

# Engineering Strategy for Design and Scale-Up of a Recycling Process

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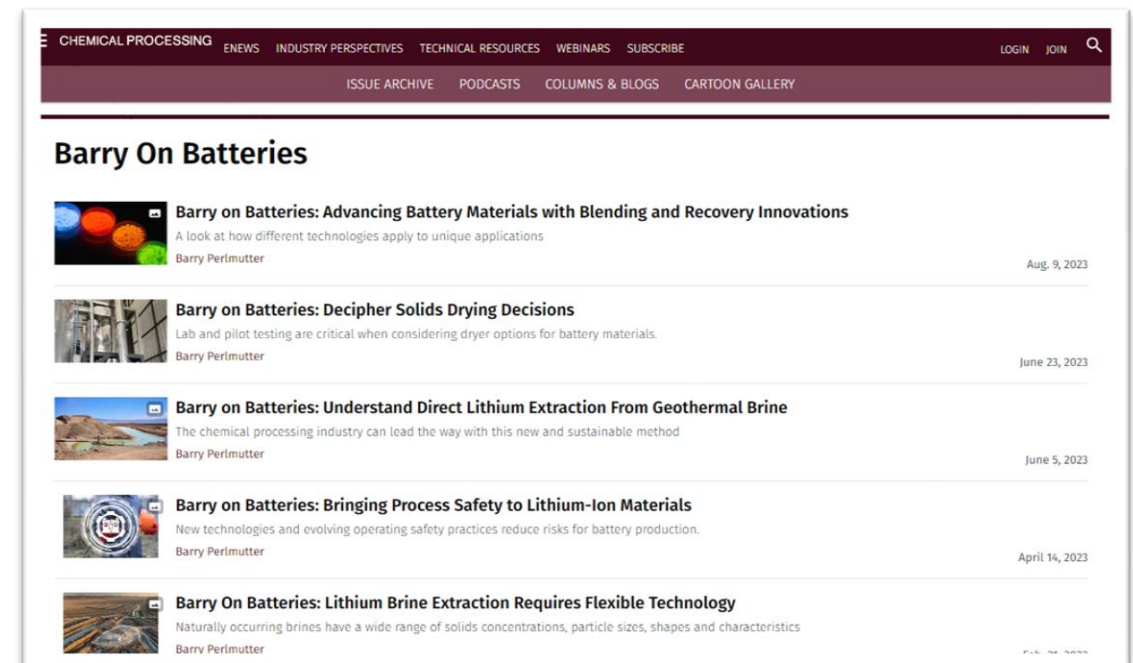
# Barry A. Perlmutter

## Overall Experience

- 40 years of international engineering and business marketing experience in the field of solid-liquid separation including filtration, centrifugation, drying, mixing & recycling
- Published & presented worldwide:
  - Author of [“Solid Liquid Filtration Handbook”](#) (Elsevier, 2015)
  - Editor of [“Integration & Optimization of Unit Operations”](#) (Elsevier, 2022)
- Professional skills focus on process solutions, innovation strategy, market expansion and business development.

## Lithium Market Expertise & Experience

- <https://perlmutterideadevelopment.com/lithium-battery-materials/>
- [Chemical Processing Magazine and Columnist for “Barry on Batteries”](#)
- [On-Lithium Insights and Presentations](#)

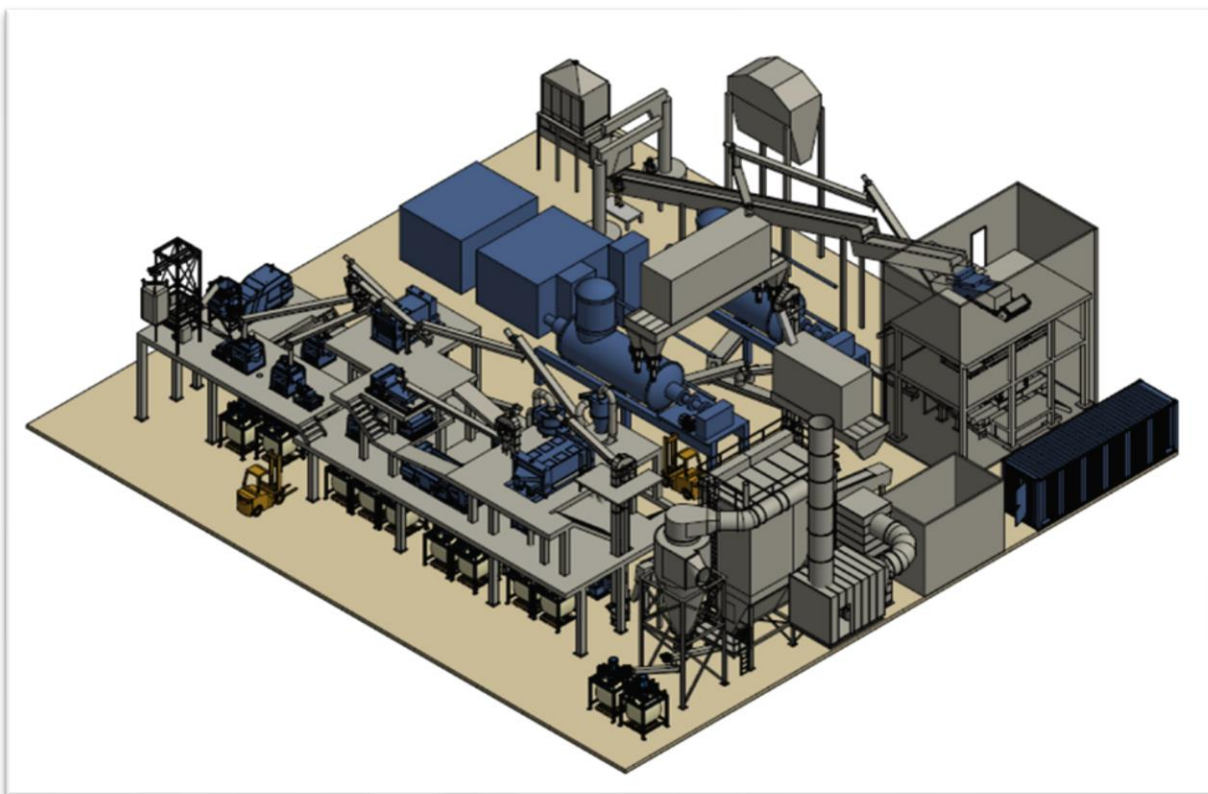


# **Lithium-Ion Batteries Recycling Process For End-of-Life (EOL) Packs, Modules & Cells, Production Scrap & Defective Battery Cells & Small-Format Consumer Batteries**

- BHS-Sonthofen GmbH - Technology Provider
  - Installations Review
- Perlmutter & Idea Development (P&ID)
  - Project Development Engineering (PDE) Stages

# BHS - Technology Provider

## Recycling Solutions



Client	Capacity	Description of Feed Stock
A	4 tons/hour	Production scrap, EV & Consumer batteries
B	50 kg/hour	Production scrap, EV batteries
C	4 tons/hour	Production scrap, EV batteries
D	2 tons/hour	Production scrap, EV batteries
E	2 x 2 tons/hour	Production scrap, EV & Consumer batteries
F	1 – 2 tons/hour	Consumer batteries
G	50 kg/hour	Consumer batteries
H	4 tons/hour	EV batteries, Consumer batteries
I	100 kg/Hour	EV batteries

## Our business units – your industries

Innovative process solutions, technology and consulting services



### Process Technology

- » Chemicals
- » Pharmaceuticals
- » Food & feed
- » Oil & gas
- » Power generation
- » Metallurgy & battery materials



### Building Materials Machinery

- » Concrete
- » Dry building materials
- » Road construction
- » Sand & gravel
- » Mining & minerals
- » Disposal



### Recycling Technology

- » Metal recovery
- » Industrial waste
- » Recycling various waste materials
- » Biomass

# Northvolt Revolt Ett

*All material may be used in both print and  
online media with reference to Northvolt*



## **BHS-Sonthofen Receives Order For BASF Battery Recycling Plant**

- **BHS-Sonthofen GmbH is supplying BASF with a plant for the mechanical reprocessing of lithium-ion batteries into dried black mass.**
- **This marks the third large-scale plant for BHS, with the first one having operated successfully for over a year.**

**<https://recyclinginside.com/battery-recycling/bhs-sonthofen-receives-order-for-basf-battery-recycling-plant/>**

<https://www.basf.com/global/en/media/news-releases/2022/06/p-22-249.html>



# **Lithium-Ion Batteries Recycling Process For End-of-Life (EOL) Packs, Modules & Cells, Production Scrap & Defective Battery Cells & Small-Format Consumer Batteries**

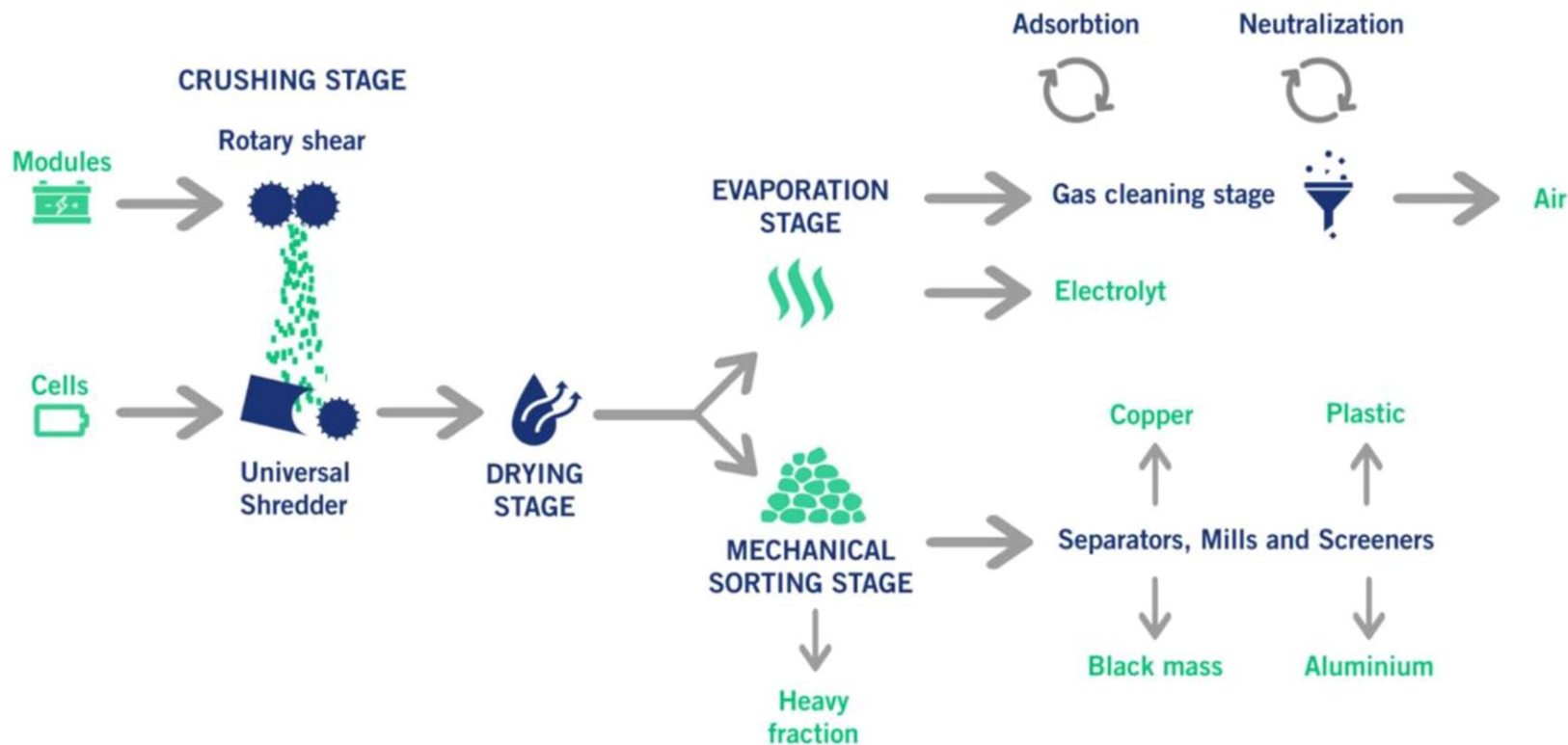
- Step 0: Deep discharging of batteries
- Step 1: Dry (inerted) shredding/crushing followed by granulating
- Steps 2/3: Black mass vacuum drying with gas treatment, electrolyte recovery & dedusting
- Step 4: Dust-tight classifying and sorting into different fractions

# BHS Technology Provider

## Recycling Solution

### Overall Process: Steps 1 - 4

#### Recycling Process for Li-Ion Batteries



# PDE Stages 1 - 5

## **PDE-Stage 1: Preliminary Engineering**

Process Descriptions, PFDs, input/outputs, general equipment descriptions and layouts.

## **PDE-Stage 2: Basic Engineering**

P&IDs, PLC control philosophy and specification, detailed equipment specifications and other documents to allow client to issue purchase orders.

## **PDE-Stage 3: Project Execution – Detailed Engineering**

Assistance is provided, as necessary, to support the client engineering teams and/or outside contractors including drawings, HAZOP studies, vendor management, etc.

## **PDE-Stage 4: Commissioning and Startup**

Supervision is provided to oversee vendors for cold and hot commissioning, startup, training and other on-site activities.

## **PDE-Stage 5: Support**

Guidance is provided for on-going operation, optimization and other recycling plant activities along with assistance with vendor support.

# **PDE-Stage 1 Scope of Work:**

- a. Process Description**
- b. General sizing approach including number of pieces of equipment such as one granulator and one dryer or two lines or another ideas/approaches.**
- c. Preliminary Block Flowsheet (PFD) including Discharging, BHS Crushing/Shredding, BHS Drying with vacuum/condensation, Gas treatment and Sorting**
- d. Final PFD**
- e. Equipment description and general specifications / information**
- f. Utility consumption and motor lists**
- g. Emissions**
  - 1.Exhaust gas flows**
  - 2.Exhaust dust flows**
  - 3.General discussion and range of emissions**
  - 4.Brine renewal/disposal based upon the battery quality and other factors**
- h. Building footprint sketch including height requirements (Outside dimensions only, building layout details are part of PDE-Stage 2)**
- i. Equipment cost estimate +/- 20%**
- j. PDE-Stage 2 engineering cost estimate**

# PDE-Stage 1 Scope of Work:

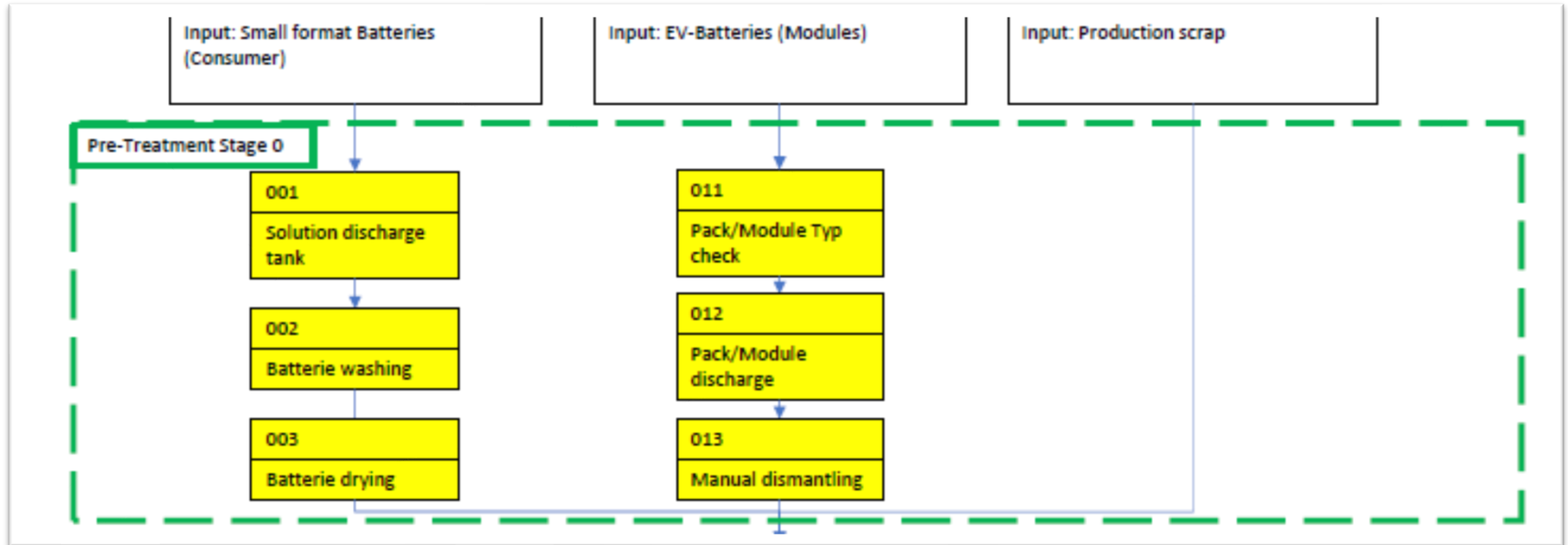
## a. Process Description

1. Throughput
2. Input specification
3. Operation time
4. Project Example

Input Type	Input Amount	Unit	Duration	Distribution		Comments
EV Batteries	10,000,000	lbs	year	4,536	ton/year	19% Large Format EV Batteries
Small-Format Batteries	42,800,000	lbs	year	19,414	ton/year	81% Button Size, Power Tool Size, etc.
Production scrap	?			?		?
Overall	52,800,000	lbs	year	23,950	ton/year	24,000 M-tons/year (1 M-ton = 1.000 kg)
Plant Operation Time	20	h	day			
Plant Operation Time	6	days	week			
Plant Operation Time	50	weeks	year			
Overall	6000	h	year			
Throughput per hour	8800	lbs	hour	4.0	ton/hour	

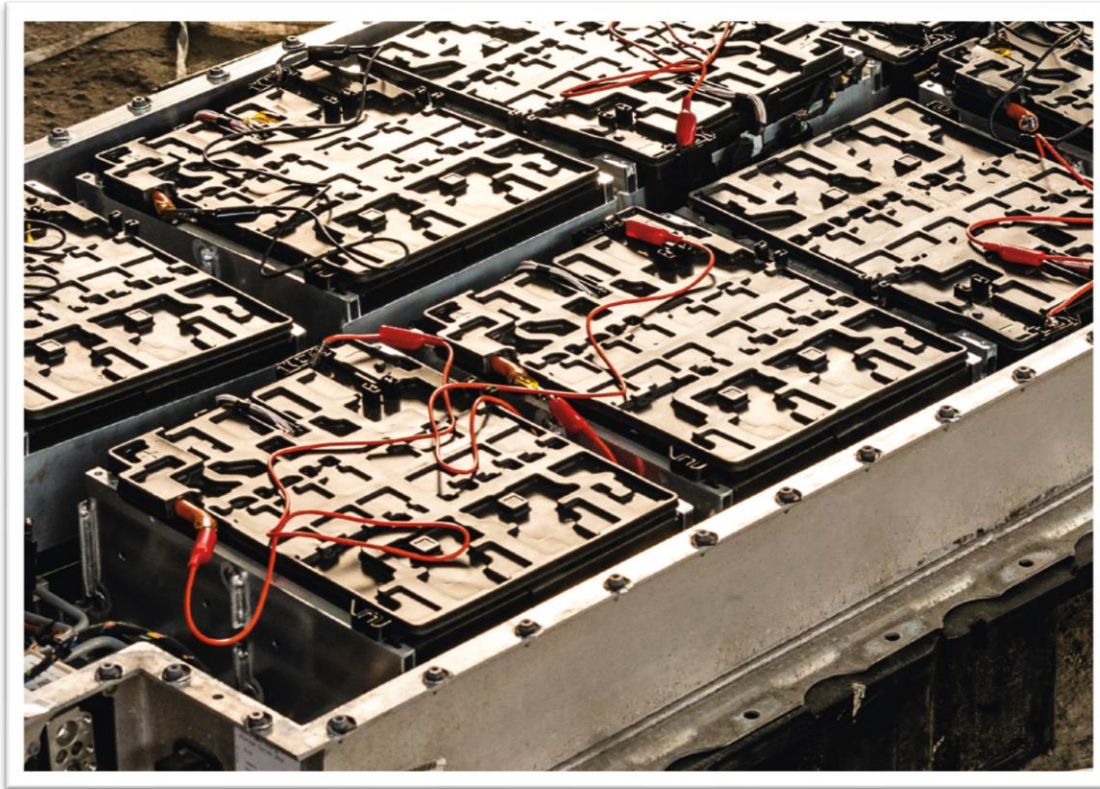
# BHS Technology Provider Recycling Solutions

## Step 0: Discharging



# BHS Technology Provider Recycling Solutions

## Step 0: Discharging



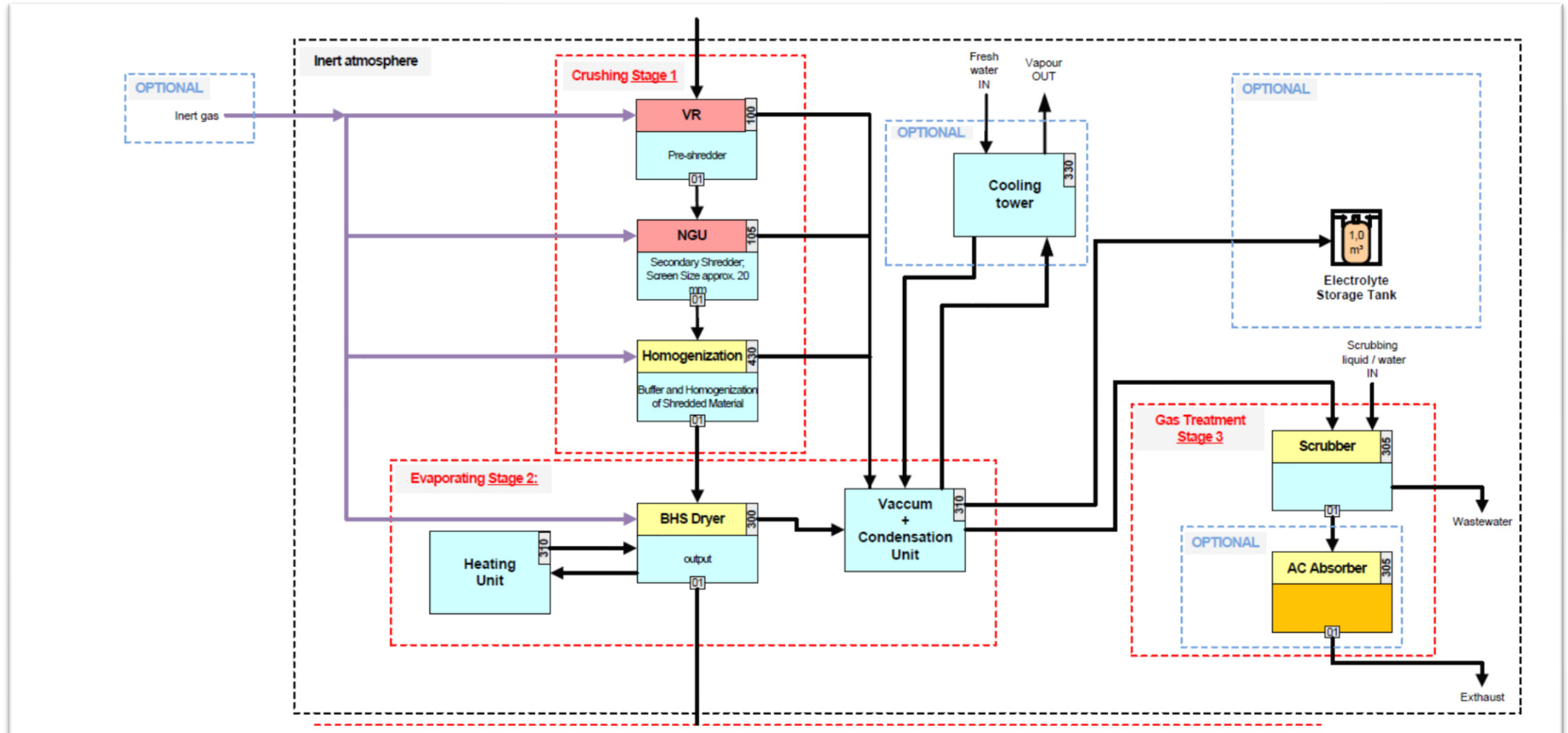
**Modules**



**Production Scrap**

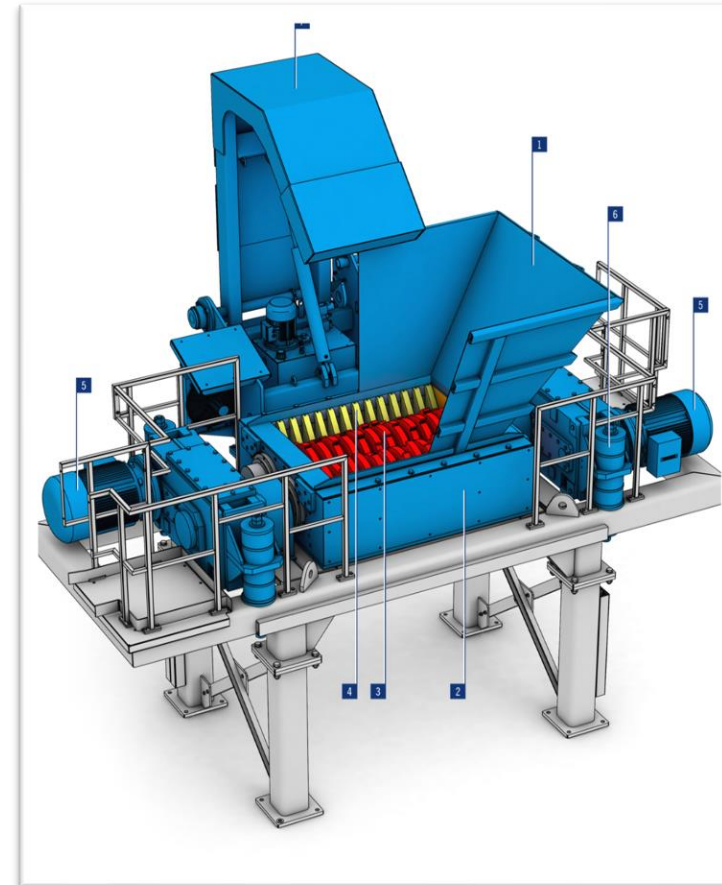
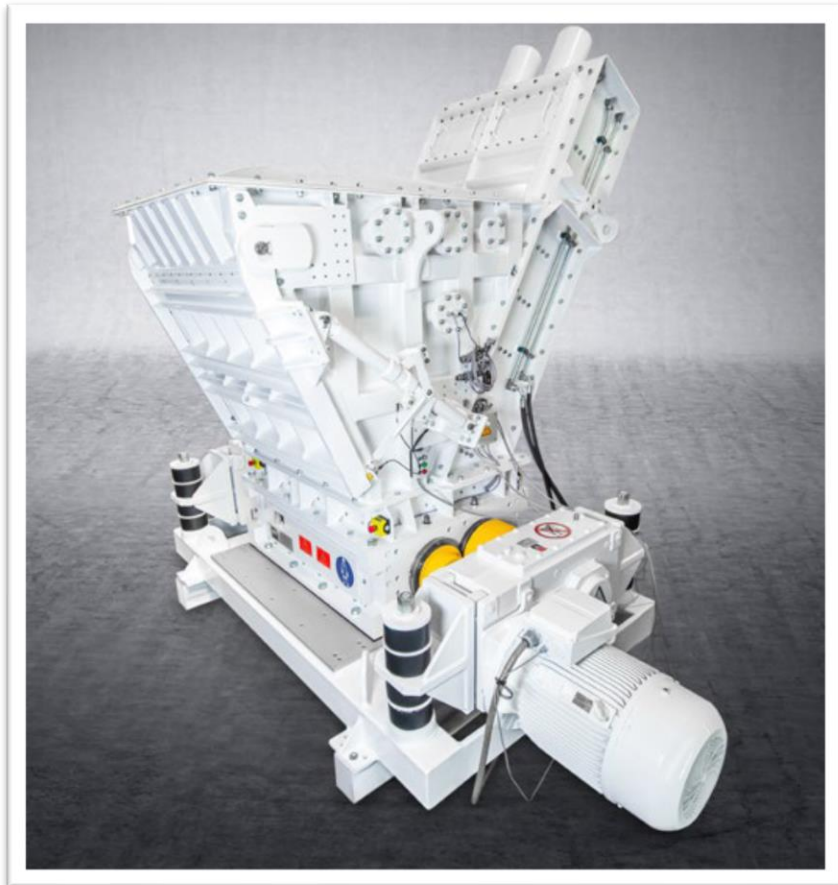
# BHS Recycling Solutions

## Overall Process: Steps 1 – 3 Dry/Inerted



# BHS Rotary Shear VR Pre-Shredder

## Step 1: Shredding/Crushing

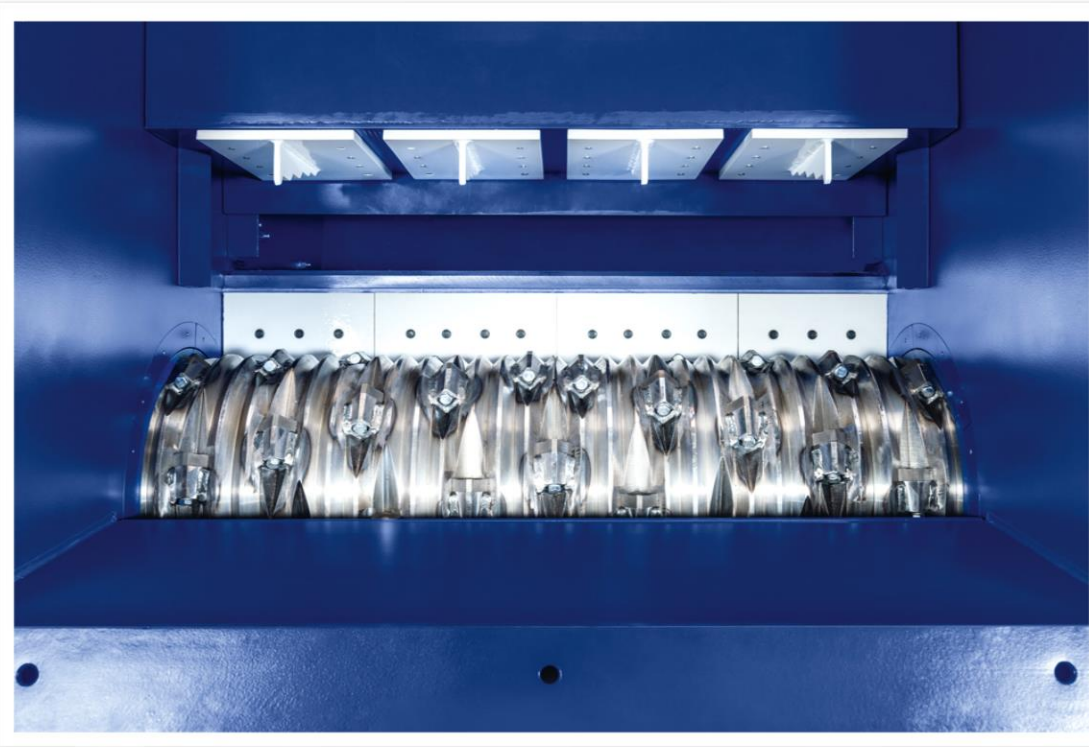
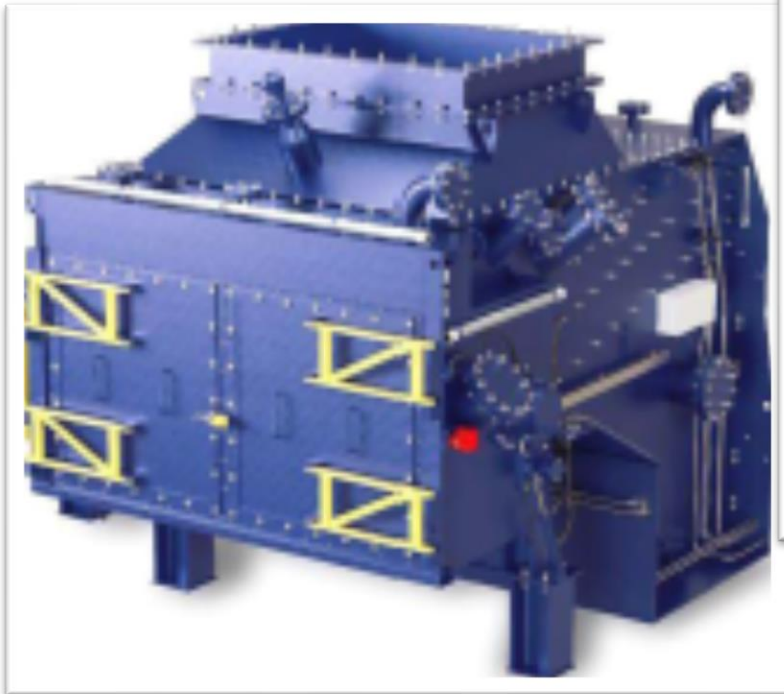


# BHS Rotary Shear VR Pre-Shredder Output



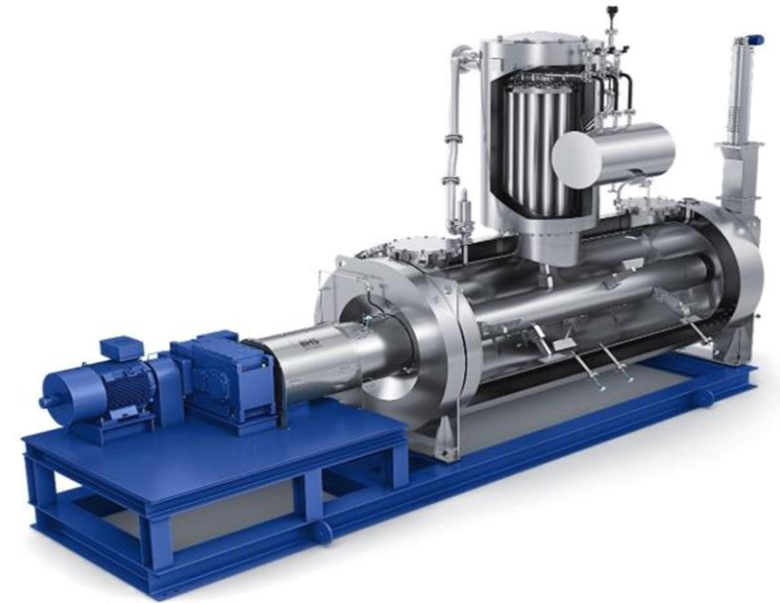
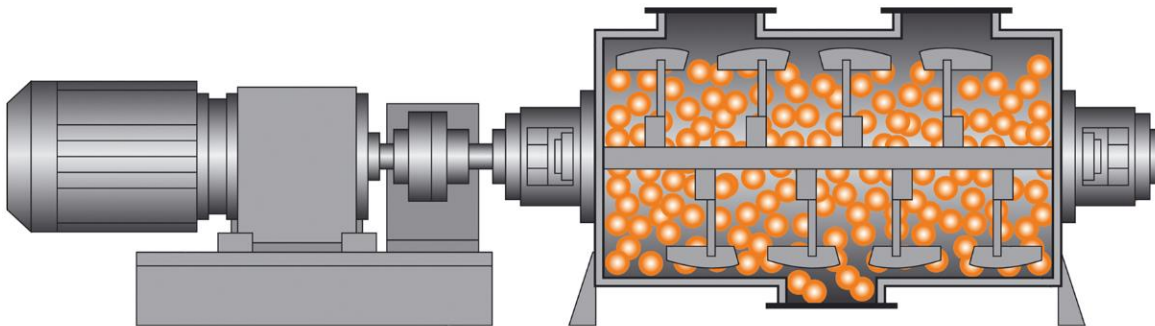
# BHS Universal NGU Granulator

## Step 1: Granulating



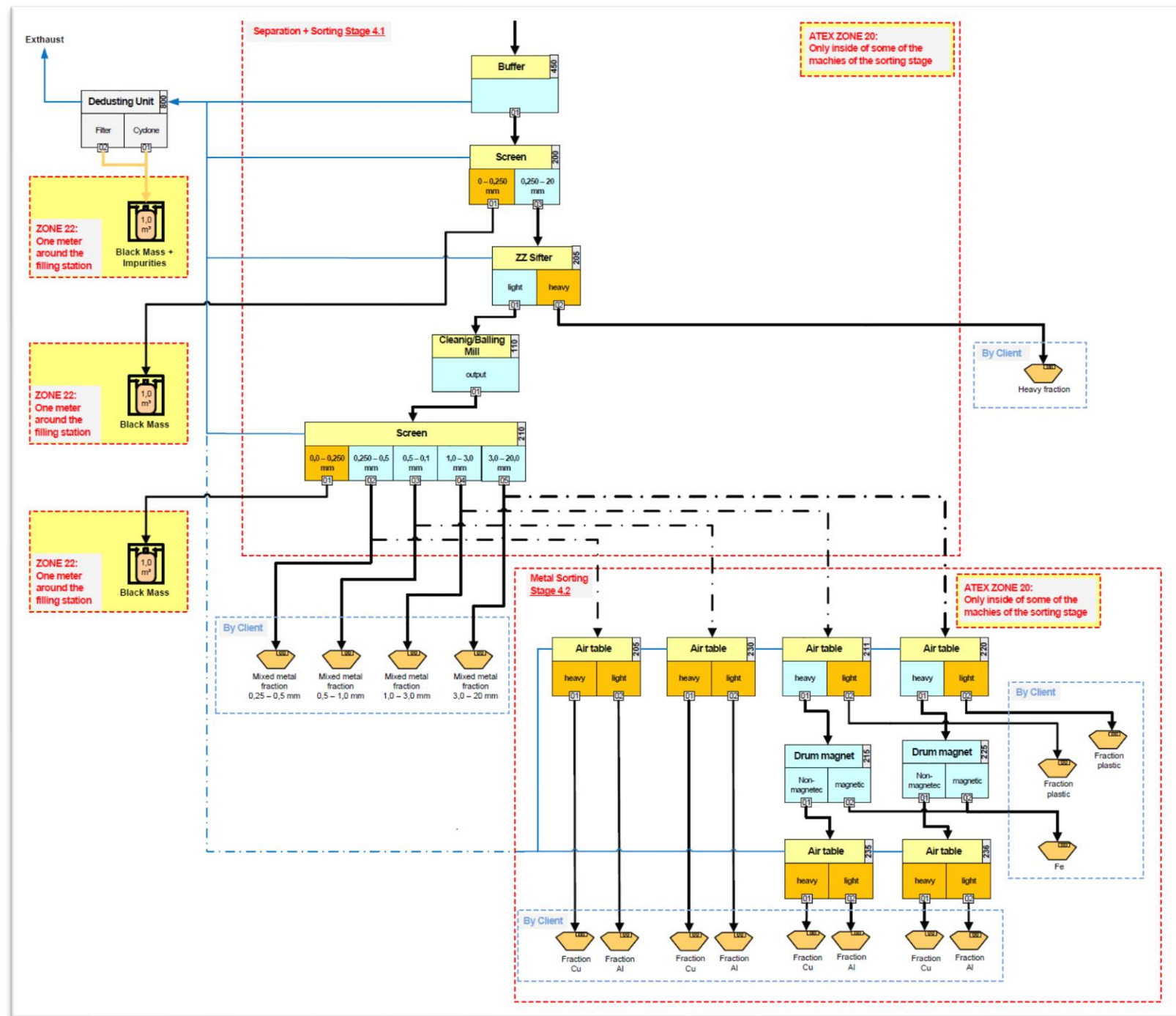
# BHS Horizontal Evaporator Vacuum Dryer

## Steps 2/3: Vacuum Drying & Electrolyte Recovery



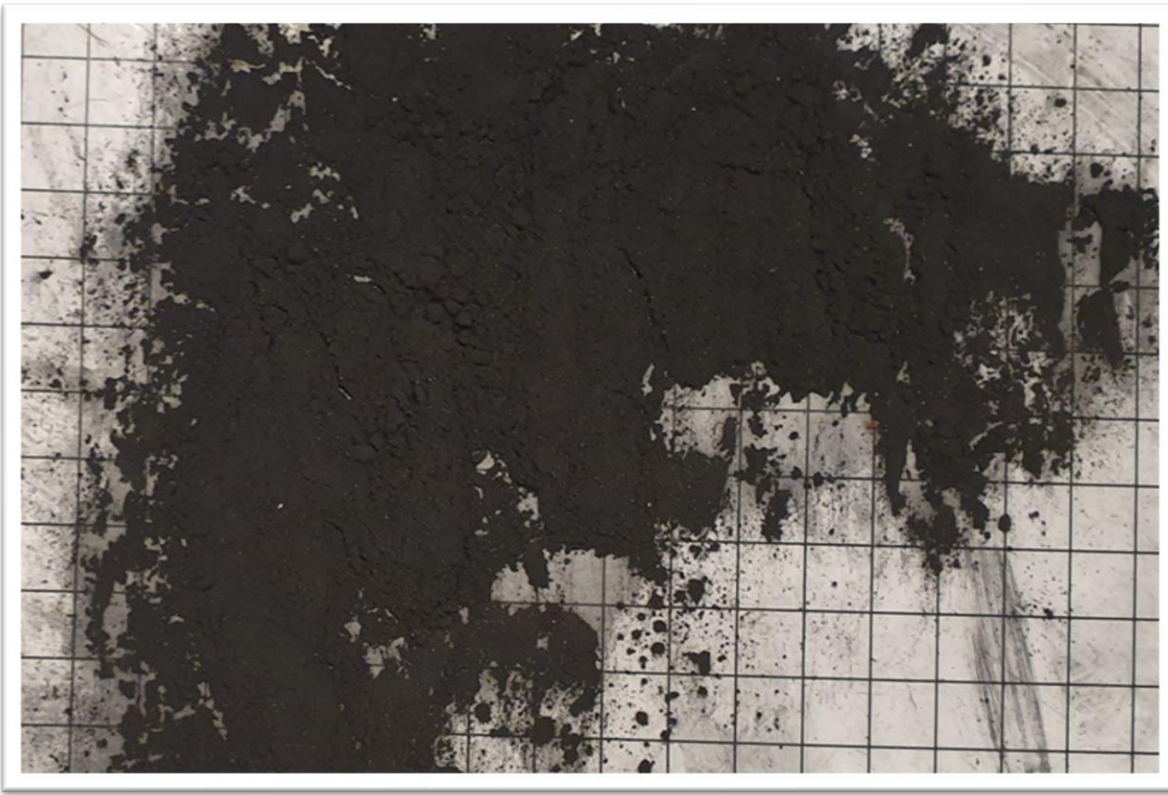
# **BHS Horizontal Evaporator Vacuum Dryer 2 x 2 tons/hour each**





# BHS Recycling Solutions

## Step 4: Output



**Black Mass**



**Mixed Materials**

## **PDE-Stage 2 Scope of Work:**

- 1. The PDE-2 provides design recommendations & information for client to finalize detailed engineering for project purchasing & construction.**
- 2. P&ID drawings (AutoCAD dwg formats) for each step in the process, based upon the PFDs in PDE-1 are used.**
- 3. Plant functional description specification (FDS)**
- 4. Equipment specifications**
- 5. Internal building layout showing core equipment (with dimensions and weights), conveying equipment and steel skid structures.**
  - a. STEP (STP) files will be used to transfer 3D geometry models.**
  - b. Layout will consider material storage, receiving and other logistics and building requirements as specified by client.**
  - c. The STP files will be simplified models that can then be used by others for detailed engineering/civil/mechanical/construction/etc.**
  - d. Building layout based upon P&ID designs and client footprints.**

# **PDE-Stage 2 Detailed Scope of Work:**

## **A. Crushing step 1**

- 1. Feeding System: Box Feeder- Elevators-Belt conveyors**
- 2. BHS process system for shredding/crushing:**
  - **BHS Lock**
  - **BHS Rotary Shear (Pre-shredder)**
  - **BHS Granulator**
- 3. Contained screw conveyors**
- 4. Buffer tank**

## **B. Drying steps 2/3**

- 1. BHS process system for drying:**
  - **BHS Horizontal Vacuum Dryer**
  - **BHS Vacuum and Condensation unit**
- 2. Scrubber-Thermal Oxidation-Other Gas Treatment**

## **PDE-Stage 2 Detailed Scope of Work:**

### **C. Sorting Step 4**

- 1. Buffer tank**
- 2. Screw conveyors**
- 3. Screening/Sifter (Zigzag)/Mills**
- 4. Dedusting**
- 5. Big Bag station and related handling equipment**

### **D. Ancillary Skid packages with Piping, Valves and Instruments, Steel Structure including Nitrogen system and Air compressor**

### **E. Plant Operation and Controls Integration**

### **F. Discharging Pre-Treatment Step 0**

- 1. Discharge with liquid brine solution for small-format batteries**
- 2. Discharge with electrical return feed for EV batteries**

# PDE-Stages

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# **SUMMARY & TAKEAWAYS**

- **Flexible Operation for EV Modules/Cells, Production Scrap, Others (Marine, etc.) & Small-Format Batteries**
- **Dry Process – Completely Inerted & Dust-Tight**
- **Recovery of Black Mass, Electrolytes, Copper, Aluminum, Plastic and Ferrous Materials**
- **Compliance with VOC and TSP Environmental Rules & avoiding liquid and wastewater pollutant emissions**
- **Full PDE Engineering Stages and Turnkey Systems including HAZOP Studies for Safe Operation**
- **Operating References & Process Optimization Including Integration with Downstream Processes**

# Engineering Strategy for Design and Scale-Up of a Recycling Process

**ACT** Like a Recycler  
But  
**THINK** Like a Chemical Plant

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