sulphur compounds and organic compounds. Control equipment and periodic or continuous measurement against applicable limits are used to manage and verify emissions.

Gas handling and leak prevention

Pyrolysis gases are flammable and may be toxic. Sealed connections, pressure management, inspection routines and gas detection reduce the risk of leaks, fires and exposure.

Fire prevention and hot surfaces

Stored waste, recovered liquids and hot equipment create fire risk. Housekeeping, separation distances, extinguishers, hot-work controls and barriers around hot surfaces are standard measures.

Vehicles, noise and dust

Trucks and loaders move frequently on industrial sites. Defined walkways, spotters and speed limits protect pedestrians. Trommels and shredders produce noise and dust that may require hearing protection and dust suppression.

Wastewater and solid residues

Contaminated condensate and runoff need characterisation and treatment. Store INPAC's carbon black and liquid products securely, and manage dust, spills and ignition risks. Testing and appropriate use or disposal are also required for other residues.

Emergency preparedness

Emergency plans define alarms, evacuation routes, assembly points, first aid, fire response and communication with emergency services, and they are practised through drills.

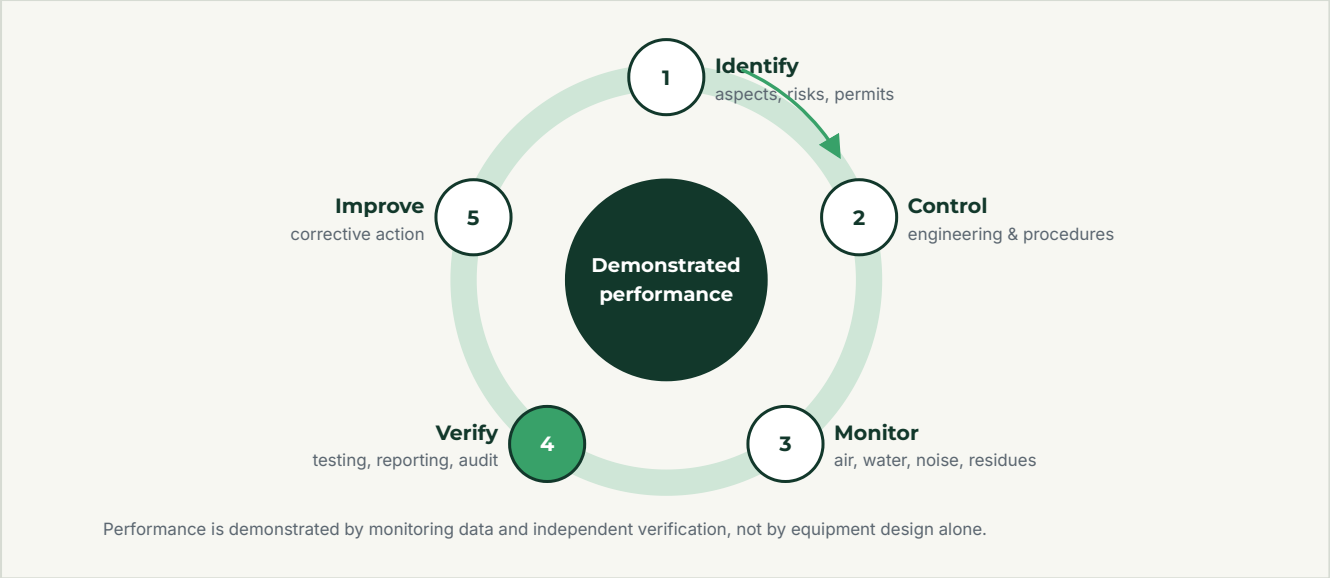


Figure 9.1 Environmental management framework: a continuous cycle that ends in demonstrated performance. *Educational schematic. Not an engineering drawing or site layout.*

ISO 14001 AND K3 EMISSIONS TESTING

INPAC holds ISO 14001 certification for its environmental management system and has passed K3 emissions testing. The reported test score is 0.4 against a limit of 130, with 0 the best score and lower scores indicating better results.

ISO 14001 addresses environmental management, not fuel or carbon-black product grading. Maintain monitoring, test records, corrective actions and periodic review alongside certification. Each emissions result relates to the parameter and conditions of its test.

CHAPTER 9 · CONTINUED

Visitor safety at TOSS Center

⚠ THE FIRST RULE

Visitors must remain in designated educational areas at all times and follow the instructions of their escort.

Mandatory visitor requirements

- Safety helmets, worn correctly for the whole visit.
- High-visibility vests.
- Appropriate closed footwear; sandals and open shoes are unsuitable.
- A safety briefing before entering the site.
- Escort supervision for every group.
- Never touch, adjust or operate machinery, controls, valves or equipment.
- Knowledge of emergency evacuation procedures and the assembly point.

Behaviour on site

Stay with your escort in designated areas. Keep clear of vehicle routes and restricted zones. Visitors must never touch or operate machinery, even when it is stationary. Do not handle feedstock, liquids or residues. Ask before taking photographs. Report illness, injury or unsafe conditions immediately to your escort.



SITE PHOTOGRAPH

ⓘ VISITOR EQUIPMENT

INPAC has prepared 40 visitor helmets and safety vests. Confirm group size, PPE fit and visit arrangements before arrival.

ⓘ FOLLOW THE SITE BRIEFING

Before entry, identify the alarm signal, evacuation route and assembly point with your escort. Follow site rules and authorised staff instructions throughout the visit. If instructed to evacuate, leave calmly with the group and remain at the assembly point for a headcount.

IF YOU HEAR OR SEE	WHAT TO DO
An alarm or evacuation instruction	Stop, follow your escort calmly to the assembly point, and wait to be counted
Smoke, fire or a strong unusual odour	Move away, inform your escort immediately, do not attempt to intervene
A vehicle approaching	Step to the designated walkway and make eye contact with the driver before moving
An injury or someone feeling unwell	Inform the escort; trained staff will coordinate first aid

PART IV · ANALYSIS

10 Operational Efficiency and System Performance

Feedstock quality and moisture influence energy use and batch duration. Equipment utilisation, maintenance and downtime determine availability. Monitor carbon-black calorific value and track Tank #1 crude pyrolysis oil separately from Tank #2 industrial-grade fuel: product quality and recovered quantity are different performance measures.

People matter as much as machinery: trained workers recognise problems early and keep consistent records. Operational data collection, written down at the time and in the same format each batch, is what turns experience into evidence. Theoretical maximum throughput, calculated from nominal capacity, should never be presented as achieved capacity.

KEY PERFORMANCE INDICATOR	EDUCATIONAL DEFINITION	WHY IT MATTERS
Tonnes processed per day	Mass of feed actually processed in a day, averaged over a stated period	Real capacity, distinct from nominal rating
Reactor utilisation	Hours a reactor is in a batch cycle ÷ hours available	Shows idle time and scheduling constraints
Output recovery	Mass of each output ÷ mass of input	Tracks yield and mass-balance completeness
Energy consumed per tonne	Total energy input ÷ tonnes processed	Cost and environmental performance
Equipment availability	Time able to operate ÷ total planned time	Reliability and maintenance effectiveness
Solid output per tonne	Carbon black and other solids ÷ tonnes processed	Product recovery, feed cleanliness and residual waste

Example operational monitoring dashboard (blank)

DAILY OPERATIONS LOG		DATE _____ · SHIFT _____ · RECORDED BY _____	
TONNES PROCESSED (DAY)	BATCHES COMPLETED	REACTOR UTILISATION %	LIQUID RECOVERED (KG)
RESIDUE GENERATED (KG/T)	ENERGY USED (KWH/T)	EQUIPMENT AVAILABILITY %	DOWNTIME (H) AND CAUSE
Notes on feedstock condition, moisture, maintenance and anomalies: _____			

PART V · APPLICATION

11 Implementing Similar Systems at Other Sites

For visitors from other facilities, the most valuable lesson is often not the technology itself but the process of deciding whether it fits. Appropriate technology depends on local circumstances and waste composition. A system that works in one place can fail in another if its assumptions are not checked.

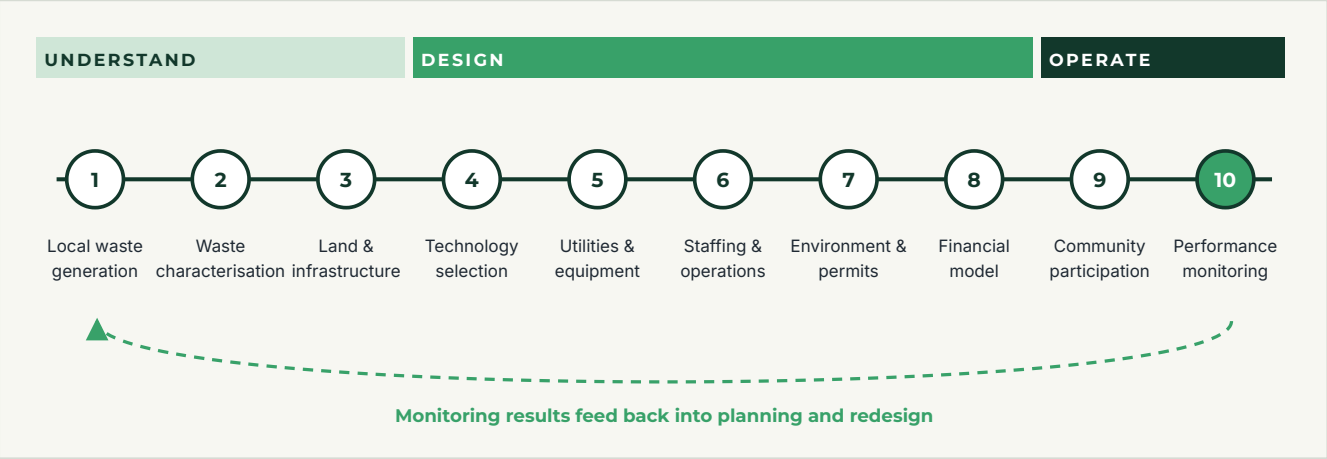


Figure 11.1 Implementation roadmap for other facilities. *Educational schematic. Not an engineering drawing or site layout.*

01 Understand local waste generation
Estimate quantities from collection records, population and weighbridge data, including seasonal and tourism peaks.

02 Conduct characterisation studies
Sample and sort over several days and seasons. Composition decides which technologies are even suitable.

03 Evaluate land and infrastructure
Consider access roads, flood risk, buffer distance to housing, drainage and space for storage.

04 Select appropriate technologies
Match options to the waste actually available; combine separation, composting, recycling and recovery.

05 Understand utilities and equipment
Electricity, water, fuel, cooling, spare parts and local maintenance capability.

06 Evaluate staffing and operations
Skills, shifts, training, supervision and occupational safety systems.

07 Environmental assessment and permits
Identify applicable assessments and permits early; they shape design and timelines.

08 Develop realistic financial models
Use conservative throughput and prices, include residue disposal, testing, maintenance and downtime.

09 Establish community participation
Engage residents, waste pickers and leaders; source separation depends on them.

10 Monitor project performance
Define KPIs before start-up, record data consistently and review results openly.

ASSESS YOUR OWN SITE

Worksheet D provides a structured site-implementation assessment covering location, waste availability, infrastructure, environmental requirements, staffing and key challenges. Complete it with colleagues after the visit while observations are fresh.

PART V · APPLICATION

12 Research Opportunities for Universities

The Living Learning Lab connects university study with practical questions about variability, scale and industrial resource recovery. The subjects below offer a framework for research proposals, from waste characterisation to life-cycle assessment. Define a focused question, an appropriate method and the data needed before requesting project authorisation from INPAC.

RESEARCH AREA	SAMPLE RESEARCH QUESTION
Plastic waste characterisation	How does the polymer composition of incoming plastic vary across seasons?
Feedstock moisture and efficiency	How strongly does feed moisture correlate with batch duration and energy use?
Thermal decomposition and products	How does the share of film versus rigid plastic affect product distribution?
Liquid-product characterisation	How do Tank #1 crude pyrolysis oil and Tank #2 industrial-grade fuel differ in properties?
Wastewater treatment	Which treatment options suit the characterised aqueous condensate?
Carbon-black characterisation	How do moisture, ash and composition relate to the tested 4,200–7,200 kcal/kg range?
Heat recovery	How much process heat could be recovered from cooling streams?
Equipment efficiency	Which maintenance practices most improve equipment availability?
Life-cycle assessment	How does the system compare with landfill for selected impact categories?
Circular economy systems	How could separation at source in Klungkung improve feed quality?

> ⚠ **AUTHORISATION COMES FIRST**
>
> Sampling, data collection and any access to equipment require prior written authorisation from INPAC and must follow site safety rules. Use of facility data in publications should be agreed in advance.

Project proposal template

1. Topic & question
A focused question that can be answered with obtainable data.

2. Hypothesis
What you expect, and why, based on literature.

3. Methodology
Sampling plan, measurements, analysis methods.

4. Data required
Which site data you need, and in what format.

5. Safety & access
What access is requested; risks and controls.

6. Expected findings
Value to the facility, community and science.

PART VI · LEARNING

13 The Role of W.E. (Waste Education)

Technology alone does not change how a community handles waste. People do. W.E. complements INPAC's technical activities by building the understanding and habits on which any waste system depends.

Environmental awareness

W.E. helps people see waste as a system: what they buy, how they separate, where collection goes, and what happens next. Seeing a processing facility makes the consequences of everyday choices concrete.

Younger generations and school visits

For children, the focus is on simple, repeatable actions such as separating organic and inorganic waste. School visits to the facility, where appropriate and safe, can be prepared with age-appropriate materials and pre-visit lessons.

Community outreach

Banjar meetings, markets and community events are natural places to discuss separation at source, reduce open burning and share what the facility can and cannot accept.

Social media education

Short, accurate content explains processes to audiences who will never visit. Accuracy matters most here: claims about products or environmental benefits should reflect verified information only.

Technical knowledge sharing and partnerships

INPAC provides the technical setting, equipment knowledge and operational supervision. W.E. translates engineering subjects into accessible learning, prepares educational materials and helps visiting groups connect observations with practical waste-management decisions. Visits and institutional activities are arranged directly with the organisers.

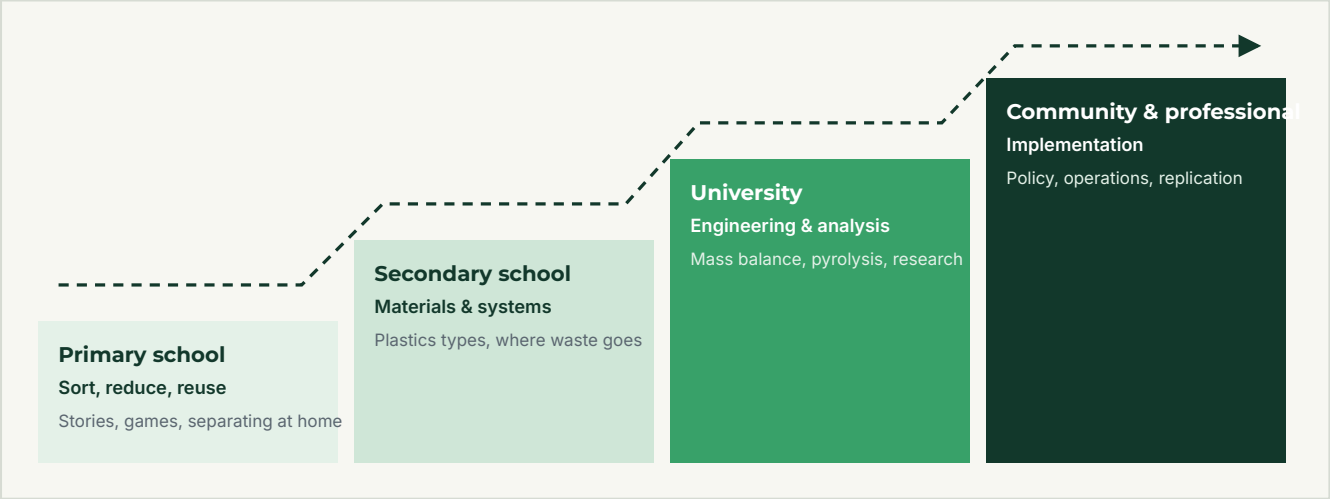


Figure 13.1 Learning pathway for different visitor audiences, from primary education to community and professional programmes. *Educational schematic. Not an engineering drawing or site layout.*

AN INDUSTRIAL FACILITY AS A PUBLIC CLASSROOM

The Living Learning Lab makes industrial processes understandable through structured observation, clear explanations and discussion. It links everyday separation habits with the technical work of material preparation, recovery and environmental management.

PART VI · LEARNING

14 The Visitor Learning Experience

This sample 90-minute itinerary combines safety orientation, guided observation and technical discussion. INPAC leads the technical and operational content; W.E. supports the educational experience. The visit coordinator confirms the final programme and adapts the route to operating conditions and visitor needs.

0–15 min — **Welcome, orientation and safety briefing**
Introductions, programme overview, PPE fitting, site rules and emergency procedures.

15–30 min — **Waste management and material sorting**
The waste challenge, the hierarchy, and how incoming material is screened.

30–50 min — **Guided observation of preparation and processing**
Escorted observation of preparation and processing systems from designated areas.

50–70 min — **Pyrolysis, outputs and environmental management**
The science, output streams, mass balance and environmental controls.

70–85 min — **Questions, discussion and technical learning**
Discussion questions by level; worksheets; technical Q&A with staff.

85–90 min — **Summary and feedback**
Key take-aways, feedback forms and next steps for interested institutions.

EXPECTED OUTCOMES

- Explain why separation and preparation matter.
- Describe pyrolysis and its outputs accurately.
- Distinguish nominal capacity from performance.
- Name the main environmental and safety controls.
- Formulate one question for further study.
- Identify one action for their own institution.



SITE PHOTOGRAPH · VISITING DELEGATION

BEFORE YOU ARRIVE

Confirm group size, arrival time and any accessibility needs with the facility in advance. Wear closed footwear and clothing suitable for an industrial site. Read Chapters 2 and 5 beforehand to get the most from the visit.

PART VI · LEARNING

15 Discussion Questions and Activities

Eighteen questions are arranged in three levels. Choose the level that suits your group, or work upward through all three. Write brief answers in the space provided, then compare them in discussion with facility staff and your peers.

FOUNDATIONAL For general adult visitors

01 Why is waste separation at the source important?

02 Which items from your own household would be unsuitable for thermal processing, and why?

03 What is the difference between pyrolysis and combustion?

04 Why does the waste hierarchy place prevention above recovery?

05 What safety precautions did you observe for visitors today?

06 What products are collected in Tank #1 and Tank #2, and how are they tested?

INTERMEDIATE For university students

07 How does feedstock composition affect thermal processing and product distribution?

08 Why is nominal batch capacity not the same as daily throughput?

09 How does moisture in the feed influence energy use and recovered-liquid quality?

10 What does the 4,200–7,200 kcal/kg result show about INPAC carbon black?

11 How do ISO 14001, K3 emissions testing and product laboratory tests differ?

12 What role can community education play in improving feedstock quality?

ADVANCED For engineering students and professionals

13 What operational data is needed to assess the efficiency of a batch pyrolysis system?

14 How would you design a mass balance that minimises the unaccounted difference?

15 How would you define a system boundary for specific energy consumption?

16 What characterisation would you require before discharging aqueous condensate?

17 What barriers might another community encounter when implementing similar technologies?

18 How could life-cycle assessment be used to compare this system with landfill?

PART VII · REFERENCE

16 Glossary and References

Glossary

Baling
Compressing loose material into dense, bound blocks for storage and handling.

Batch process
A process in which a fixed charge is loaded, processed and removed before the next charge, as opposed to continuous feeding.

Char / carbon black
Char is the general carbon-rich solid from pyrolysis. INPAC recovers carbon black with a laboratory-tested calorific value of 4,200–7,200 kcal/kg.

Circular economy
An economic model that keeps materials in use at their highest value for as long as possible.

Combustion
An exothermic oxidation process involving oxygen; it may be flaming or flameless.

Condensation
The change from vapour to liquid when a vapour is cooled below its dew point.

Condenser
Heat exchanger that cools vapours so condensable fractions become liquid.

Feedstock
The material fed into a process, here prepared waste entering a reactor.

Heat transfer
Movement of thermal energy by conduction, convection or radiation.

Hydrocarbon
A compound made of hydrogen and carbon, the main constituent of many plastics and fuels.

Key performance indicator (KPI)
A defined, measurable value used to track performance over time.

Leachate
Liquid that has passed through waste and picked up dissolved and suspended contaminants.

Life-cycle assessment (LCA)
A standardised method for assessing environmental impacts across a product or system life cycle.

Mass balance
Accounting of all mass entering and leaving a system, based on conservation of mass.

Moisture content
The proportion of a material's mass that is water.

Municipal solid waste (MSW)
Everyday waste from households, businesses and institutions managed by or for local government.

Nominal capacity
Design rating of equipment under defined conditions, not guaranteed achieved throughput.

Non-condensable gas
Gas that does not condense at collection conditions, such as hydrogen and methane.

Pyrolysis
Thermal decomposition in the absence of oxygen in the reaction zone.

Reactor
A vessel in which a controlled chemical or thermal process takes place.

Residence time
The time material or vapour spends within a defined zone of a process.

Source separation
Separating waste into categories at the point where it is generated.

Specific energy consumption
Energy used per unit of material processed, e.g. kWh per tonne.

Thermal efficiency
Useful heat delivered to a process divided by total heat supplied.

Trommel
Rotating cylindrical screen that separates material by size.

Waste characterisation
Systematic measurement of the composition and properties of a waste stream.

Waste hierarchy
Ranking of management options from prevention to final disposal.

References

Further reading on waste management, plastic pyrolysis and environmentally sound resource recovery.

[1] United Nations Environment Programme and International Solid Waste Association (2024). Global Waste Management Outlook 2024: Beyond an age of waste — Turning rubbish into a resource. Nairobi: UNEP. **https://www.unep.org/resources/global-waste-management-outlook-2024**

[2] Kaza, S., Yao, L., Bhada-Tata, P. and Van Woerden, F. (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development Series. Washington, DC: World Bank. **https://hdl.handle.net/10986/30317**

[3] Basel Convention (2023). Technical guidelines on the environmentally sound management of plastic wastes. Adopted by decision BC-16/4; UNEP/CHW.16/6/Add.3/Rev.1. Secretariat of the Basel, Rotterdam and Stockholm Conventions. **https://www.basel.int/Implementation/Plasticwaste/Technicalguidelines/Overview/tabid/7992/Default.aspx**

[4] Al-Salem, S.M., Antelava, A., Constantinou, A., Manos, G. and Dutta, A. (2017). A review on thermal and catalytic pyrolysis of plastic solid waste (PSW). Journal of Environmental Management, 197, 177–198. **doi:10.1016/j.jenvman.2017.03.084**

Further reading and next steps

- Use the reference list of Al-Salem et al. (2017) to explore primary studies on plastic pyrolysis conditions and products.
- Consult the Basel Convention technical guidelines for environmentally sound management principles for plastic wastes.
- For Indonesian regulatory requirements on waste management, environmental approval and emissions, consult current official government sources and qualified advisers.
- For environmental management systems, consult ISO 14001; for life-cycle assessment methods, consult ISO 14040 and ISO 14044.

EDUCATIONAL USE AND SAFETY

Use this handbook for teaching, guided observation and discussion. Diagrams illustrate process principles, and worked numerical examples are labelled as hypothetical.

Industrial operation is restricted to trained, authorised personnel following approved site procedures. Visitors must follow the safety briefing and remain with their escort. This educational resource does not replace operating procedures, safety documents or engineering manuals.

HOW TO CITE THIS HANDBOOK

INPAC Solutions and W.E. (Waste Education). Living Learning Lab: Understanding Waste, Technology & Resource Recovery. University, Professional & Institutional Visitor Handbook. TOSS Center, Klungkung, Bali, Indonesia.

PRACTICAL WORKSHEET A

Waste Characterisation

A

Record what you observe in incoming or stored material. Estimates by eye are acceptable; mark them as estimates.

NAME / GROUP _____ **INSTITUTION** _____ **DATE OF VISIT** _____

WASTE TYPE	ESTIMATED SHARE (%)	CONTAMINATION OBSERVED	MOISTURE (DRY / DAMP / WET)
Food & garden organics			
Plastic film & bags			
Rigid plastics			
Paper & cardboard			
Textiles			
Rubber			
Glass & metals			
Fines, soil & grit			
Other / hazardous items			

OVERALL CONTAMINATION OBSERVATIONS
What materials are mixed together? Any hazardous items noticed?

MOISTURE OBSERVATIONS
Signs of water, rain exposure, decomposing organics.

HOW COULD PREPARATION IMPROVE THIS MATERIAL FOR DOWNSTREAM PROCESSING?

PRACTICAL WORKSHEET B

Technology Observation

B

For each piece of equipment you observe, note its function and what goes in and comes out. Observe from designated areas only.

NAME / GROUP _____ **INSTITUTION** _____ **DATE OF VISIT** _____

EQUIPMENT	FUNCTION	INPUTS	OUTPUTS	OBSERVATIONS
Trommel				
Shredder				
Baler / storage				
Horizontal reactor				
Condensation system				
Gas handling				
Cooling equipment				

WHICH STAGE SEEMED MOST SENSITIVE TO FEEDSTOCK QUALITY, AND WHY?

QUESTIONS TO ASK FACILITY STAFF

PRACTICAL WORKSHEET C

Mass Balance

C

Record authorised observations or use the Chapter 8 teaching example. Mark every value M (measured), E (estimated) or A (assumed) and state its basis.

NAME / GROUP **INSTITUTION** **DATE OF VISIT**

STREAM	MASS (KG)	M / E / A	% OF INPUT
Feedstock input			100%
Recovered liquid (identify tank)			
Separated water			
Carbon black / other solid residue			
Gas (state estimation method)			
Other accounted material / hold-up			
Unaccounted difference			

CALCULATIONS

Difference = Input − (Liquid + Water + Residue + Gas + Other accounted). Stream share (%) = mass ÷ input × 100. Keep separated water outside the liquid-oil mass. Other accounted material needs an identified basis; it is not a balancing error.

Hypothetical example (kg): input 1,000; liquid 438; water 41; residue 297; estimated gas 176; assumed other accounted material 48. Total accounted 1,000 kg (100%); unaccounted difference 0 kg.

WORKING SPACE

WHICH VALUE IS LEAST CERTAIN, AND HOW WOULD YOU MEASURE IT BETTER?

PRACTICAL WORKSHEET D

Site Implementation Assessment

D

Use this sheet to evaluate whether a similar approach could suit your own facility or region. Refer to Chapter 11.

NAME / GROUP **INSTITUTION** **DATE OF VISIT**

SITE LOCATION
Region, access, neighbours, flood risk

WASTE AVAILABILITY
Quantity, composition, seasonality, data source

INFRASTRUCTURE
Land, roads, power, water, storage

ENVIRONMENTAL REQUIREMENTS
Assessments, permits, monitoring

STAFFING
Skills, training, shifts, safety systems

COMMUNITY & STAKEHOLDERS
Who must be involved and how

KEY CHALLENGES

READINESS FACTOR	READY	PARTLY	NOT YET	NEXT ACTION
Waste data				
Site & permits				
Finance				
People & community				

PRACTICAL WORKSHEET E

Research Proposal

E

Develop a focused research question and method for discussion with INPAC. Arrange written authorisation before sampling, data collection or equipment access.

NAME / GROUP | **INSTITUTION** | **DATE OF VISIT**

RESEARCH TOPIC

RESEARCH QUESTION

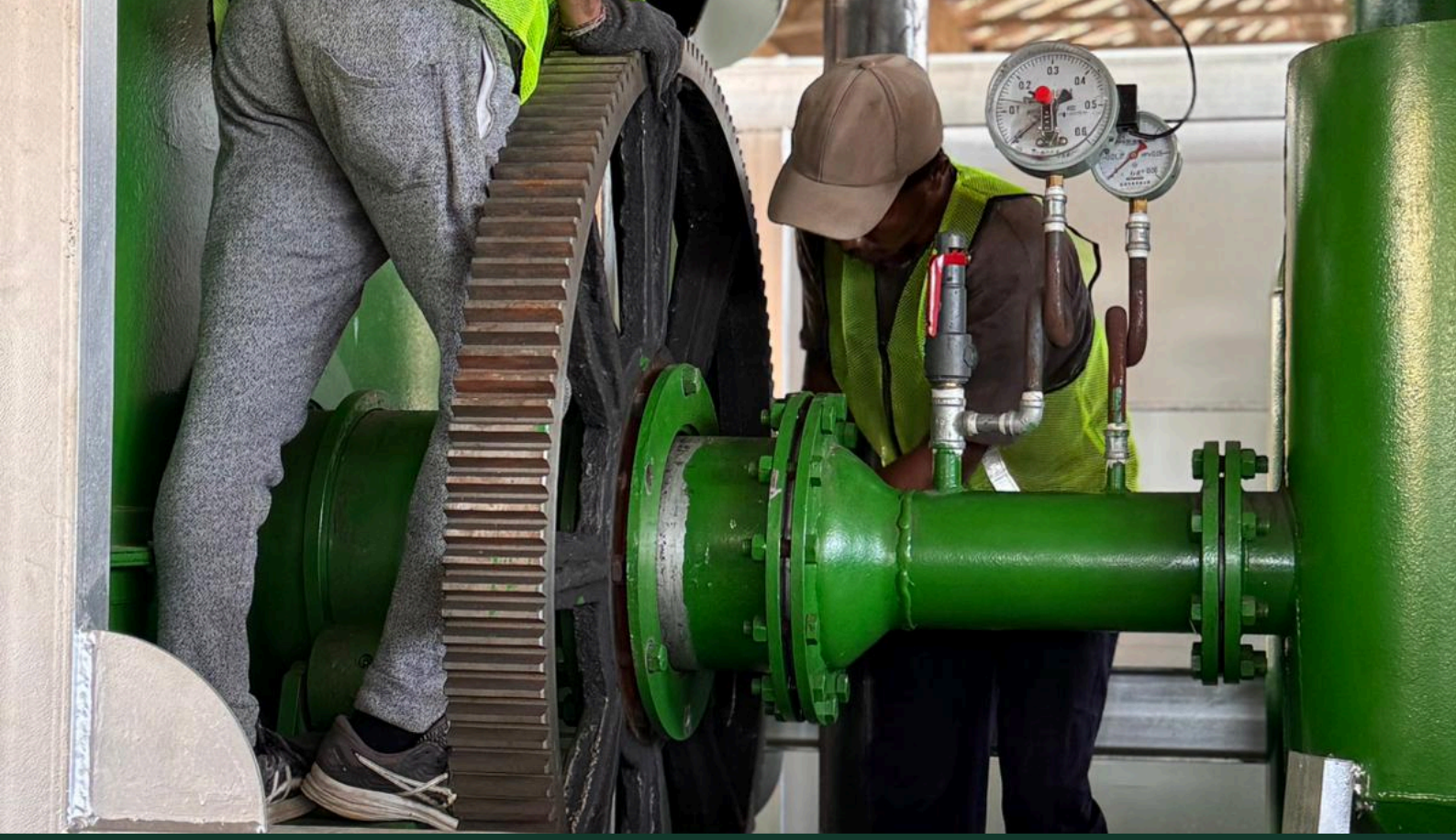
HYPOTHESIS

PROPOSED METHODOLOGY
Sampling, measurements, analysis, timeline

REQUIRED DATA
What, from whom, in what format

EXPECTED FINDINGS AND VALUE

SAFETY, ACCESS AND ETHICS CONSIDERATIONS



For a Cleaner Tomorrow

Understanding waste is the first step towards managing it better. At TOSS Center, Klungkung, INPAC Solutions and W.E. connect technical knowledge with practical education, helping students, professionals and communities make informed decisions about materials, resource recovery and environmental responsibility.

inpac. we

PT INPAC SOLUTION INDO · W.E. (Waste Education)
TOSS Center, Klungkung, Bali, Indonesia
Educational resource. Not an operating procedure.