TOWNGAS

Supercritical-Water Gasification and OXZEO Light-Olefin Synthesis

Integrated wet-organic-waste and bauxite-residue process design

SEVENTH EDITION — PUBLIC ACCESS VERSION: Ten 300 t/d hydrothermal trains; douzha-led regional feed portfolio; purposeful salt separation; one-pass residue qualification; shared Rectisol, bi-reforming and OXZEO; 20-year China economics in RMB.

Document basis	Value
Commercial throughput	3,000 t/d gross slurry; 999,000 t/y at 333 d/y
Hydrothermal configuration	10 independently isolatable trains × 300 t/d
Shared downstream	B5 acid-gas cleanup, B6 bi-reforming, B7 OXZEO and product recovery
Operating life	20 years
Currency / cost year	RMB, 2026 screening basis
Estimate class	Class 4 screening / pre-FEED; not a vendor guarantee
Publication status	Public-access V7; private commercial cost details and source identities removed

Prepared for public technical access and website publication; restricted commercial cost details removed
August 2026

Contents

List of figures

List of principal tables

Table 6.4 Carbon destination and olefin production

Table 7.2 Energy duties and recovery

Table 10.2 CAPEX and Table 10.3 OPEX

Tables 10.5–10.6 and 10.11–10.12 Twenty-year scenarios, results and source reconciliation

Abstract

This report develops a ten-train process that treats two difficult waste classes together: wet organic residues led by douzha, and alkaline bauxite residue. The organic fraction supplies renewable carbon and water for supercritical-water gasification (SCWG); the mineral fraction supplies iron- and alkali-bearing surfaces while undergoing controlled washing and dealkalization. Douzha remains the anchor because it arrives wet and finely divided. Cassava cake, fruit and vegetable pulp, soluble food-processing liquor and limited milled straw are optional regional co-feeds that raise carbon density without changing the core reactor. Manure is treated as a separately qualified gate-fee feed because its nitrogen, phosphorus, ash and chloride can consume the benefit of its carbon.

The commercial basis is 10 independently isolatable 300 t/d hydrothermal trains, or 3,000 t/d and 999,000 t/y gross slurry. Gases merge after B4 into shared Rectisol and ZnO purification, strongly endothermic steam/CO2 bi-reforming and OXZEO light-olefin synthesis. Solids enter a common B8 finishing system. The revised base case does not depend on indefinite bauxite-residue recycle or claim complete one-pass dealkalization: soluble alkali is intentionally withdrawn at B3/B4, a one-pass residue is sold only if it meets a destination specification, and off-specification solids receive a second wash or retreatment.

The balanced regional blend contains 62.40 t/d solids and 25.947 t/d carbon per train at 20.80 wt% total solids. At 42% overall carbon-to-olefin efficiency it produces 42.35 kt/y light olefins; an improved 55% case produces 55.45 kt/y. The public economic screen uses rounded Chinese planning assumptions of RMB 0.40/kWh electricity, RMB 650/t biomass pellets and RMB 20/t purchased water. Central total capital remains RMB 2.814 billion pending vendor quotations. Revised central cash OPEX is approximately RMB 219.9 million/y before EU export/compliance. Current conversion with commodity pricing remains uneconomic, while stronger service contracts and a certified premium become marginally positive; improved conversion produces a substantially stronger result. These results remain pre-tax and unlevered and include a two-year ramp sensitivity.

Nomenclature and accounting conventions

Accounting convention. Internal water, CO2 and gas recycles cancel at the plant battery limit but remain in equipment sizing.

Term	Meaning in this report
B1–B4	Feed preparation, SCWG, hot salt separation, and heat recovery/phase separation; repeated ten times
B5–B7	Shared acid-gas cleanup, bi-reforming and OXZEO/product-recovery island
B8	Shared bauxite-residue washing, qualification and off-specification retreatment
SCWG	Supercritical-water gasification above water's critical point
OXZEO	Bifunctional oxide–zeolite conversion of CO/H2 synthesis gas to light olefins
Carbon efficiency	Feed carbon appearing in saleable C2–C4 olefins at the plant battery limit
TCI	Total capital investment, excluding financing during construction and recoverable VAT
NPV / IRR	Pre-tax unlevered project metrics over 20 operating years
Gate fee	Net contractual payment for accepting waste, after any supplier-specific logistics allowance

1. Introduction and design basis

1.1 The project begins with the wastes, not the reactor

The starting question is not which catalyst should be purchased. It is which regional materials are costly to store, dilute enough to be awkward for conventional thermal treatment, chemically compatible with hydrothermal conversion, and available close enough to one another to support continuous operation. That ordering matters. A process built around a single ideal laboratory feed can fail as soon as supplier moisture changes; a process built around a controlled waste portfolio can absorb seasonal variation while keeping the reactor inside a defined carbon, solids, nitrogen, ash and chloride envelope.

Douzha is the organic anchor. It is already wet, finely divided and rich in carbohydrate, protein and lipid, so the process avoids the drying duty that weakens conventional gasification. Bauxite residue is the mineral anchor. It is alkaline, voluminous and difficult to reuse at the rate at which alumina refineries generate it. The conceptual connection is therefore direct: use water that is already present in douzha as the reaction medium, convert its renewable carbon into gas, and use the same high-temperature circuit to transfer soluble alkali and salts out of the residue. The plant is both a carbon-conversion facility and a residue-conditioning facility.

The next question is whether douzha alone supplies enough carbon per tonne of high-pressure slurry. It can operate the process, and it is not replaced in this design. However, its protein raises aqueous nitrogen and its water dilutes the product basis. Regional carbohydrate residues can therefore be metered beside it when they improve delivered carbon, C/N ratio or gate-fee value. This changes the recipe, not the core flowsheet. The plant should be presented as a broad wet-organic-waste platform, provided each candidate stream is pumpable after preparation, characterizable, legally acceptable and compatible with the destinations designed for its contaminants.

> **DESIGN THOUGHT PROCESS:** Identify difficult regional wastes → screen them for SCWG chemistry and pumpability → build a douzha-led blend → place the plant where short-haul wet feed and denser mineral feed intersect → size ten isolatable hydrothermal trains → merge only clean gas into the common conversion island.

1.2 Why bauxite residue requires an engineered outlet

Bauxite residue is the iron-rich alkaline solid left after alumina extraction. Global production is on the order of hundreds of millions of tonnes per year and the cumulative stored inventory is measured in billions of tonnes. Its environmental difficulty is not captured by the word 'mud': high pH and soluble sodium make drainage management important; fine particles create dust and containment risks when dry; iron, aluminium, titanium and silica phases make the material dense and abrasive; and trace elements can restrict reuse. Storage areas therefore carry long-duration water-balance, dam-integrity, land and liability obligations even when routine operation is well controlled. [1,2,3]

The project does not treat bauxite residue merely as a cheap catalyst. That framing would tolerate a small make-up rate while leaving the main residue problem untouched. Instead, the feed rate, B3 salt withdrawal, B4 washing and B8 product qualification are designed to create a measurable treated-residue stream. Iron-bearing phases may still promote gasification and water–gas shift chemistry, but catalytic value is secondary to controlled dealkalization and a safe destination. Any use in cement, sorbents, iron-rich products or metals recovery requires product-specific leaching, mineralogical and performance evidence; colour and total iron alone are not qualification.

One pass should not be promised to remove every form of sodium. Washing readily removes free caustic, carbonate and other soluble ions, whereas sodium locked in sodalite, cancrinite, hydrogarnet or related aluminosilicate phases can remain. Hydrothermal treatment may open or transform part of that structure, but performance depends on source mineralogy, temperature, liquid-to-solid ratio and residence time. The revised design therefore has a one-pass product target rather than a universal 'fully dealkalized' claim: material meeting pH, soluble sodium, chloride and leachability limits leaves the plant; material that fails receives a second counter-current wash or a defined retreatment campaign. [4,5]

1.3 Why supercritical water is selected

Water above 374 °C and 22.1 MPa has low dielectric character, high diffusivity and complete miscibility with many organic intermediates and gases. Wet biomass can therefore be hydrolysed, fragmented and reformed without evaporating all feed water before reaction. Carbohydrates pass through sugars, aldehydes, ketones and organic acids; proteins hydrolyse to amino

acids and deaminate; lipids hydrolyse to glycerol and fatty acids. Subsequent reforming, cracking, water–gas shift and methanation distribute carbon among CO2, CH4, CO, dissolved organics and solid carbon. Alkali and iron-bearing minerals can accelerate several of these steps, although the same inorganic inventory creates the salt-separation problem that dominates availability.

$$(C_6H_{10}O_5)_n + nH_2O \rightarrow nC_6H_{12}O_6 \rightarrow CO_2 + CH_4 + CO + H_2 + aqueous\ intermediates$$

SCWG is selected because the feed is intrinsically wet, not because pressure is inexpensive. The high-pressure island requires specialised pumps, thick-wall or tubular reactors, salt-tolerant heat exchange, controlled letdown and corrosion-resistant wetted surfaces. The decision is justified only when avoided drying, waste-service value and multiple products compensate for those systems. The economic model consequently reports cost per tonne of wet waste and cost per tonne of olefin side by side.

1.4 The central integration issue

Hydrothermal equilibrium at high water activity favours water–gas shift and, at the selected temperature and catalytic environment, substantial methane formation. OXZEO does not consume a methane-rich gas directly; it requires a controlled mixture of CO and H2. This is the central chemistry-to-process mismatch. Raising SCWG temperature and shortening residence time may reduce methane, but water–gas shift can still remove CO as CO2 and the higher-severity operating point may worsen char, salt deposition or materials duty. The revised design therefore retains B6 bi-reforming and treats methane suppression as an optimisation, not as evidence that B6 can be deleted.

The salt behaviour is not described as a design mistake. Precipitation is deliberately exploited to remove sodium, potassium, phosphate, sulfate and related species from the two-waste system. The engineering problem is where precipitation occurs. Crystals formed in a controlled B3 separator can become a managed concentrate; crystals formed on the B2 wall or in H-101 can stop a train. The process objective is purposeful precipitation with controlled nucleation, continuous underflow, redundant separation and rapid recovery after a flush.

1.5 Commercial design basis

Table 1.1 — Commercial boundary and design basis.

Parameter	Selected basis	Engineering interpretation
Hydrothermal trains	10 × 300 t/d	Scale-out isolates plugging and permits one train to wash while common units remain online
Gross feed	3,000 t/d; 999,000 t/y	Includes feed water, wet wastes, dry fibre, mineral and recycle/makeup water
Operating schedule	333 d/y	Approximately 8,000 h/y for the shared back end; hydrothermal modules rotate through short outages
Operating life	20 years	Economic horizon requested by the owner
B2 condition	625 °C; 25 MPa; 30–90 s screen	Final residence time and wall heat flux require continuous pilot data
B6 condition	~850 °C; ~2.8 MPa	External heat required; steam/CO2 ratio follows measured clean-gas composition
B7 condition	~400 °C; 2–3 MPa	Multiple cooled beds or licensed equivalent; recycle and purge included
Central feed	B1 balanced regional design	Douzha remains largest component; optional co-feeds raise carbon density
Central product target	55.45 kt/y at 55% feed-C efficiency	Financeability target, not a guaranteed yield
Currency / cost year	2026 RMB	China labour, utility and commodity context; imported packages quoted separately

1.6 What the design can and cannot claim

The report is a calculated screening/pre-FEED design. Total mass and carbon are closed on stated pseudo-components, equipment duties are internally consistent, and economics use one RMB basis. It is not a substitute for a licensed OXZEO

package, a salt-equilibrium model, a corrosion campaign or binding supplier and offtake contracts. Values described as targets must be verified before they are used as guarantees.

- The platform can accept diverse wet organic residues, but only inside a feed-acceptance envelope; packaged food waste, grit, plastics, PFAS-bearing materials, high-halogen wastes and unknown industrial sludges are not automatically acceptable.
- Bauxite residue can be materially dealkalized and washed, but complete one-pass removal of structural sodium is not assumed.
- The B3 concentrate and ammonium sulfate are potential products only after impurity, legal and destination qualification.
- ISCC PLUS and ISO 14067 support traceability and carbon claims; they do not create a guaranteed premium or make light olefins subject to EU CBAM.

2. Waste products and how they are used together

2.1 Douzha as the anchor wet feed

Douzha remains the largest single feed in the balanced design: 150 t/d per train, or 499,500 t/y across ten trains. Its water is process medium rather than inert ballast, and its fine particle size helps suspend smaller quantities of milled fibre and mineral solids. Carbohydrate and lipid contribute gasifiable carbon, while protein supplies additional carbon and hydrogen but also transfers nitrogen to the aqueous phase. Supplier-to-supplier variation in moisture and protein is therefore important: a wet-tonne contract without dry-solids, carbon and nitrogen adjustment would transfer process risk to the plant.

Other organic streams are not required to 'replace' douzha. They are control variables. When douzha arrives wetter than normal or protein loading approaches the ammonia-recovery limit, starch-rich cassava cake or a clean carbohydrate pulp can increase carbon without proportionally increasing nitrogen. When the feed is too viscous, the system reduces dry fibre and adds qualified recycle water. The anchor feed remains recognisable through these corrections, which simplifies supplier traceability and start-up.

2.2 Bauxite residue as a treatment feed and process aid

Seven tonnes per day of dry bauxite residue are metered to each train. The rate is large enough to create a meaningful 23,310 t/y treatment stream across the complex while remaining small relative to organic dry matter. The material is stored and slurried separately because sodium, chloride, particle size and moisture must be measured independently. Its iron oxides may contribute redox and gasification activity; soluble alkali can promote water–gas shift and char conversion; aluminosilicate and titanium phases largely report to washed solids. These functions do not remove the need for a commercial catalyst if pilot data show insufficient activity or unacceptable variability.

The residue is purposefully exposed to the hydrothermal and washing circuit. Dissolved sodium and associated salts leave through B3/B4; the washed mineral fraction leaves through B8. The base design does not send all B8 solids back to B1. Eliminating the large routine recycle avoids accumulation of chloride, silica, titanium and trace metals and makes the treated-residue output visible. A small off-specification retreatment loop is retained, but it is a quality-control operation rather than an indefinite catalyst inventory.

2.3 Compatible regional organic co-feeds

Table 2.1 — Compatible streams are selected by reaction chemistry and contaminant destination, not by the generic word 'biomass'.

Waste stream	Why it fits SCWG	Dose / role in this design	Limiting chemistry or handling
Douzha	Wet, fine, pumpable after homogenisation; mixed carbohydrate/protein/lipid	Anchor: 150 t/d per train in B1	Protein nitrogen, spoilage, variable moisture
Cassava cake	Wet starch and fibre hydrolyse readily; relatively low N	60 t/d B1; carbon-density control	Cyanogenic residues, sand, seasonal moisture, starch gelation
Fruit and vegetable pulp	Sugars, pectin and cellulose enter the same hydrolysis/reforming network	20 t/d B1; flexible regional feed	Packaging, grit, chloride from washing, rapid acidification
Soluble organic liquor	Dissolved COD replaces part of dilution water and avoids milling	10 t/d B1; liquid carbon trim	Cleaning chemicals, conductivity, sulfur, refractory COD
Soybean straw	High dry carbon raises C/N and slurry carbon	12 t/d B1; milled below the pumpable PSD limit	Yield stress, bridging, lignin/char, erosion
Bagasse or cane trash	Regionally abundant lignocellulosic carbon	Alternate dry-fibre lane after milling	Silica, seasonal storage, fibrous rheology
Brewery/distillery residues	Wet carbohydrate and soluble organics	Alternate liquor or wet-pulp lane	Sulfate, cleaning chemicals, variable alcohol/acid
Dewatered manure	Biodegradable carbon plus potential gate fee	Separate B3 qualification campaign; capped initially	High N/P/ash/Cl, grit, pathogens before B2, antibiotic/metal screening

Carbohydrate-rich streams are the easiest substitutions because their first chemical step is shared. Hydrolysis converts starch and cellulose into sugars; dehydration and retro-aldol reactions produce smaller oxygenates; reforming and water–gas shift then produce gas. Lipid-rich wastes can also be converted, but fatty acids may change heat-transfer films, phase behaviour and

coking. Protein-rich wastes increase ammonia and heterocyclic nitrogen products. The reactor can accept all three biochemical families, yet the downstream system must be sized for the consequences of the chosen mixture.

2.4 Feed recipes and calculated properties

Table 2.2 — One-train feed-envelope calculations. All recipes total 300 t/d gross slurry.

Case	Wet t/d	Dry t/d	Solids	C t/d	C in slurry	Ash/mineral t/d	C/N
B0 douzha-rich control	300	57.20	19.07%	23.688	7.896%	8.652	6.82
B1 balanced regional design	300	62.40	20.80%	25.947	8.649%	9.147	10.97
B2 higher-carbon operating envelope	300	66.16	22.05%	27.864	9.288%	9.498	17.74
B3 manure qualification campaign	300	65.66	21.89%	26.848	8.949%	11.771	13.90

Table 2.3 — Selected B1 balanced regional design per 300 t/d train.

Component	B1 t/d	Dry solids t/d	Carbon t/d	Function
Douzha	150.0	25.80	11.894	Anchor wet matrix and renewable carbon
Cassava cake	60.0	15.00	6.600	Starch-rich carbon with modest nitrogen
Fruit and vegetable pulp	20.0	3.00	1.320	Flexible sugar/pectin/cellulose residue
Soluble organic liquor	10.0	0.80	0.336	Replaces water with dissolved organic carbon
Soybean straw	12.0	10.80	5.797	Dry-carbon and C/N adjustment
Bauxite residue	7.0	7.00	0.000	Residue treatment feed; mineral/catalytic contribution
Recycle or makeup water	41.0	0.00	0.000	Sets solids, viscosity and flush inventory

B1 contains 20.80 wt% total solids and 8.649 wt% carbon. It retains more than one percentage point below the 22 wt% high-carbon envelope, leaving room for lot-to-lot moisture error. Its C/N mass indicator of 10.97 is materially higher than the douzha-rich control because cassava and straw add carbon with less nitrogen. The recipe is a calculation basis, not a fixed ratio imposed on every batch: the control system recalculates water and co-feed addition from measured total solids, elemental analysis, ash and rheology.

2.5 Broad wet-organic-waste platform: the feed acceptance envelope

The chemistry is broad but the engineering window is finite. A candidate waste is incorporated easily only when it can enter one of four controlled lanes: pumpable wet food residues, soluble organic liquors, prepared dry fibres, or separately quarantined high-ash/high-nitrogen residues. Each lane has its own screen, storage, metering and cleaning system before the final high-shear blend tank. One undifferentiated waste pit would make chloride, ash and certification failures impossible to trace.

Table 2.4 — Feed flexibility is governed by a release envelope, not an unrestricted waste claim.

Acceptance variable	Normal design target	Automatic response outside target
Total solids	18–22 wt% final slurry	Recalculate water and dry-fibre dose; hold batch if rheology remains outside curve
Particle size	D90 <0.5 mm for fibre; no hard grit >1 mm	Remill, screen or reject; do not rely on the HP pump to comminute
Yield stress / restart	Within qualified pump-loop envelope after 12 h hold	Reduce fibre/starch; increase water; repeat restart test

Acceptance variable	Normal design target	Automatic response outside target
Feed carbon	8.5–9.5 wt% gross slurry for B1/B2 operation	Add qualified cassava/fibre/liquor or reduce dilution
Nitrogen	Inside B4 ammonia-recovery capacity	Reduce protein/manure fraction or segregate campaign
Ash and soluble salts	Inside B3 continuous-withdrawal capacity	Lower high-ash feed; switch separator; increase purge within water balance
Chloride	Supplier- and alloy-specific limit; final set by corrosion loop	Segregate, prewash, purge water or reject lot
Sulfur	Inside Rectisol/ZnO and sulfur-recovery load	Reduce feed dose; verify COS hydrolysis and guard-bed life
Excluded contamination	No uncontrolled plastics, PFAS, solvents, halogenated organics or unknown toxic sludge	Quarantine and reject unless a separate permitted campaign is designed

2.6 Slurry preparation and why the wastes mix successfully

Douzha and wet pulps enter enclosed agitated equalisation tanks. Cassava cake is macerated before it can form concentrated starch lenses. Dry straw is magnetically cleaned, milled and loss-in-weight fed into a high-velocity recirculation loop. Bauxite residue is made into a separate measured slurry or fed as conditioned dry powder into a dust-controlled eductor. Combining all materials only in the final blend tank keeps mineral inventory and chloride corrections independent from the organic feed.

A nominal solids percentage does not prove pumpability. Fibres create a yield stress, starch can gelatinise during heat-up, fine mineral particles can settle after a shutdown, and fats can coat heat-transfer surfaces. Release therefore requires a rheogram, particle-size distribution, density, conductivity and a stop/restart test. Two 100% positive-displacement pumps per train provide duty/standby operation, and the suction system is designed for flooded inlet conditions. High-pressure water can displace organic slurry before maintenance without forcing an uncontrolled mixture into the common gas header.

The blend works chemically because all organic fractions converge on a limited set of hydrothermal intermediates. It works mechanically only because each fraction is dosed below a measured rheological limit. Carbon and slurry formation are therefore the two central feed controls: carbon determines product potential; viscosity, settling and particle size determine whether that carbon can reach the reactor continuously.

2.7 Nitrogen from douzha protein

Protein is not simply a contaminant. Hydrolysis produces amino acids, and deamination transfers much of their nitrogen to dissolved ammonia/ammonium. Leaving that nitrogen in mixed recycle water increases corrosion, oxygen demand and the risk of an unqualified salt concentrate. The preferred B4 route is solids removal followed by pH- and temperature-assisted ammonia stripping or a gas-permeable membrane, with sulfuric-acid absorption to make an ammonium-sulfate solution. Recent hydrothermal-liquor studies report high ammonia removal and recovery when the contacting and pH conditions are controlled, demonstrating that nitrogen can become a separate product rather than a wastewater load. [18,19,20]

The B1 calculation contains approximately 2.365 t N/d per train. At 75% recovery, ten trains would recover about 17.74 t N/d, equivalent to roughly 83.6 t/d ammonium sulfate or 27.9 kt/y. At 900–1,200 RMB/t this is a gross upside of approximately RMB 25–33 million/y before acid, steam, polishing and product-registration cost. It is not booked in base revenue until metals, chloride, organics and fertilizer rules are satisfied.

2.8 Chloride control

Chloride is not assumed to be an inherent constant in every bauxite-residue source; it is measured. It may enter through refinery water, coastal handling, food-processing brines, cleaning chemicals or manure. Once inside a closed water loop it can concentrate, increasing the risk of pitting and stress-corrosion cracking in hot high-pressure equipment. A single plant-wide chloride number is therefore inadequate: limits are set separately for B1 feed, B3 underflow, B4 recycle water, B8 wash water and each metallurgy transition.

- Segregate suppliers and reject or separately campaign high-chloride lots before blending.
- Use counter-current prewashing for bauxite residue when soluble chloride and sodium justify the water duty.
- Withdraw precipitated chloride-bearing material at B3 where its phase behaviour permits; do not assume all chloride precipitates under the same conditions as sulfate or carbonate.

- Wash B8 solids and control B4 recycle by chloride mass balance rather than a fixed recycle percentage.
- Treat the controlled aqueous purge by membrane concentration, electrodialysis, evaporation/crystallisation or a permitted external facility selected from actual composition.
- Use corrosion coupons and alloy-specific testing to set the final feed limit; a design corrosion allowance does not replace chemistry control.

3. Regional sourcing and plant location

3.1 The location opportunity

The interactive siting screen from curtis-lee.com does not prove that feedstocks are too dispersed. It identifies a useful regional pattern: wet organic residues are concentrated in the Guangdong manufacturing and food-processing belt and in Guangxi cassava, sugar and food-processing districts, while major bauxite and alumina activity lies farther west in Guangxi. A coastal Beibu Gulf integration hub can sit between those source classes, with port and industrial infrastructure, rather than forcing all material toward an inland single-feed location. Official regional planning documents confirm material cassava, sugarcane, grain/oil/soy, fruit and vegetable, brewing and livestock-processing activity across the two provinces. [21,22,23,24]

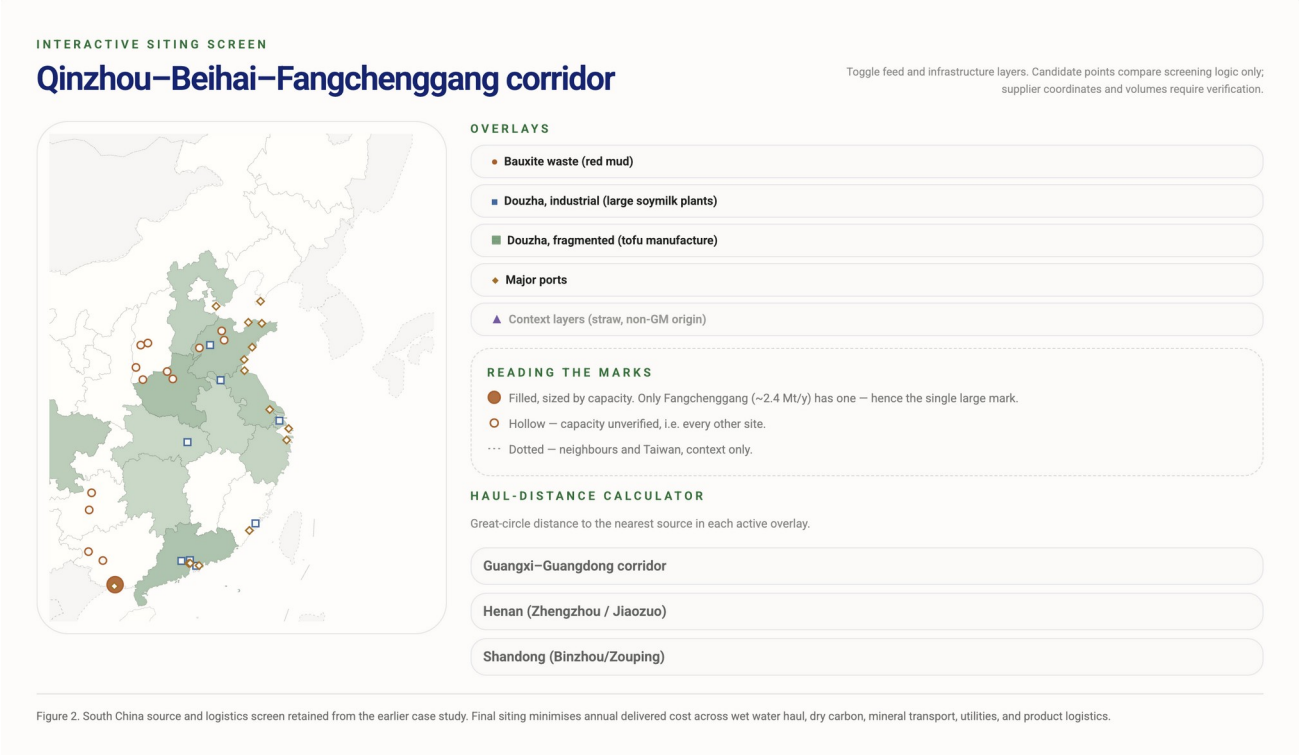

Figure 3.1 — Interactive siting screen for the Qinzhou–Beihai–Fangchenggang corridor, reproduced from the Towngas project page on curtis-lee.com. The displayed supplier points are screening evidence; coordinates, capacities and delivered-cost assumptions still require verification.

3.2 Why wet feed governs siting

A tonne of low-solids douzha or fruit pulp is mostly water. Hauling it long distances consumes truck capacity without adding proportional carbon, and warm storage increases odour and biological deterioration. Dense dry bauxite residue and baled straw can travel farther or use rail/port backhaul. The plant should therefore be close to the largest stable wet-organic cluster, with mineral feed treated as the longer transport leg. A provisional planning rule is less than roughly 75 km for dilute wet residues and up to 150 km or more for dry, dewatered or backhauled solids, but the final decision is made in RMB per delivered tonne of dry carbon and in tonnes of contaminants delivered with it.

The ten-train configuration supports distributed sourcing. Each train can receive a common B1 recipe, while segregated day tanks allow one supplier class to be isolated without shutting the whole complex. The back end sees composition-controlled clean gas rather than supplier identity. This is more robust than locating ten small complete plants beside ten suppliers because Rectisol, bi-reforming, OXZEO and deep product separation benefit from shared scale.

3.3 Candidate-hub screening

Table 3.1 — Positive regional fit does not remove the need for supplier-level diligence.

Criterion	Why it matters	Preferred evidence before land selection
Wet-feed radius	Controls water haul, spoilage and gate-fee margin	Geocoded supplier list; 12 monthly volumes; moisture and dry-carbon distributions
Bauxite-residue route	Creates the second waste-service proposition	Refinery source, mineralogy, soluble/structural

Criterion	Why it matters	Preferred evidence before land selection
		Na, chloride, current disposal cost
Port / rail / highway	Enables dense solids, product export and maintenance access	Delivered-cost quotations and hazardous/waste transport permissions
Industrial utilities	Reforming, refrigeration, compression and water treatment are material loads	Firm power, gas/steam, cooling, water, wastewater and emergency capacity
Olefins offtake	Mixed C2–C4 product cannot be stored or exported casually	Pipeline/terminal/fractionation route and buyer specification
Certification boundary	EU premium depends on auditable feed and product chain	ISCC-ready supplier declarations, mass-balance system and customs route
Permitting and community	High-pressure syngas, methanol solvent and residue handling need industrial zoning	Pre-application regulator review, safety distances and emergency-response access

3.4 Recommended location logic

A Qinzhou–Beihai–Fangchenggang industrial corridor is a credible first screening region because it can connect Guangxi mineral and carbohydrate resources with western Guangdong food-processing and port logistics. The recommendation is not a final site nomination. It is a better hypothesis than treating the province boundary as a feedstock barrier. The final short list should compare at least three industrial parks using delivered dry carbon, bauxite-residue treatment value, power/gas cost, product export route, shared wastewater capacity and permit schedule.

SITING DECISION RULE: Choose the location that minimises the combined annual cost of wet-feed water haul, dry-carbon procurement, mineral transport, utilities and product logistics—not the point that appears visually central on a map.

4. Overall process architecture

4.1 Ten hydrothermal trains and one shared conversion island

The commercial plant uses ten complete B1–B4 trains. Each train has independent feed tanks, high-pressure pumps, final heating, SCWG reactor, twin hot-salt separators, heat recovery, depressurization and primary phase separation. A dirty or off-specification train is isolated before the common gas header. Only after water, entrained solids, pressure, sulfur and gas composition are inside the acceptance window does its gas enter shared B5 purification.

Sharing begins downstream of B4 because Rectisol refrigeration, sulfur recovery, bi-reforming, synthesis-gas compression, OXZEO recycle and product fractionation have strong economies of scale. Solids and aqueous streams remain identified by source train until their analytical release, then enter shared B8 washing or central water/nitrogen treatment. This arrangement balances modular hydrothermal risk against conventional downstream scale.

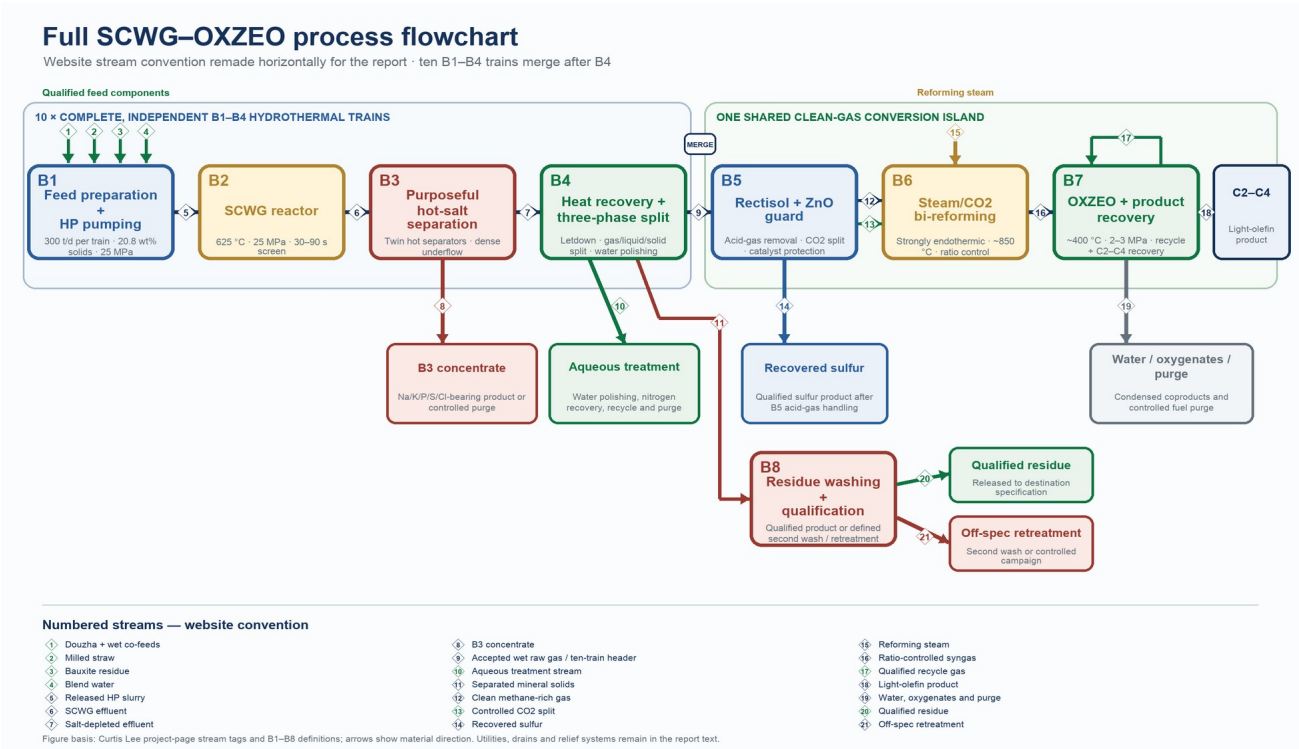

Figure 4.1 — Full horizontal reconstruction of the Curtis Lee project-page process drawing. Arrows show material direction and diamonds retain streams 1–21; ten complete B1–B4 trains merge only after B4 into shared B5–B7 facilities, while B3 concentrate, aqueous treatment, recovered sulfur, B8 residue and controlled retreatment remain explicit outlets.

4.2 Stream routing

Table 4.1 — Principal stream routing and the conditions that protect shared equipment.

Stream	Origin → destination	Normal contents	Release condition
S-101	Feed receipt → B1 final blend	Douzha, approved co-feeds, fibre, bauxite residue, water	Batch solids, carbon proxy, rheology, PSD, N/S/Cl and traceability accepted
S-201	B2 → B3	Supercritical water, product gas, salts and mineral solids	Temperature/pressure stable; reactor wall and DP within envelope
S-301	B3 underflow → concentrate cooling	Dense brine/crystal slurry	Controlled mass withdrawal; no pressure-boundary accumulation
S-401G	B4 separator → clean-gas header	H2, CH4, CO2, CO, acid-gas traces	No liquid carryover; sulfur, water and pressure inside header specification
S-401W	B4 → water/nitrogen recovery	Water, NH3/NH4+, dissolved organics and ions	Filtered; allocated to ammonia recovery, polishing, recycle or purge
S-401S	B4 → B8	Washed mineral and residual solid carbon	Train identity retained until product qualification
S-501	B5 → B6	Sulfur-free methane/H2/CO/controlled CO2	Total sulfur below OXZEO/reformer contract; water and methanol controlled

Stream	Origin → destination	Normal contents	Release condition
S-601	B6 → B7	CO/H2 synthesis gas with controlled ratio	CH4 slip, steam, CO2 and H2/CO inside OXZEO envelope
S-701	B7 recovery → offtake	Ethylene, propylene and C4 cut	Buyer purity and certification documents released
S-801	B8 → customer / retreatment	Conditioned iron-rich residue	Destination pH, soluble Na, Cl, metals, leaching and performance passed

4.3 Train isolation and common-mode protection

A check valve is not sufficient protection between a salt-bearing train and a shared synthesis plant. Each gas connection uses two isolation valves with a bleed, independent pressure and water analysers, and a permissive logic that requires stable composition before opening. A high-high B4 liquid level, gas-header reverse flow, sulfur excursion or unstable letdown closes the train and diverts its gas to a closed fuel or disposal system. The other nine trains remain in service.

Common utilities are N+1 where failure would stop all gas conversion: reformer combustion air, synthesis recycle compression, Rectisol circulation and refrigeration, instrument air, cooling-water pumps and control power. Product recovery may operate at turndown when one or two trains are offline. The hydrothermal modules do not rely on the common back end for emergency depressurization; each has a local quench/blowdown receiver sized for its inventory.

4.4 Process design summary

Table 4.2 — B1–B8 process definition without a routine bauxite-residue recycle dependency.

Block	Purpose	Selected operating concept	Dominant design question
B1	Make a stable carbon-controlled slurry	Segregated receipt, fine milling, high-shear blending, two 100% HP pumps/train	Can every approved batch restart after settling without bridging?
B2	Convert wet organics and expose residue	625 °C, 25 MPa, rapid near-critical heat-up, 30–90 s screen	Can conversion be sustained without char and wall deposition?
B3	Purposefully withdraw precipitated salts	Twin lead/lag hot separators with continuous underflow and flush	Can crystals be made to leave through the bottom rather than attach to the wall?
B4	Recover heat; depressurize; split gas/water/solids	H-101 before staged letdown; primary and secondary separation	Can clean gas be produced without eroding valves or recycling Cl/TOC indefinitely?
B5	Protect reformer and OXZEO	Shared Rectisol, COS management, lead/lag ZnO, sulfur recovery	Can total sulfur remain below the licensor limit during transients?
B6	Convert CH4/CO2/H2O to CO/H2	Fired tubular bi-reformer with composition-controlled steam and CO2	Can the endothermic methane round-trip be reduced without coking?
B7	Convert syngas to C2–C4 olefins	Cooled OXZEO beds, recycle, purge and product separation	Can activity, selectivity and catalyst life reach plant targets on real gas?
B8	Create controlled mineral outlet	Counter-current wash, conditioning, product release, off-spec second wash	Which destinations accept the measured mineral and leaching properties?

5. Detailed process chemistry and engineering

5.1 B1 — receiving, feed preparation and high-pressure pumping

5.1.1 Receiving and quality segregation

Douzha, cassava cake and fruit pulp arrive through enclosed tipping or tanker bays into independent equalisation tanks. Storage is deliberately short: the process does not pay to chill material that can be consumed immediately, but temperature, pH and tank vapour are monitored because acidification changes rheology and odour. Soluble liquor receives a conductivity and pH screen before unloading so a cleaning-chemical excursion cannot enter the common water inventory. Retained samples and supplier mass records support invoice adjustment, environmental compliance and ISCC chain of custody.

Straw and alternate dry fibre use a covered store, magnet, shredder and hammer mill. Bauxite residue uses a dedicated silo or agitated slurry tank with abrasion-resistant transfer. Manure, if admitted, remains physically and administratively segregated until pathogen, grit, metals, antibiotic-screen and composition results are released. SCWG destroys pathogens in the reactor, but it cannot prevent worker exposure, odour or cross-contamination in reception.

5.1.2 Blend calculation and rheology control

The batch controller solves three linked constraints: total flow must equal 300 t/d, measured solids must remain within the qualified pump curve, and carbon must remain high enough to justify pressure equipment. Nitrogen, ash and chloride are inequality constraints set by B3, B4 and metallurgy capacity. No operator is asked to infer these relationships from a wet-tonne recipe; the laboratory total-solids and elemental results update the batch mass calculation automatically.

$$m_{water,trim} = 300 - \Sigma\, m_{wet,i} \quad \text{and} \quad x_{C,slurry} = \Sigma(m_{wet,i} \cdot TS_i \cdot x_{C,i}) \,/\, 300$$

The final tank uses high-shear recirculation to wet mineral fines and distribute fibre without aeration. Density and torque are online proxies; an actual rheogram and particle-size test release each operating campaign. Feed hold-up is minimised, but the pump suction and recirculation loop are sized so a controlled 12-hour hold and restart can be demonstrated.

5.1.3 High-pressure feed

Two 100% positive-displacement pumps per train raise approximately 12.5 t/h to 25 MPa. Pulsation dampers, flooded suction, abrasion-tolerant check valves and a full-flow clean-water line are mandatory. A pump can be switched only after the standby unit has been pressure-tested against a recirculation path. Loss of suction pressure, rising pulsation, falling flow at constant speed or increasing preheater differential pressure stops organic and mineral feed while clean water continues to sweep the hot circuit.

Table 5.1 — B1 design controls.

B1 parameter	Screening value	Verification / protection
Final slurry	18–22 wt% total solids	Supplier-specific pump loop and hot restart
Nominal train flow	12.5 t/h	Coriolis/density cross-check; tank mass reconciliation
Discharge pressure	25 MPa plus line loss	Relief to closed receiver; two-block isolation
Fibre size	D90 <0.5 mm screen	No hard grit >1 mm; removable spool inspection
Pump arrangement	2 × 100% per train	Weekly hot standby test and automatic water displacement
Release data	TS, density, rheology, PSD, C/H/N/S, ash, Na/K/Cl/P	Electronic batch certificate before feed valve opens

5.2 B2 — supercritical-water gasification

5.2.1 Reaction sequence

Heating first accelerates hydrolysis and ionic reactions. Starch, cellulose and protein fragments become soluble oligomers, sugars, amino acids and acids. Near the critical region, solvent properties change rapidly; poorly managed residence in the 200

–400 °C range encourages Maillard products, polymerisation and wall films. The feed heater is therefore designed to cross this region quickly, using salt-depleted effluent in H-101 and a short final trim heater.

At the selected outlet temperature, fragmentation and reforming produce H2, CO, CO2 and CH4. Water–gas shift consumes CO and produces H2; methanation consumes CO or CO2 with hydrogen; steam reforming and dry reforming oppose methane formation at high temperature. Alkali can accelerate shift and gasification, while iron-bearing phases can provide catalytic surfaces. The measured product is an equilibrium-constrained, kinetically modified mixture rather than the output of one overall reaction.

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad \Delta H^\circ_{298} \approx -41\ kJ/mol$$

$$CO + 3H_2 \rightleftharpoons CH_4 + H_2O \qquad \Delta H^\circ_{298} \approx -206\ kJ/mol$$

$$CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O \qquad \Delta H^\circ_{298} \approx -165\ kJ/mol$$

These exothermic methanation reactions are favoured by lower temperature, high pressure and abundant hydrogen, while high temperature favours the reverse reforming direction. The process therefore uses 625 °C as a screening compromise: hot enough to reduce refractory liquid products and discourage methane relative to milder SCWG, but below a blanket assumption that 700 °C automatically solves conversion. The correct temperature is the one that maximises plant carbon efficiency and online time, not the gas H2 yield in an isolated batch test.

5.2.2 Reactor and heat-transfer concept

A vertical externally heated vessel with replaceable nickel-alloy wetted internals is used for screening, although parallel tubular or bayonet designs may prove more inspectable. At an assumed hot-fluid density of 120 kg/m^3 and 60 s nominal residence, 12.5 t/h requires approximately 1.74 m^3 reacting volume. A gross volume near 2.3 m^3 provides disengagement and instrumentation allowance. This is a process volume, not a mechanical drawing; wall thickness, cyclic fatigue, nozzle reinforcement and thermal gradients must be resolved under the applicable Chinese pressure-vessel code.

The wall is protected by feed-flow permissives, multiple skin thermocouples and a maximum heat-flux constraint. A falling flow at fixed firing rate can carbonise the feed against the wall before the average outlet temperature changes. High wall temperature or B3 differential pressure therefore cuts organics and residue first, retains clean-water flow and isolates the train gas. Online GC is useful for H2/CH4/CO/CO2 response, but the performance test is a 95–105% carbon balance that includes aqueous TOC and recovered solid carbon.

5.2.3 Methanation suppression: corrected interpretation

Operating hotter and with shorter residence can suppress net methane formation, and that option should be tested. It does not by itself create an OXZEO-ready gas. High water activity and water–gas shift can still drive CO toward CO2, while aggressive severity can increase salt deposition, corrosion, char or heater duty. Less methane also means less carbon available for the reformer to convert into CO if the avoided methane has instead become rejected CO2 or solid carbon. The useful metric is therefore downstream olefin carbon per tonne of feed, not minimum methane at the B2 outlet.

> **CORRECTED DESIGN POSITION:** B2 severity is optimised to reduce the methane round-trip only when total carbon efficiency, salt behaviour and materials performance improve together. B6 remains in the base flowsheet until a continuous gas composition proves it unnecessary.

5.3 B3 — purposeful salt precipitation and continuous separation

5.3.1 Why precipitation is desired

Inorganic salts lose solubility as water becomes supercritical. The same phenomenon that plugs an uncontrolled SCWG plant can be used to transfer sodium and other soluble species out of bauxite residue. B3 is therefore both an availability device and a product operation. The target is not to prevent all salt formation; it is to make supersaturation and nucleation occur in a vessel that has controlled wall temperature, solids residence and continuous underflow. Salt research and hydrothermal separation studies consistently show that phase behaviour depends strongly on temperature, pressure, ion pairing and mixed-salt composition, so a single pure-salt solubility curve is insufficient.[6,7]

5.3.2 Separator design

Each train has two 100% hot separators in lead/lag or duty/standby service. Tangential entry creates a downward solids path; a cooled or transpiring wall can bias nucleation away from the pressure boundary; and a dense underflow leaves continuously through a short, erosion-tolerant line. A five-minute hot inventory at the assumed density is approximately 8.7 m^3, giving a provisional 10 m^3 gross vessel. The exact design follows pilot settling velocity, crystal habit and salt load.

A separator is considered successful only if it sustains mass withdrawal and recovers baseline pressure drop after a controlled flush. Dry salt yield alone is not enough. Differential pressure, underflow density, wall temperature, acoustic response and flush-water recovery are trended together. One vessel can be isolated and depressurised into a cooled receiver while the other carries water circulation or production, allowing the reactor to avoid a full thermal cycle for every cleaning event.

5.3.3 Concentrate destination

B3 underflow is cooled under pressure, flashed in a wear-resistant pot and filtered or concentrated. It may contain sodium, potassium, phosphorus, sulfur, chloride, trace metals and residual organics. The stream is described as a nutrient- and alkali-bearing concentrate until product testing proves otherwise. Fertilizer value requires nutrient assay, chloride limits, heavy metals, pathogens, organics and applicable registration; a cement/mineral destination requires a different specification. The economic base assigns only a small combined by-product value.

Table 5.2 — Salt precipitation is deliberate; uncontrolled deposition is not.

Salt-control layer	Function	Failure response
Supplier ion limits	Prevent B3 overload before material enters B1	Quarantine, prewash, reduce dose or reject
Rapid heat-up	Reduce upstream precipitation and organic wall films	Lower solids rate; switch final-heater path; water flush
Twin B3 vessels	Maintain separation while one vessel flushes	Isolate affected separator; hold reactor at clean-water circulation
Controlled underflow	Keep crystals moving to a cooled product receiver	Increase withdrawal; verify density/interface; avoid single-valve flashing
Removable liners/spools	Concentrate erosion and deposit damage in replaceable parts	Planned exchange based on inspection and wall-loss trend
Water-only recovery	Remove deposits without uncontrolled decompression	Terminate organic feed; verify DP recovery before restart

5.4 B4 — heat recovery, depressurization, phase separation and aqueous polishing

5.4.1 Heat recovery before pressure letdown

Salt-depleted effluent first transfers heat to cold slurry in H-101. Recovering heat while both streams remain pressurised avoids a large flash before the main exchanger and preserves temperature driving force. The exchanger must tolerate residual fine solids, so printed-circuit, double-pipe, bayonet or other geometry is selected from fouling and erosion tests rather than heat-transfer coefficient alone. Parallel modules, isolation and hydroblasting access are more valuable than an optimistic minimum area.

5.4.2 Staged pressure reduction

The effluent is depressurised through several stages with sacrificial trim rather than one valve. A hydraulic power-recovery device can be evaluated only if solids testing proves reliable; otherwise staged letdown limits local velocity and cavitation. The first separator retains sufficient pressure to keep acid gases with the gas stream. A second flash removes dissolved gas, and a three-phase separator splits aqueous liquid, mineral solids and any immiscible organic phase. High vibration, abnormal valve position or downstream high level initiates water-only operation and routes material to the closed blowdown receiver.

5.4.3 Aqueous polishing, nitrogen recovery and water recycle

The aqueous train uses fine-solid removal, ammonia recovery, organic polishing and a controlled salt/chloride purge. Activated carbon, catalytic wet oxidation, membrane separation or biological polishing can be selected after real refractory-TOC analysis; no single unit is imposed on an unknown liquor. Ammonia stripping or gas-permeable transfer occurs after solids removal and before the final water recycle, producing a separate acid absorber stream.

Water recycle is governed by chloride, sodium, refractory organic carbon, ammonia and trace-metal inventories. A nominal high recycle fraction is economically desirable but is not a fixed guarantee. The purge increases automatically when a

conservative component approaches its limit; makeup water closes the final slurry. This mass-balance control prevents an apparent zero-liquid-discharge claim from hiding a growing corrosion inventory.

5.5 B5 — acid-gas removal and catalyst protection

Ten-train gas is compressed or pressure-matched into a shared chilled-methanol Rectisol unit after bulk water removal. Methanol selectively absorbs H2S, COS and CO2. Flash staging and regeneration produce a sulfur-rich fraction for sulfur recovery and a CO2-rich fraction that is split between B6 ratio control and export, sequestration or controlled release according to the carbon case. The methanol system requires refrigeration, water control, closed drainage and solvent-loss monitoring.

A lead/lag ZnO guard follows bulk removal. It is intentionally a polishing bed, not the main sulfur-removal process. Its job is to absorb breakthrough and analytical uncertainty before nickel reforming catalyst and OXZEO active sites. Two independent total-sulfur measurements control bed switching and isolate B7 on disagreement. COS hydrolysis or an equivalent licensed solution is included if the solvent configuration cannot reliably meet total-sulfur specification.

$$ZnO + H_2S \rightarrow ZnS + H_2O$$

Table 5.3 — B5 is a shared quality barrier, not merely an emissions unit.

B5 function	Design target	Why it matters
Bulk H2S/COS removal	Rectisol and sulfur recovery sized to real gas	Prevents excessive disposable guard-bed consumption
CO2 split	Retain only the fraction needed for B6 ratio control	Avoids compressing rejected carbon through the synthesis loop
Water/methanol control	Below reformer and OXZEO contract limits	Prevents condensation, catalyst damage and composition error
ZnO outlet	<0.1 ppmv total sulfur screening target	Protects reformer and bifunctional synthesis catalyst
Transient routing	Off-spec gas to fuel/disposal, never B7	Start-up and analyser failure cannot contaminate the common loop

5.6 B6 — bi-reforming and the methane round-trip

5.6.1 Thermodynamics

Bi-reforming combines steam and dry reforming so methane, carbon dioxide and water form CO/H2 synthesis gas. Both principal reforming reactions are strongly endothermic. Summing two steam-reforming equivalents with one dry-reforming equivalent gives the convenient overall relation below and a standard reaction enthalpy of approximately +660 kJ per stoichiometric reaction as written. Heat must be supplied through reformer tubes; the reaction is not exothermic. [16,17]

$$CH_4 + H_2O \rightleftharpoons CO + 3H_2 \qquad \Delta H^\circ_{298} \approx +206\ kJ/mol$$

$$CH_4 + CO_2 \rightleftharpoons 2CO + 2H_2 \qquad \Delta H^\circ_{298} \approx +247\ kJ/mol$$

$$3CH_4 + CO_2 + 2H_2O \rightleftharpoons 4CO + 8H_2 \qquad \Delta H^\circ_{298} \approx +660\ kJ$$

The overall stoichiometry gives H2/CO = 2, but actual B5 gas already contains H2 and CO. Steam and CO2 are therefore adjusted from online composition. Excess steam suppresses carbon deposition but raises furnace and downstream water duty; excessive CO2 lowers hydrogen ratio but circulates more inert/rejected carbon. Equilibrium, methane slip, tube-skin temperature and coke margin are solved together in a rigorous reformer model.

5.6.2 Equipment and integration

The shared B6 system is a fired tubular package near 850 °C and 2.8 MPa, with upstream sulfur guard, feed preheat, steam addition, CO2 recycle and optional pre-reforming. Hot syngas generates high-pressure steam and preheats reformer feed before ratio trim and B7 compression. Burner staging, low-NOx design, tube-skin monitoring and decoking connections are included. A purge-fuel stream offsets part of furnace fuel, but the endothermic reaction remains the largest irrecoverable thermal penalty after sensible-heat recovery.

This penalty is the price of linking a methane-rich hydrothermal gas to CO-based OXZEO chemistry. It is not hidden inside a generic utility factor. The process economics improve sharply if B2 delivers more CO and less methane without losing carbon,

or if a licensed OXZEO system accepts a different H2/CO ratio. They do not improve if methane is suppressed only by turning the same carbon into rejected CO2.

5.7 B7 — simplified OXZEO synthesis and product recovery

5.7.1 Chemistry in practical terms

OXZEO uses two cooperating catalyst functions. A metal oxide activates CO/H2 and forms oxygenated C1/C2 intermediates; a shape-selective zeolite converts those intermediates inside small pores to ethylene, propylene and C4 olefins. Separating CO activation from carbon–carbon coupling can achieve much higher light-olefin selectivity than a conventional Fischer–Tropsch product distribution. Published research reports high selectivity, but activity, stability and the distance between the two functions remain active development questions. Dalian Institute researchers report participation in a kilotonne-scale industrial pilot, which is encouraging but is not equivalent to a commercial guarantee for this biomass-derived gas. [13,14,15]

The report intentionally avoids an extended speculative mechanism. For process design, five facts matter: the feed must contain CO and H2; sulfur and selected contaminants must be extremely low; heat must be removed to protect selectivity; unconverted syngas requires recycle and purge; and catalyst performance must be demonstrated on the actual B6 gas, including trace water, CO2 and methane.

5.7.2 Reactor, recycle and separation

The screening basis uses 45% single-pass CO conversion and 70% carbon selectivity to C2–C4 olefins on converted carbon, with recycle of unconverted syngas. Overall plant carbon efficiency is lower because B3/B4 solids and aqueous carbon, B5 CO2 rejection, B6 methane slip and B7 purge occur before saleable product. Multiple cooled beds or a boiling-water reactor hold the catalyst near 400 °C. High bed temperature or sulfur breakthrough cuts fresh syngas and maintains an inert/recycle flow for controlled cooling.

Product recovery condenses water and oxygenates, removes CO2 and separates fuel gas from ethylene, propylene and a C4 cut. A mixed light-olefin offtake may avoid some fractionation, whereas separate polymer-grade products require deeper dehydration, acetylene and oxygenate control, refrigeration and fractionation. The economic model uses a netback rather than assuming that every tonne receives the published price of a finished polyethylene or polypropylene resin.

Table 5.4 — OXZEO is simplified in narrative but not simplified in risk allocation.

B7 parameter	Screening input	Commercial requirement
Single-pass CO conversion	45%	Licensed value on real B6 gas and defined space velocity
C2–C4 selectivity	70% of converted carbon	Product-specific carbon balance including oxygenates and paraffins
Overall feed-C efficiency	42% current screen; 50–55% target	Battery-limit carbon closure sustained over catalyst cycle
Temperature	Approximately 400 °C	Axial/radial profile inside selectivity and material limits
Sulfur	<0.1 ppmv screening	Licensor guarantee and analyser voting
Catalyst life	Not guaranteed	Long-duration real-gas demonstration and regeneration/replacement plan
Product netback	7,500 RMB/t commodity basis	Buyer term sheet for mixed or separated olefins

5.8 B8 — residue finishing, qualification and off-specification retreatment

B4 mineral solids are washed counter-currently to minimise fresh water while reducing soluble sodium and chloride. Mechanical dewatering is followed by low-temperature drying or conditioning with recovered heat. Air oxidation may stabilise some iron phases, but no revenue or catalyst-credit is assigned to an unproven oxygen-carrier regeneration. XRF, XRD, pH, soluble sodium, chloride, total and leachable metals, residual carbon, particle size and destination performance determine release.

A one-pass product stream is the objective. Material meeting the selected cementitious, sorbent, aggregate, iron-concentrate or hydrometallurgical-feed specification leaves B8. Off-specification material receives a second wash, source-specific hydrothermal retreatment or disposal in a permitted route. This explicit fork is more credible than asserting full dealkalization or recycling every tonne until contaminants accumulate.

Table 5.5 — B8 turns a variable residue into specification-led outlet streams.

Potential outlet	Evidence required	Economic treatment
Cementitious or clinker feed	Alkali, chloride, mineralogy, grindability, strength, setting and leaching	No premium until cement-plant trial and contract
Iron-rich sorbent/product	Fe phase, surface area, capacity, regenerability and contaminant release	Low conditional value only
Magnetic concentrate	Magnetic yield, Fe grade, Ti/Al/Na impurities and buyer penalty	Pilot yield and offtake required
Hydrometallurgical feed	Fe/Sc/Ti assay, recovery, reagent consumption and residue liability	No scandium revenue in base case
Second wash/retreatment	Failure against pH, soluble Na, Cl or leaching endpoint	Operating cost and capacity included; not a routine closed recycle
Permitted disposal	Waste classification and facility acceptance	Conservative fallback cost

5.9 Process integration discussion

The process succeeds only when the material destinations remain linked. More protein may increase feed carbon but raises ammonia-recovery duty. More manure may bring a gate fee but overload B3 salts and B4 nitrogen. More bauxite residue increases treatment value but also increases abrasion, separator load and product-qualification responsibility. More steam protects B6 catalyst but increases firing and separation. These are not late contradictions; they are the normal variables used to select the feed recipe and operating point.

The revised architecture makes these choices visible. B3 salt withdrawal is desired and measured; B4 nitrogen recovery prevents valuable nitrogen from becoming recycle-water burden; B8 has a real product/retreatment split; B6 endotherm is in the energy balance; and B7 yield is not equated with laboratory selectivity. This is the process basis used for the balances that follow.

5.10 Operating windows, transitions and train management

5.10.1 Start-up from water circulation

A hydrothermal train starts on clean water. B1 establishes stable pump suction and discharge pressure, H-101 and the trim heater raise the circuit through the critical region, and B3 proves that both underflow and standby paths are available. Organic feed is introduced first at low carbon loading; bauxite residue and dry fibre follow only after wall temperature, pressure drop and gas composition stabilise. The train gas remains outside the common header until B4 water carryover, B5 inlet composition and sulfur are inside specification. This sequence prevents a cold salt separator, a wet gas header or an unproven analyser from becoming a common-mode event.

5.10.2 Normal recipe movement

Recipe changes are made in small mass increments at constant gross train flow. When douzha moisture rises, the controller first reduces trim water; only after that correction is exhausted does it adjust cassava, liquor or fibre. When carbon falls, a carbon-rich co-feed is added only if predicted solids, yield stress, nitrogen, ash and chloride remain inside their limits. The final blend tank provides enough averaging time for a complete batch certificate, so the reactor does not see alternating supplier slugs.

Table 5.6 — Recipe and inventory changes follow a defined hierarchy.

Change	First control action	Second action if limit remains	Do not do
Douzha becomes wetter	Reduce makeup/recycle-water addition	Increase qualified cassava/liquor within solids and N limits	Raise gross flow above train hydraulic basis
Slurry yield stress rises	Reduce dry fibre or gelatinising starch; add water	Lower total solids and accept temporary product loss	Force the batch through HP checks
Feed carbon falls	Add measured carbohydrate residue	Reduce dilution or move toward B2 envelope after release	Assume wet tonnes equal carbon
Nitrogen approaches B4 limit	Reduce protein/manure dose	Increase segregated ammonia-recovery operation	Recycle ammoniacal water indefinitely
B3 salt load rises	Reduce high-ion feed and increase controlled withdrawal	Switch separator and shorten campaign	Cool salt-bearing fluid upstream of B3

Change	First control action	Second action if limit remains	Do not do
Chloride inventory rises	Stop high-Cl supplier and increase purge	Prewash residue; lower recycle; external purge treatment	Use conductivity alone as chloride proof

5.10.3 Separator switch and controlled recovery

A rising B3 differential pressure initiates a staged response. Underflow is increased while interface and density are checked; if pressure does not recover, organic and mineral feed are reduced while water flow remains. The standby separator is heated and pressure-matched before the flow path changes. The fouled vessel is double-isolated, cooled and depressurised to its receiver, then flushed from the cleanest boundary toward the underflow. The recovered deposit is weighed and analysed. Restart requires baseline differential pressure and a confirmed open underflow—not simply completion of a timed wash.

5.10.4 Planned and emergency shutdown

A planned shutdown isolates B7 fresh syngas, maintains recycle for controlled catalyst cooling, retains steam through B6, then removes bauxite residue, fibre and wet organics from B1 in that order. Clean water continues until carbon, conductivity and suspended solids reach the cleaning endpoint. An emergency trip is faster but follows the same principle: remove reaction feed, remove heat, preserve a safe sweep path and depressurise into a contained system. The plant never attempts to save product by sending an unverified transient from one train into the common OXZEO loop.

5.10.5 Ten-train availability model

The shared back end is designed for ten-train flow and stable turndown with eight trains. If each hydrothermal module averages 90% availability and outages are not correlated, expected active capacity is approximately nine train equivalents. Correlation matters more than the simple average: a bad supplier lot, common recycle-water excursion or shared-control failure can remove several trains at once. Segregated feed tanks, source-traceable water and independent train permissives are therefore economic safeguards. The financial scenarios use 333 operating days for the plant; actual annual product must be calculated from active-train hours, not from calendar nameplate alone.

6. Closed mass, carbon and production balances

6.1 Balance method

The balance is calculated on one 300 t/d B1 hydrothermal train and then multiplied by ten and 333 operating days. Internal water, CO2 and synthesis-gas recycles are shown where they size equipment but cancel at the battery limit. Because no measured gas analysis or dissolved-organic formula is yet available for the selected blend, the model uses reconciled pseudo-components. Total mass and carbon close exactly on the stated allocation; a rigorous hydrogen/oxygen/mineral-phase balance is reserved for measured data rather than closed by inventing molecular species.

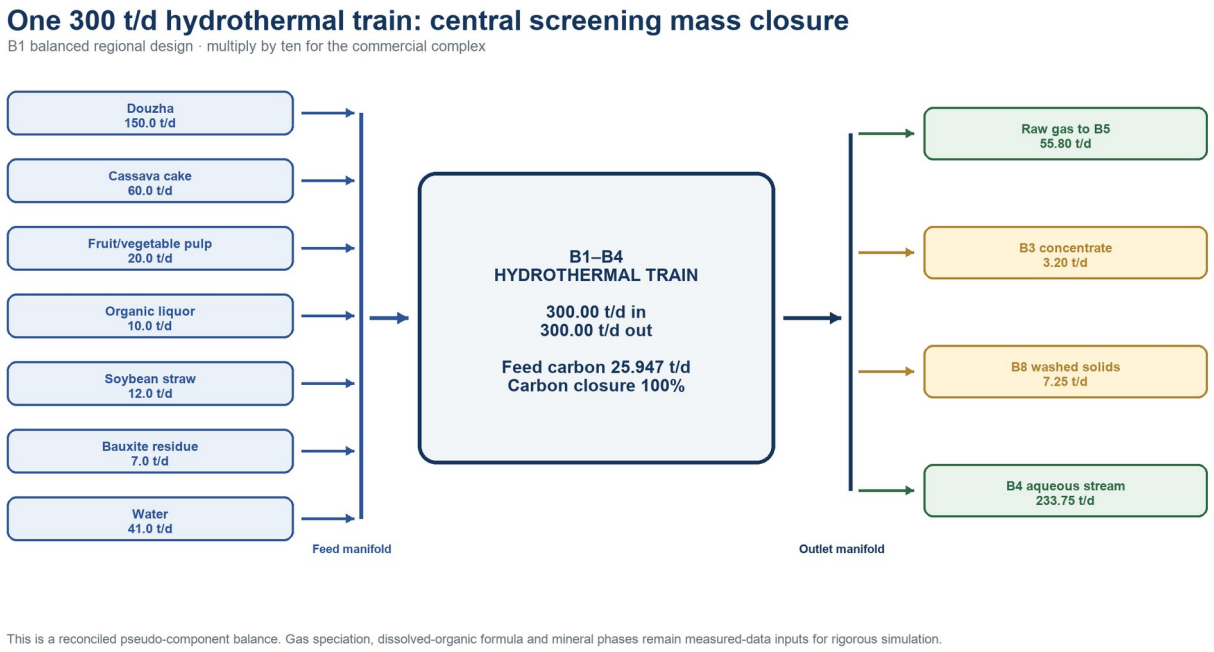

Figure 6.1 — Corrected one-train battery-limit mass flow. The graphic shows one representative 300 t/d train; the commercial complex contains ten identical train envelopes.

6.2 One-train feed balance

Table 6.1 — One-train B1 feed closure.

Feed	As received t/d	Dry solids t/d	Water t/d	Carbon t/d
Douzha	150.00	25.80	124.20	11.894
Cassava cake	60.00	15.00	45.00	6.600
Fruit and vegetable pulp	20.00	3.00	17.00	1.320
Soluble organic liquor	10.00	0.80	9.20	0.336
Soybean straw	12.00	10.80	1.20	5.797
Bauxite residue	7.00	7.00	0.00	0.000
Recycle or makeup water	41.00	0.00	41.00	0.000
Total	300.00	62.40	237.60	25.947

Dry solids are 62.40/300 = 20.80 wt%. Organic dry matter is 53.253 t/d and ash/mineral is 9.147 t/d. Feed carbon is 25.947 t/d, or 8.649 wt% of gross slurry. The ten-train plant processes 207,792 t/y dry solids and 86,404 t/y carbon.

6.3 B1–B4 pseudo-component mass closure

Table 6.2 — Reconciled one-train hydrothermal outlet balance.

B4 outlet	Mass t/d per train	Pseudo-component detail	Balance role
Raw gas to B5	55.80	17.12 CH4; 34.25 CO2; 2.73 CO; 1.50 H2; 0.20 acid/trace gas	Contains 90% of feed carbon
B3 concentrate	3.20	Soluble/precipitated Na/K/P/S/Cl-bearing salts and retained water	Controlled salt product/purge
B8 washed solids	7.25	5.95 mineral + 1.30 solid carbon	Qualified residue or retreatment
B4 aqueous stream	233.75	229.00 water; 2.15 NH3 equivalent; 1.30 dissolved organics; 1.30 remaining ions/solubles	Nitrogen recovery, polishing, recycle and purge
Total	300.00	Matches B1 input	0.00 t/d mass imbalance

The gas split corresponds to 12.84 t C/d in methane, 9.34 t C/d in carbon dioxide and 1.17 t C/d in carbon monoxide. The remaining 2.60 t C/d is split equally between dissolved organic carbon and solid carbon. These values are plausible screening allocations, not predicted equilibrium composition. Their purpose is to size B5/B6 and make every lost carbon tonne visible. A pilot GC, total-organic-carbon analysis and dry-solid carbon assay must replace the allocation before FEED.

6.4 Carbon balance through B5–B7

Table 6.3 — Carbon closure per train. The improved case changes downstream recovery, not the B1–B4 allocation.

Carbon destination	Current 42% case t C/d	Improved 55% case t C/d	Interpretation
B4 aqueous organics	1.297	1.297	Upstream conversion loss; water-polishing load
B8 solid carbon	1.297	1.297	Char/coke allocation; affects residue quality
B5 CO2 rejection	5.057	5.057	CO2 not needed for B6 ratio control
Saleable C2–C4 olefins	10.898	14.271	Overall battery-limit carbon efficiency
B6/B7 CO2, methane and purge	7.398	4.024	Conversion/selectivity loss and inert control
Total feed carbon	25.947	25.947	100.00% closure

Olefin mass is calculated by dividing product carbon by an average carbon mass fraction of 0.857 for a C2–C4 mixture. The current case yields 12.72 t/d per train and 42.35 kt/y for ten trains. The improved case yields 16.65 t/d per train and 55.45 kt/y. The difference is 13,107 t/y of product without increasing gross slurry capacity, which explains why carbon efficiency is the most valuable technical lever after availability.

6.5 Feed-case product envelope

Table 6.4 — Product capacity changes with carbon, but ash, nitrogen and rheology constrain the usable feed envelope.

Feed case	C t/d/train	Olefin at 42% kt/y	Olefin at 55% kt/y	Solids	C/N
B0 douzha-rich control	23.688	38.66	50.62	19.07%	6.82
B1 balanced regional design	25.947	42.35	55.45	20.80%	10.97
B2 higher-carbon operating envelope	27.864	45.47	59.55	22.05%	17.74
B3 manure qualification campaign	26.848	43.82	57.38	21.89%	13.90

The higher-carbon B2 envelope produces more olefin on paper, but it is not selected as the immediate base because its 22.05 wt% solids leave little margin for supplier variability. B1 retains douzha as the largest component and leaves hydraulic room while still improving carbon and C/N. Manure does not maximise product; its value depends on a gate fee that compensates for additional ash, nitrogen, phosphate and chloride duty.

6.6 Nitrogen, sulfur and mineral closure

The calculated B1 nitrogen input is 2.365 t N/d per train. A 75% recovery target assigns 1.774 t N/d to ammonia recovery and 0.591 t N/d to residual aqueous/trace nitrogen. Sulfur is not calculated from a generic recipe because supplier values are highly variable; the feed-release and B5 design require measured total sulfur and speciation. Sodium, potassium, phosphorus and chloride similarly close by measured B3 concentrate, B4 purge and B8 wash inventories rather than by assuming a saleable fertilizer formula.

Table 6.5 — A closed process requires a measured destination for every conservative species.

Conservative element	Principal exit	Secondary exit	Required closure measurement
Nitrogen	B4 recovered ammonia/ammonium sulfate	Residual water, N2/trace gas, B3 concentrate	TKN, NH3/NH4+, nitrate/nitrite, gas N species
Sulfur	B5 sulfur recovery	B3 aqueous/solid salts and B4 purge	Total S, sulfide, sulfate, H2S, COS
Sodium / potassium	B3 concentrate	B4 purge and B8 wash/solids	ICP/IC mass balance and leachable alkali
Chloride	B4 controlled purge	B3 concentrate and B8 wash/solids	Ion chromatography at every recycle boundary
Iron / Al / Ti / Si	B8 qualified mineral stream	B3 fines or permitted purge	XRF/XRD, magnetic yield and leachability

6.7 Annual ten-train battery limits

Table 6.6 — Commercial feed requirement for supplier contracting.

Battery-limit input	t/d complex	t/y at 333 d
Douzha	1,500	499,500
Cassava cake	600	199,800
Fruit and vegetable pulp	200	66,600
Soluble organic liquor	100	33,300
Soybean straw	120	39,960
Bauxite residue	70	23,310
Recycle or makeup water	410	136,530
Total gross slurry	3,000	999,000

Table 6.7 — Annual B1–B4 output closure before internal water recycle.

Hydrothermal outlet	t/d complex	t/y
Raw gas to shared B5	558.0	185,814
B3 concentrate	32.0	10,656
B8 washed solids	72.5	24,142
B4 aqueous stream	2,337.5	778,388
Total	3,000.0	999,000

BALANCE LIMITATION: The mass and carbon arithmetic is closed and reproducible. Molecular hydrogen/oxygen closure, mixed-salt phase equilibrium and real-gas reformer/OXZEO recycle require measured pilot composition and a validated property package before equipment guarantees.

6.8 Principal process stream table

Table 6.8 — Principal process streams. 'Measured' identifies flows that require the rigorous gas/recycle simulation.

ID	Description	Flow basis	T °C	P MPa	Principal contents / sizing note
S-101	B1 final slurry, one train	300.00 t/d	25–45	0.1	20.8 wt% solids; 25.947 t C/d; batch released
S-102	HP slurry to H-101	300.00 t/d	30–50	25.0	Positive-displacement pump; water displacement available
S-201	B2 reactor outlet	300.00 t/d	625	25.0	Supercritical fluid, gas, mineral and precipitating salts
S-301U	B3 salt underflow	3.20 t/d product basis	350–550	24–25	Dense brine/crystals; actual internal slipstream larger before dewatering
S-302	Salt-depleted hot effluent	~296.8 t/d	550–620	24–25	Feeds H-101; residual fines set exchanger cleaning duty
S-401G	B4 raw gas, one train	55.80 t/d	35–60	2.5–4.0	CH4/CO2/CO/H2 plus acid-gas traces; no liquid carryover
S-401W	B4 aqueous stream	233.75 t/d	40–90	0.2–1.0	Water, NH3/NH4+, DOC and ions; split to recovery/recycle/purge
S-401S	B4/B8 solids	7.25 t/d	40–90	0.1–0.5	Mineral plus solid carbon; counter-current wash
S-500	Ten-train common raw gas	558.0 t/d screen	35–60	header	Composition-weighted header; dirty trains blocked
S-501	B5 clean reformer feed	Measured	−30 to 40	2.8–3.5	Sulfur <0.1 ppmv screen; controlled water/methanol and CO2 split
S-601	B6 hot synthesis gas	Measured	~850	~2.8	CO/H2 with CH4/CO2/steam slip; H2/CO trimmed for B7
S-701	B7 olefin products	42.35–55.45 kt/y	ambient after recovery	product	Ethylene, propylene and C4 cut to buyer specification
S-801	Qualified washed residue	Up to 72.5 t/d wet screen	ambient	0.1	Released by destination; off-specification fraction retreated

The stream table separates battery-limit values from internal hydraulic flows. B3 underflow, for example, carries additional hot water before cooling and dewatering even though the net concentrate product is 3.20 t/d per train. Similarly, B5/B6/B7 recycle may be several times fresh-gas flow and cannot be sized from product alone. This distinction prevents a closed mass balance from being misused as an equipment datasheet.

6.9 Reconciliation with the supplied industrial gasification and shift balances

The supplied gasification and shift balances are accepted as authoritative plant documents. They describe oxygen-blown coal gasification near 6.5 MPa followed by water–gas shift, rather than 25 MPa SCWG, so their compositions are not copied into the proposed reactor. Their direct contribution is stronger: they define the level of stream closure, phase accounting and utility integration expected of the Towngas model. Each proposed stream must show wet and dry gas, condensed water, solids, unconverted carbon, sulfur and dissolved gases, rather than only a headline gas composition. [37,38]

Table 6.9 — Authoritative reference-plant streams used to upgrade the Towngas balance format; values are not SCWG yield predictions.

Reference stream	Flow / condition	Principal measured composition	Towngas design consequence
0706 gasifier raw gas	81,915.74 Nm^3/h wet; 1,380 °C; 6.5 MPa(g)	26.771% H_2; 32.819% CO; 16.172% CO_2; 23.810% H_2O; 0.265% H_2S; 4,249.68 kg/h ash; 918.70 kg/h residual C	B2 balance must include wet gas plus entrained mineral and carbon
0709 wash-tower gas	149,371.4 Nm^3/h wet; 242 °C; 6.24 MPa	14.66% H_2; 17.97% CO; 8.82% CO_2; 58.33% H_2O; 0.13% H_2S	Cooling/washing changes water inventory and gas volumetric flow
0710 black water	34,214.6 kg/h; 249.54 °C; 6.46 MPa	33,868.5 kg/h water; 272.47 kg/h ash; 73.63 kg/h residual C; dissolved gas	B4 requires a real high-pressure water/solid/dissolved-gas stream
Shift inlet	298,742.8 Nm^3/h wet; 240 °C; 6.20 MPa	17.97% CO; 14.66% H_2; 8.82% CO_2; 58.33% H_2O	Dry H_2/CO and water/gas ratio must be calculated separately

Reference stream	Flow / condition	Principal measured composition	Towngas design consequence
Shift outlet	148,684.0 Nm^3/h wet; 40 °C; 5.60 MPa	19.73% CO; 45.80% H_2; 33.88% CO_2; 0.15% H_2O	Ratio control and condensation are separate design functions
Shift condensates	92,188.9 + 31,701.4 kg/h	Water with dissolved CO_2 and H_2S at two pressure/temperature levels	Heat, acid-gas and water recovery require explicit destinations

RECONCILIATION RULE: Use the supplied plant documents exactly for their stated process and battery limits. Transfer stream-accounting discipline, phase definitions and equipment implications; calculate proposed SCWG composition from the Towngas feed and validated SCWG data.

7. Energy balance and heat recovery

7.1 Energy-accounting method

The energy model separates gross process heat, internal sensible-heat recovery, purge-fuel credit and shaft work. This prevents the 600 °C feed temperature rise from being reported as purchased duty when most of it can be recovered from hot effluent. It also prevents an exothermic synthesis reactor from being used to conceal the high-temperature endotherm in B6. Values are stated per 300 t/d train equivalent so the ten-train calculation can be audited.

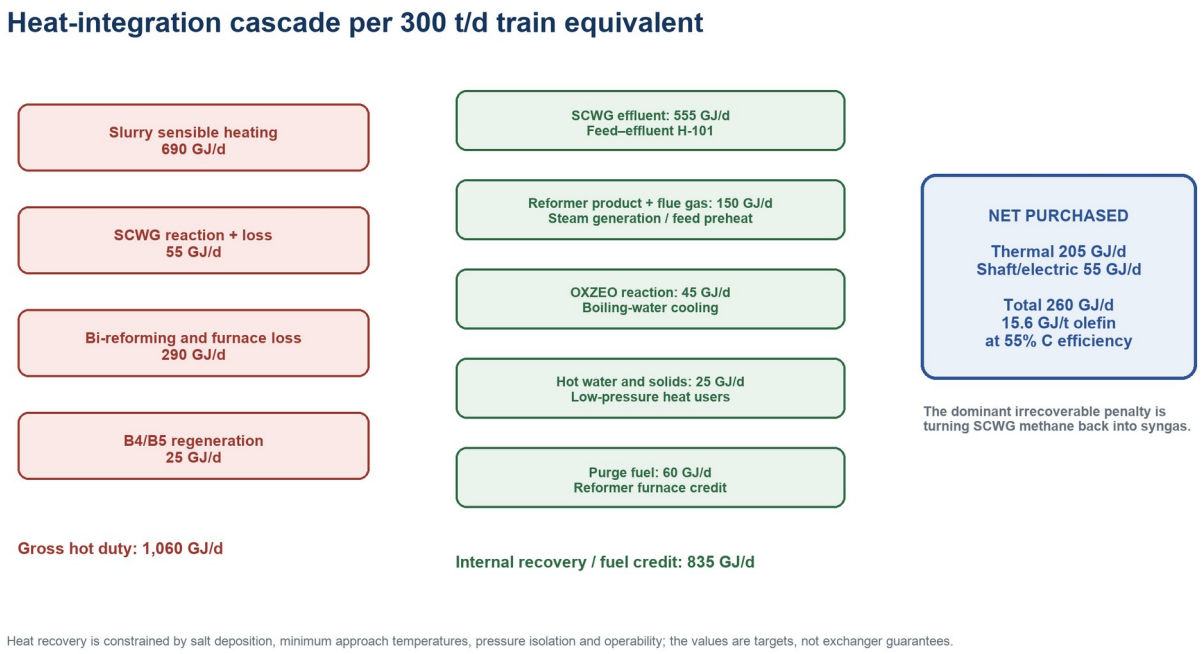

Figure 7.1 — Heat-integration target per train. Green streams are internal recovery or purge-fuel credit; purchased thermal and electrical energy remain after the cascade.

7.2 One-train energy duties

Table 7.1 — Screening energy balance. Negative rows are internal recovery or internal fuel credit.

Duty / source	GJ/d per train	Calculation or interpretation
Slurry sensible heating	690	300 t/d × effective mean Cp and 25→625 °C; includes high-pressure water property allowance
SCWG net reaction + reactor loss	55	Screening endotherm/trim and external loss; replace with pilot enthalpy closure
B6 reforming + furnace loss	290	Strongly endothermic bi-reforming with tube/furnace efficiency allowance
B4/B5 regeneration heat	25	Ammonia recovery, methanol regeneration and low-pressure users
Gross hot duty	1,060	Before internal heat recovery and purge-fuel credit
H-101 feed–effluent recovery	−555	Salt-depleted B2 effluent to cold feed
Reformer product / flue-gas recovery	−150	Steam generation and reformer-feed preheat
OXZEO reaction recovery	−45	Boiling-water cooling / steam generation target
Hot water and solids recovery	−25	Low-grade heat for B8 drying and B4 users
Purge-fuel credit	−60	B7 purge/fuel gas to B6 furnace
Net purchased thermal	205	Natural gas, steam or electrified high-temperature heat equivalent
Shaft/electric work	55	HP pumping, compression, Rectisol refrigeration, water and auxiliaries

Duty / source	GJ/d per train	Calculation or interpretation
Net purchased energy	260	Thermal plus electrical equivalent

Annual net purchased energy is 260 × 10 × 333 = 865,800 GJ/y. At 55,452 t/y product the intensity is 15.61 GJ/t olefin; at the current 42,345 t/y it rises to 20.45 GJ/t. On gross slurry the value is 0.867 GJ/t. Both bases are necessary: the slurry basis describes waste treatment, while the product basis describes competitiveness.

7.3 Bi-reformer duty check

The raw-gas screen contains 17.12 t/d methane per train, or approximately 1,070 kmol/d. If all methane followed the 3:1:2 bi-reforming stoichiometry, the standard reaction endotherm would be about 235 GJ/d before sensible heating and furnace loss. The 290 GJ/d B6 allowance is therefore consistent with a strongly endothermic fired process after crediting preheat but allowing conversion and furnace inefficiency. A value near zero or an exothermic sign would be chemically incorrect.

$$1{,}070\ kmol\ CH_4/d \times (660\ GJ\ per\ 3{,}000\ kmol\ CH_4) \approx 235\ GJ/d\ reaction\ enthalpy$$

This check also shows why methane suppression is commercially important. Every mole of methane formed in B2 releases heat in the methanation direction and then requires high-grade heat to reform in B6. Sensible heat can be recovered, but the chemical round-trip cannot be recovered completely. The best B2 operating point is the one that avoids methane while retaining carbon as useful CO precursor and preserving salt-handling availability.

7.4 Heat-exchanger network

Table 7.2 — Heat recovery is distributed so a single fouled exchanger cannot stop all ten trains.

Exchanger / service	Hot stream	Cold stream	Target duty	Operability constraint
H-101 train feed/effluent	B3 salt-depleted effluent	B1 pressurised slurry	555 GJ/d/train	Residual fines, near-critical Cp change, thermal stress and cleanability
E-601 syngas boiler	B6 reformer product	Boiler feedwater / reformer steam	80 GJ/d/train eq.	CO/H2 metallurgy, dew point and tube-skin limit
E-602 flue-gas recovery	B6 furnace flue gas	Combustion air / feed / steam	70 GJ/d/train eq.	Acid dew point, NOx and turndown
E-701 OXZEO boiler	Exothermic B7 beds	Boiler feedwater	45 GJ/d/train eq.	Bed hot spots and rapid trip response
E-801 low-grade recovery	B4 water / B8 solids	Ammonia recovery / residue drying	25 GJ/d/train	Fouling and low temperature driving force
Final coolers	B4/B5/B7 products	Cooling water / refrigeration	Balance after recovery	Seasonal cooling-water temperature and methanol loss

A pinch target is constrained by more than minimum approach temperature. Dirty and clean streams cannot be cross-connected in a way that permits product contamination; high-pressure train isolation must survive an exchanger tube failure; salt-bearing material must not cool below its deposition window before B3; and B6 needs high-grade heat that low-temperature B4 water cannot supply. The network therefore uses heat quality as well as quantity.

7.5 Utility basis

Table 7.3 — Utility split underlying the RMB OPEX model.

Utility	Annual screening demand	China price basis	Annual cost RMB m
Electricity	≈50.9 GWh/y	0.40 RMB/kWh; rounded public planning assumption	20.4
Thermal energy	≈682,650 GJ/y	650 RMB/t pellets; 16.5 GJ/t LHV and 80% useful heat assumed	33.6
Cooling water	Included in utilities	Site-specific circulation and makeup	Included
Process/makeup water	Fresh trim 136,530 t/y plus cooling/purge makeup	20 RMB/t purchased-water planning assumption; treatment separate	Included in OPEX water line
Nitrogen/instrument air	Shared ten-train system	Vendor package / electricity	Included
Air separation	Not included	No ASU in the current SCWG/OXZEO	0

Utility	Annual screening demand	China price basis	Annual cost RMB m
		battery limit	

7.6 Energy-reduction priorities

- Increase feed carbon without exceeding pumpability and salt limits, so fixed high-pressure heating serves more product carbon.
- Raise H-101 recovery only after deposit and cyclic-fatigue tests; exchanger availability is worth more than a nominally higher effectiveness.
- Optimise B2 temperature/residence to reduce methane only when total carbon closure improves.
- Use internally recovered steam and purge fuel in B6 before purchasing additional fuel.
- Develop a lower-temperature or electrified reforming option only with a complete electricity-price and carbon-footprint comparison.
- Match product purity to a buyer. Avoid deep cryogenic fractionation if a mixed certified olefin stream has a firm offtake.

7.7 Ten-train site energy and utility balance

The ten-train plant must be evaluated as an integrated utility site rather than ten copies of every auxiliary. Hydrothermal heat recovery remains train-specific for isolation, but steam drums, boiler-feedwater treatment, cooling towers, instrument air and much of the electrical distribution are shared. Diversity is limited because all trains normally operate; a utility should not be downsized on the assumption that several trains are always offline. N+1 rotating equipment and a credible common-back-end trip case are included.

Table 7.4 — Integrated utility loads at the commercial scale.

Site quantity	Ten-train annual value	Equivalent continuous load	Design interpretation
Gross thermal duty before recovery	3,529,800 GJ/y	≈122.6 MW during 8,000 h	Large but mainly internally recovered sensible heat
Internal recovery / purge credit	2,780,550 GJ/y	≈96.6 MW	Distributed H-101 plus shared reformer/OXZEO steam system
Purchased thermal	682,650 GJ/y	≈23.7 MW	Reformer and trim heat; fuel/steam/electric option must be priced
Electricity	≈50.9 GWh/y	≈6.36 MW	Average; compressor and refrigeration peak/starting load higher
Gross aqueous flow to B4	2,337.5 t/d	≈97.4 t/h	Most is recycled only after ammonia/TOC/Cl release
Potential ammonium sulfate	≈27.9 kt/y	≈4.7 t/h product	Acid storage, absorber heat and product tank sized only after purity proof

A site-wide steam balance gives priority to reformer steam/carbon ratio, Rectisol regeneration and ammonia recovery. OXZEO and reformer-product heat can generate steam, but export is credited only after those internal users and start-up cases are met. Electricity export is not included. If an industrial park can supply lower-carbon steam or firm low-cost power, the choice between fired and electrified high-temperature heat should be evaluated using both RMB and product carbon footprint.

7.7.1 Cooling and refrigeration

Cooling duty is not calculated by subtracting all recovered heat from gross heat: gas compression aftercooling, Rectisol refrigeration, B4 condensation, OXZEO product recovery and summer approach temperatures create additional rejection. A detailed water balance must distinguish closed-loop circulation from makeup and blowdown. Seawater cooling may be geographically attractive but introduces chloride, materials and environmental-discharge questions that remain separate from the process-water chloride inventory.

7.7.2 Start-up energy

Normal heat integration is unavailable during a cold start. The plant therefore needs enough independent firing or steam/electric capacity to heat one hydrothermal train, establish B5/B6 and then bring further trains online sequentially.

Starting all ten trains together would create an unnecessary peak and a large off-specification gas inventory. Black-start and emergency power support controls and safe shutdown, not full production.

7.8 Industrial utility and water-system reconciliation

The public economic model does not reproduce the private methanol cost breakdown. It instead uses rounded planning assumptions of RMB 0.40/kWh electricity, RMB 650/t biomass pellets and RMB 20/t purchased water. Towngas utility quantities are calculated from project duties because the technical reference systems include oxygen production and a different synthesis train.

Table 7.4 — Which utility information transfers directly and which requires project scaling.

Utility evidence	Public planning or technical basis	Proposed-project treatment
Electricity	Rounded public screen: 0.40 RMB/kWh	Retain calculated 50.9 GWh/y pending motor schedule; annual cost RMB 20.4m
Production water	Rounded public screen: 20 RMB/t purchased water	Calculate fresh makeup from feed water, recycle, cooling and purge
Biomass fuel	Rounded public screen: 650 RMB/t pellets	Calculate 682,650 GJ/y with stated LHV/efficiency; annual cost RMB 33.6m
ASU	30,000 Nm³/h and 12,000 Nm³/h technical reference systems	Excluded from current battery limit; add only if oxygen-assisted reforming is selected
Water reuse	300 m³/h equalisation–clarification–UF–RO reference train	Adopt architecture; scale from B4 chemistry and desired purge

The reference 30,000 Nm^3/h ASU requires approximately 159,000 Nm^3/h main air and lists a 13,980 kW main air-compressor shaft duty; its booster train has a normal power basis around 22,790 kW and major steam/cooling-water duties. The 12,000 Nm^3/h system lists 71,000 Nm^3/h dry air, 6,482 kW shaft power and a 7,500 kW motor. These loads explain a substantial fraction of the reference electricity consumption and must not be hidden inside a comparison with an SCWG plant that has no ASU.[39,40,42]

8. Equipment, materials, chloride control and safety

8.1 Major equipment list

Table 8.1 — Major process equipment. Quantities support ten-train isolation and shared downstream scale.

Area / tag	Service	Quantity	Screening size or duty	Critical confirmation
B1 receiving trains	Wet feed tanks, fibre preparation, residue slurry	Segregated shared + train day tanks	3,000 t/d complex	Supplier variability, odour, storage and metering
P-101 A/B	High-pressure slurry pumps	20 total	12.5 t/h each duty	Wear, check-valve life and restart on B1 slurry
H-101	Feed/effluent recovery	10 trains; modular	555 GJ/d/train	Deposit, thermal stress and tube-failure isolation
R-201	SCWG reactor	10	~2.3 m^3 gross/train screen	Residence, heat flux, alloy, fatigue and char
V-301 A/B	Hot salt separators	20	~10 m^3 gross each screen	Mixed-salt settling, wall adhesion and underflow
B4 letdown/separation	Staged pressure reduction and phase split	10 trains	55.8 t/d gas/train	Erosion, level control and gas cleanliness
B5 Rectisol/ZnO	Shared gas purification	1 train with spared pumps/beds	558 t/d wet raw-gas screen	Actual gas load, refrigeration and sulfur speciation
B6 reformer	Shared methane/CO2/steam reforming	1 shared system, multiple furnaces/boxes	~2,900 GJ/d gross eq.	Tube metallurgy, catalyst, firing and decoking
B7 OXZEO	Shared synthesis, recycle and recovery	Licensed multi-bed system	42–55 kt/y olefin envelope	Real-gas performance, catalyst life and product spec
B8 / N recovery	Residue washing and ammonium sulfate recovery	Shared, source-traceable	72.5 t/d solids; aqueous 2,337.5 t/d	Product quality and water/chloride balance

8.2 Materials of construction

The most severe combination is hot pressurised water, alkali, chloride, sulfide, organic acids, erosive mineral solids and precipitating salts. A nickel-base alloy wetted surface or liner is assumed in B2/B3 and the hottest feed-effluent service until corrosion data justify a reduction. Replaceable inlet devices, liners and spools concentrate erosion in inspectable parts. Carbon steel is introduced only after pressure, temperature and acid-gas chemistry permit it; using it early to reduce CAPEX can simply move cost into unplanned outage.

Table 8.2 — Metallurgy remains a test result, not a catalogue assumption.

Service	Candidate strategy	Qualification evidence
B1 wet/slurry handling	Lined carbon steel or suitable stainless; abrasion liners at elbows	Ambient/hot corrosion, abrasion and cleaning-chemical compatibility
HP pump and feed heater	Duplex/high-alloy wetted parts; replaceable checks and liners	B1 slurry wear and chloride stress-corrosion test
B2/B3 hot HP boundary	Nickel-base alloy liner or solid alloy; replaceable internals	Mixed feed/salt coupon loop, weld and cyclic-fatigue review
B4 letdown	Hard-faced sacrificial trim and erosion-resistant downstream spool	Two-phase particle erosion at expected pressure ratio
Wet acid gas / Rectisol	Low-temperature carbon/stainless selection by water and acid-gas envelope	Licensor metallurgy and methanol/water conditions
Reformer	Conventional high-temperature reformer alloys and catalyst tubes	Vendor creep life, tube-skin and decoking case
B8 solids	Lined equipment, enclosed transfer and dust control	Alkali/chloride abrasion and personnel exposure

8.3 Chloride monitoring and purge control

Chloride is controlled by a plant-wide inventory. Each supplier load has a measured contribution; B3, B4 and B8 exits are sampled; and recycle-water chloride is trended against alloy-specific alarm and trip levels. The operator can reduce recycle,

increase purge, prewash a residue lot or switch supplier before the hot loop approaches its limit. Conductivity is an online warning but cannot replace chloride-specific laboratory or ion-chromatography confirmation.

Table 8.3 — Chloride control connects supplier release to metallurgy and product quality.

Location	Measurement	Control action
Supplier unloading	Cl, conductivity, Na/K, source history	Reject, segregate or allocate prewash
B1 final blend	Batch Cl and conductivity	Prevent HP-feed release above campaign limit
B3 underflow	Cl mass and mineral/salt phase	Verify whether intended salt route is working
B4 recycle water	Continuous conductivity + frequent IC	Increase controlled purge or stop recycle
B8 product/wash	Soluble and total Cl	Second wash or alternate destination
Corrosion coupons	Metal loss, pitting and cracking evidence	Revise chemistry limit, alloy or inspection interval

8.4 Control architecture

Table 8.4 — Control actions preserve train independence and common-back-end quality.

Control layer	Measured variables	Automatic response
Feed batch release	TS, density, rheology, C/N/S/Cl, ash, PSD	Hold transfer until approved electronic certificate
B1 pump protection	Suction pressure, flow, pulsation, discharge pressure	Stop solids; continue clean-water displacement
B2 reaction protection	Wall/outlet T, feed flow, pressure, carbon response	Cut firing/feed; water quench; isolate train gas
B3 availability	DP, underflow density/flow, wall T, flush recovery	Switch separator; flush isolated vessel; reduce solids
B4 phase control	Valve vibration/position, separator levels, water carryover	Staged shutdown; closed receiver; block common header
B5 quality barrier	Total sulfur, H2S/COS, water, methanol, pressure	Switch ZnO; route off-spec gas away from B6/B7
B6 coke/heat control	Steam/carbon, CO2 split, tube skin, CH4 slip	Increase steam within limit, reduce feed, burner trip
B7 selectivity protection	Bed T/DP, H2/CO, sulfur, conversion, recycle	Cut fresh syngas; controlled recycle/inert cool-down
B8 product release	pH, Na, Cl, metals, leachability, performance	Release to named destination or second wash/retreatment

8.5 Preliminary HAZOP register

Table 8.5 — Preliminary HAZOP items requiring formal multidisciplinary review.

Deviation	Credible cause	Consequence	Safeguard / response
No/low B1 flow with heat	Pump trip, fibre bridge, check-valve failure	Wall overheating, char, rapid pressure/temperature excursion	Independent flow trip cuts firing and organics; maintains water; local blowdown
High B3 differential pressure	Underflow failure, wall deposition, salt surge	Reactor backpressure and blocked outlet	Twin separator switch, feed reduction, water flush, independent relief
Letdown erosion/failure	Solids carryover or excessive single-stage pressure ratio	Loss of containment, downstream high level	Staged sacrificial trims, vibration/position monitoring, closed receiver
Liquid carryover to gas header	B4 level/control failure	Rectisol/reformer upset and common-mode contamination	High-high independent level closes double block; knockout and coalescer
Sulfur breakthrough	Rectisol upset, exhausted ZnO, analyser fault	B6/B7 catalyst poisoning	Lead/lag beds, analyser voting, immediate off-spec diversion
Low steam/carbon B6	Steam trip or ratio-control failure	Reformer coking and tube overheating	Hard permissive, feed cut, steam purge and decoking provision
B7 high temperature	Cooling loss, composition excursion, runaway secondary reactions	Selectivity loss, catalyst damage, pressure rise	Multi-point T trip, cut fresh gas, recycle/inert cooling, relief
Methanol release	Seal/flange/drain failure in Rectisol	Fire, toxicity and environmental release	Closed drains, detection, bunding, classified equipment and remote isolation
High chloride inventory	Supplier excursion or inadequate purge	Pitting/SCC and off-spec residue	Inventory alarm, stop recycle, increase purge, quarantine source
Dust during B8 drying	Open transfer or failed extraction	Alkaline/metal-bearing worker exposure	Enclosed handling, local extraction, hygiene and PPE

8.6 Relief, blowdown and emergency philosophy

Each hydrothermal train depressurises to its own water-filled quench/blowdown receiver sized for liquid inventory and flash gas. Salt-bearing two-phase relief is not discharged directly into a conventional common flare header without knockout, quench and backpressure analysis. B5–B7 clean hydrocarbon/syngas relief remains segregated from dirty hydrothermal relief until composition and hydraulic study permit combination.

CO, H2, CH4, H2S and methanol require fixed detection, forced ventilation, hazardous-area electrical classification and remote isolation. The reformer requires burner-management, combustion safeguards and tube-rupture response. Emergency power maintains control, analyser shelters, critical cooling and safe valve positions. A loss of the shared back end causes every train to stop organic feed and transition to controlled clean-water circulation rather than forcing off-spec gas into B7.

8.7 Analytical release plan

Table 8.6 — Analytical data close the process and prevent optimistic product claims.

Location	Online measurements	Laboratory / periodic measurements
Supplier and B1	Mass, density, pH, conductivity, tank T	TS, rheology, PSD, CHNS, ash, ions, metals, excluded contaminants
B2 outlet	T/P/flow, GC H2/CH4/CO/CO2	Aqueous TOC, solid carbon, full C/N/S/mineral balance
B3	DP, underflow flow/density, wall T	Ion balance, crystal/mineral phase, organics, leachability
B4	Levels, water carryover, conductivity, ammonia proxy	NH3/NH4+, TOC/COD, ions, metals, purge/recycle release
B5/B6	Total S, H2S/COS, water, gas composition, tube skin	Methanol carryover, catalyst poisons and periodic carbon deposition
B7	Bed T/DP, GC conversion/selectivity, recycle flow	Full product spec, oxygenates, catalyst deposition and activity trend
B8	Moisture and process pH	XRF/XRD, Na/Cl, carbon, metals, leachability and destination performance

9. Certification, product carbon footprint and EU market positioning

9.1 Why this is a standalone workstream

Certification is not an appendix to engineering. Feed declarations determine which carbon can carry a circular or bio-based claim; the mass balance must reconcile with conversion and loss; and product documents must survive buyer and certification audits. The website should therefore present ISCC, ISO carbon-footprint accounting and market claims as their own section rather than scattering them among environmental paragraphs.

9.2 ISO 14067 product carbon footprint

ISO 14067 provides principles and requirements for quantifying and reporting a product carbon footprint consistently with life-cycle assessment standards. It addresses climate change, not every environmental or social impact. The plant should calculate separate footprints for mixed light olefins, any separated ethylene/propylene products, ammonium sulfate and each qualified residue product. Allocation between waste treatment and co-products must be transparent and sensitivity-tested because a high gate fee signals that treatment is a real function of the system. [9,29]

Table 9.1 — Minimum ISO-aligned carbon-accounting treatment.

Footprint element	Required treatment
Feed status	Document whether each stream is waste, residue, by-product or purchased feed under the relevant programme
Inbound logistics	Use supplier-specific wet mass, distance, vehicle/backhaul and storage loss
Utilities	Meter electricity, purchased fuel/steam, refrigeration and water treatment by operating period
Biogenic carbon	Track carbon through gas, product, CO2, water and solids; do not treat all biogenic CO2 as automatically zero-impact
Bauxite-residue service	State the baseline storage/treatment and avoid claiming displaced virgin material without performance evidence
Co-product allocation	Report physical and economic allocation and test substitution where justified
Export route	Include product separation, terminal, shipping and EU delivery when quoting an EU-market footprint

9.3 ISCC PLUS chain of custody

ISCC PLUS is the most relevant voluntary certification route for circular and bio-based chemical feedstocks and products. It accepts defined bio-circular wastes and residues and provides chain-of-custody options including mass balance. The plant information system must retain supplier declarations, incoming mass, sustainability characteristics, conversion factors, storage and process losses, outgoing claims and period balances. A batch that fails traceability can still be processed if legally permitted, but its product cannot silently enter the certified inventory. [8,25,27]

Mass balance does not mean that evidence is optional. Physical mixing can occur in a shared system only while bookkeeping remains auditable and claimed output does not exceed eligible input after conversion loss. Supplier contracts need audit access, correction rights and responsibility for misdeclaration. Sales contracts must distinguish physical biogenic carbon from mass-balance attribution so the customer understands the claim being purchased.

9.4 EU product premium: market evidence and limits

European chemical producers already market certified biomass-balanced products using renewable feedstocks and ISCC PLUS or equivalent systems. That demonstrates buyer demand for lower-product-carbon-footprint and renewable-attribution products, but public sources generally do not disclose a universal premium. A green-olefin premium is therefore modelled as 10%, 20% and 30% above a China commodity netback, subject to a firm buyer specification and long-term offtake. It is a commercial scenario, not a published exchange price. [12]

The assumed premium must pay for more than certification. Export may add terminal handling, shipping, inventory, product-quality assurance, independent audit and working-capital cost. The economic scenarios add RMB 20–25 million/y to OPEX for

the EU cases. A premium should be booked only on the certified volume actually sold into the contract, not on total theoretical product.

Table 9.2 — Claim control protects both commercial value and scientific credibility.

Claim	What supports it	What must not be implied
Certified bio/circular attribution	Eligible feed records and ISCC-compliant chain of custody	That every molecule in the product can be physically traced to one waste batch
Lower product carbon footprint	Verified ISO-aligned LCA using metered plant data	That waste status automatically gives a zero footprint
Bauxite-residue treatment	Measured Na/Cl/leaching change and a controlled product or disposal destination	That catalyst use alone eliminates the regional residue inventory
EU premium	Binding offtake price and volume	That all EU buyers pay the same uplift
Carbon credit	Approved methodology, additionality, registration, monitoring and title	That avoided emissions and product premium can always be added without double counting

9.5 EU CBAM

The definitive EU Carbon Border Adjustment Mechanism began in 2026 and currently covers cement, aluminium, fertilisers, iron and steel, hydrogen and electricity categories. Light olefins are not currently one of the listed sectors. The premium case is therefore based on voluntary buyer value, renewable-content strategy and Scope 3/product-footprint reduction—not on avoided CBAM certificates. A fertilizer or mineral co-product may have a different customs classification and must be checked separately. [11,26]

9.6 China environmental and carbon-market interface

Chinese permits govern waste acceptance, wastewater, air emissions, pressure systems, hazardous chemicals and residue destinations independently of voluntary certification. National ETS or CCER prices can inform sensitivity, but they are not automatic revenue: the project needs a valid methodology, additionality, registered ownership and verified reductions. The economic base therefore excludes carbon-credit revenue. Product premium, gate fee and carbon credit are kept separate to avoid counting the same environmental attribute more than once.

9.7 Website presentation

The website version should begin with the waste portfolio and regional map, then show the ten-train process. A standalone certification section should explain three simple ideas: trace the wastes, calculate the product footprint, and sell only the claim that the evidence supports. The EU market discussion should state that a premium is possible and commercially important, while also stating that it requires contracted buyers and does not arise from CBAM coverage of olefins.

9.8 Certification ledger and saleable-claim calculation

The certification ledger follows carbon and eligible mass through physical loss. Incoming douzha or co-feed is recorded by supplier, date, wet mass, total solids, eligible status and sustainability characteristics. The system does not issue one tonne of product claim for one tonne of wet input. A conversion factor links eligible dry carbon to certified product after B3/B4 carbon loss, B5 CO2 rejection and B7 purge. If non-certified feed is processed in the same period, the eligible share is allocated under the selected chain-of-custody rule and cannot exceed the verified balance.

Table 9.3 — The premium depends on a transaction-ready ledger, not a sustainability paragraph.

Ledger field	Source	Control / reconciliation
Supplier and point of origin	Approved supplier declaration and delivery document	Unique lot ID; audit rights; correction and quarantine workflow
Wet mass and total solids	Weighbridge, tank mass and laboratory TS	Wet-to-dry reconciliation; invoice and eligible-input basis
Eligible feed category	Certification evidence and legal waste/by-product status	No default eligibility from material name alone
Carbon and conversion factor	CHNS/TOC balances by accounting period	Certified output reduced by measured gas, water, solid and purge losses
Storage and process loss	Tank, flare/fuel, wastewater and residue records	Loss entered before output attribution

Ledger field	Source	Control / reconciliation
Outgoing product	Tank/line mass, product analysis and sales document	Claim wording, volume and certificate linked to buyer lot
Product carbon footprint	Metered utilities, logistics and allocation model	Version-controlled ISO-aligned calculation and independent verification

Commercially, the ledger determines the premium volume. If only 70% of feed carbon is eligible or only 80% of product is sold to an EU certified buyer, premium revenue applies to the lower auditable volume after loss. The economic cases use 100% of product only to show the upper sensitivity; a bank model should use contracted certified tonnes by buyer and deduct unsold or downgraded inventory.

9.7 Public-planning plant carbon accounting

The supplied company method calculates plant emissions as fuel combustion plus process emissions plus net purchased electricity plus purchased heat, less only qualifying recovered carbon dioxide. Process emissions are closed by carbon mass balance: carbon entering in feed minus carbon leaving in methanol or other products, ash/slag, exported carbon streams and measured storage. Internal carbon dioxide recycle is not an avoided emission merely because it circulates inside the plant. [44]

$$Eplant = Ecombustion + Eprocess + Enet\ electricity + Epurchased\ heat - Equalifying\ recovered\ CO_2$$

Table 9.7 — Public-planning greenhouse-gas accounting controls.

Accounting item	Supplied reference method	Towngas implementation
Electricity	Net purchased MWh × 0.5366 t CO_2/MWh reference factor	Use metered net import and label factor year/region; keep 0.5366 as the public-planning reference case
Purchased heat	Purchased GJ × measured factor; 0.11 t CO_2/GJ default when unavailable	Use heat-balance-specific factor where possible; never confuse emission factor with RMB/GJ price
Process carbon	Input carbon less carbon in product, ash/slag and other measured exits	Close olefins, CO_2, purge fuel, aqueous carbon, B8 solids and exported by-products
Recovered CO_2	Deduct only qualifying recovered/exported quantity	Internal B5-to-B6 recycle is not automatically deducted
Biogenic carbon	Identify source and destination	Track eligible biogenic carbon through ISCC mass balance and ISO 14067 product footprint

10. China CAPEX, OPEX and 20-year economic evaluation

10.1 Cost basis and benchmark

All costs are in 2026 RMB. The company provided a useful benchmark: approximately RMB 1.5 billion for a 300,000 t/y Inner Mongolia methanol plant, equivalent to 5,000 RMB per annual tonne of methanol capacity. That benchmark is an order-of-magnitude comparison, not a direct scale factor. The present plant processes almost one million tonnes per year of dilute slurry through ten 25 MPa trains but produces only 42–55 kt/y of olefins. It also includes hot salt handling, residue washing, Rectisol, reforming, OXZEO and olefin separation. Product-normalised capital must therefore be much higher than the methanol comparator.

July 2026 National Bureau of Statistics market monitoring reported LLDPE around 8,423 RMB/t and polypropylene around 8,875 RMB/t. These are traded resin prices, not mixed-olefin plant-gate prices. The economic model uses a lower 7,500 RMB/t olefin netback after recognising product mix, separation, quality and logistics. A certified EU case adds 10–30% to that netback only as a buyer-contract scenario. [10]

Table 10.1 — China price and project-finance assumptions.

Economic parameter	Central value	Treatment
Operating life	20 years	Requested project life; no terminal value
Discount rate	10% nominal pre-tax unlevered	20-year annuity factor 8.5136
Total capital	RMB 2.814 billion	China Class 4 screen; range RMB 2.2–4.0 billion
Current conversion	42% feed C to olefin	42.35 kt/y
Improved target	55% feed C to olefin	55.45 kt/y
Commodity netback	7,500 RMB/t	Mixed light-olefin plant-gate screen, below NBS resin observations
EU premium	+10%, +20%, +30%	Not guaranteed; requires certified volume and offtake
Base feed-service fees	RMB 83.6m/y	70 RMB/t douzha; 150 RMB/t added wet wastes; 160 RMB/t bauxite residue
Contracted circular fees	RMB 203.5m/y	250 RMB/t eligible wet organics; 160 RMB/t bauxite residue
Carbon credits / scandium	Zero	Excluded until methodology, recovery and contract exist

10.2 CAPEX

Table 10.2 — Central ten-train Class 4 capital estimate.

CAPEX area	RMB million	Share
B1 receiving, preparation and HP feed	140	5.0%
B2 ten-train SCWG island	880	31.3%
B3/B4 salt, heat recovery, letdown and water	330	11.7%
B5 shared Rectisol, ZnO and sulfur recovery	250	8.9%
B6 shared bi-reformer and steam integration	260	9.2%
B7 OXZEO, recycle and product recovery	390	13.9%
B8 residue and nitrogen recovery	150	5.3%
Utilities and offsites	260	9.2%
Buildings, owner/EPCM and residual contingency	154	5.5%
Total capital investment	2,814	100.0%

The Class 4 range is approximately RMB 2.2–4.0 billion. B2 receives the largest uncertainty because no mature commercial reference combines this slurry, pressure, temperature and salt duty. B3/B4 are also high-risk because availability depends on online withdrawal and cleanability, not just vessel size. B7 includes a licensed/reactor allowance and product recovery, but catalyst royalty and imported package exposure require vendor quotation. The estimate excludes downstream polymerisation, financing during construction and recoverable VAT.

MAIN COST DRIVER: The high-pressure hydrothermal island and its salt-resistant feed/heat/separation equipment are sized by almost 1.0 million t/y of watery slurry, while revenue is generated by only about 42–55 thousand t/y of olefins. This capital dilution—not the OXZEO catalyst price alone—is the main reason the plant struggles financially.

10.3 OPEX

Table 10.3 — Annual cash OPEX before EU export/compliance increment.

Cash OPEX	RMB million/y	Basis
Electricity	20.4	≈50.9 GWh/y at public 0.40 RMB/kWh
Biomass thermal energy	33.6	≈682,650 GJ/y; 650 RMB/t pellets; stated LHV/efficiency assumptions
Maintenance and inspection	70.0	Towngas high-pressure/salt/cold/reformer project allowance
Labour and site services	32.0	Towngas project headcount and site-services allowance
Catalysts, ZnO, methanol and chemicals	32.0	Towngas project allowance pending vendor guarantees
Water, purge treatment and disposal	15.0	Purchased water, treatment and concentrate-disposal allowance
Insurance, administration and certification	15.0	Owner cost, assurance and routine audits
Subtotal before product tax	218.0	Rounded public China planning basis
Operating tax at 55% product case	1.9	Provisional 35 RMB/t public-model allowance
Total annual cash OPEX	219.9	Improved-conversion central case before EU increment

Maintenance is intentionally substantial. Ten pumps, reactors and twin separator sets create many isolation and inspection points; high alloys, reformer tubes, refrigeration and synthesis catalyst remain specialised even with domestic fabrication. Purchased energy is the largest variable cost, driven chiefly by the endothermic reformer and gas compression/refrigeration. Higher carbon feed can lower cost per tonne of product, but it does not reduce the absolute water throughput unless the final solids limit also rises.

10.4 Revenue and waste-service value

Table 10.4 — Product and service value. Gate fees and premiums are contracts, not assumed market facts.

Revenue / credit	Current 42% commodity case	Improved 55% contracted case	Basis
Light olefins	42.35 kt/y; RMB 317.6m	55.45 kt/y; RMB 415.9m	7,500 RMB/t netback
Organic-waste service	Included in RMB 83.6m total fees	~RMB 199.8m	Supplier contracts; competing uses may create purchase cost
Bauxite-residue service	RMB 3.7m	RMB 3.7m	160 RMB/t screening fee
Salt/residue by-products	RMB 5m	RMB 5m	Low combined value; destination qualification required
Ammonium sulfate	Excluded	Excluded from central; RMB 34–45m gross upside	75% N recovery and 900–1,200 RMB/t only after qualification
EU premium	Excluded	Analysed separately	10–30% scenario on certified contracted volume
Carbon credits / scandium	Excluded	Excluded	No methodology or recovery/offtake basis

Douzha may already have animal-feed or local disposal outlets. A positive gate fee cannot be assumed for every supplier, and a cleaner co-feed may need to be purchased. The contracted case therefore requires a portfolio of long-term terms with minimum volume, moisture/carbon adjustment, contamination liability and transport allocation. Counting a high gate fee and a high product premium is legitimate only if separate counterparties sign both; otherwise the economic bridge is a spreadsheet assumption.

10.5 Twenty-year scenario results

All four scenarios use 20 operating years, a 10% pre-tax unlevered discount rate, RMB 2.814 billion initial capital, ten-train feed rate, 333 operating days per full-rate year and RMB 5 million/y of qualified salt/residue value. Public planning assumptions are RMB 0.40/kWh for electricity, RMB 650/t for biomass pellets and RMB 20/t for purchased water. Pellet heating value is 16.5 GJ/t and useful-heat efficiency is 80%. A provisional public-model operating-tax allowance of RMB 35/t product is included. The cases exclude debt, income tax, depreciation, working capital, terminal value, carbon credits, scandium and ammonium-sulfate income; the ramp screen uses 70% output in year 1 and 90% in year 2.

Table 10.5 — Definition of the four 20-year cases. Each row is a complete alternative project case, not a chronological construction stage.

Case	Feed-C efficiency	Feed-service fees	Olefin netback	Cash OPEX	Question being tested
A	42%	Base: RMB 83.6m/y	7,500 RMB/t; no premium	RMB 219.5m/y	Current technical and weak commercial baseline
B	42%	Contracted: RMB 203.5m/y	9,000 RMB/t; EU +20%	RMB 241.5m/y	Commercial rescue at unchanged conversion
C	55%	Contracted: RMB 203.5m/y	7,500 RMB/t; no premium	RMB 219.9m/y	Technical improvement without premium
D	55%	Contracted: RMB 203.5m/y	9,000 RMB/t; EU +20%	RMB 241.9m/y	Technical and commercial improvement together

HOW TO READ THE CASES: A is the baseline. B and C are two different ways to move away from A: B improves the commercial package while holding conversion at 42%; C improves conversion and service contracts but deliberately removes the EU premium. D then adds the EU premium to C. Therefore C should not be read as the next chronological step after B.

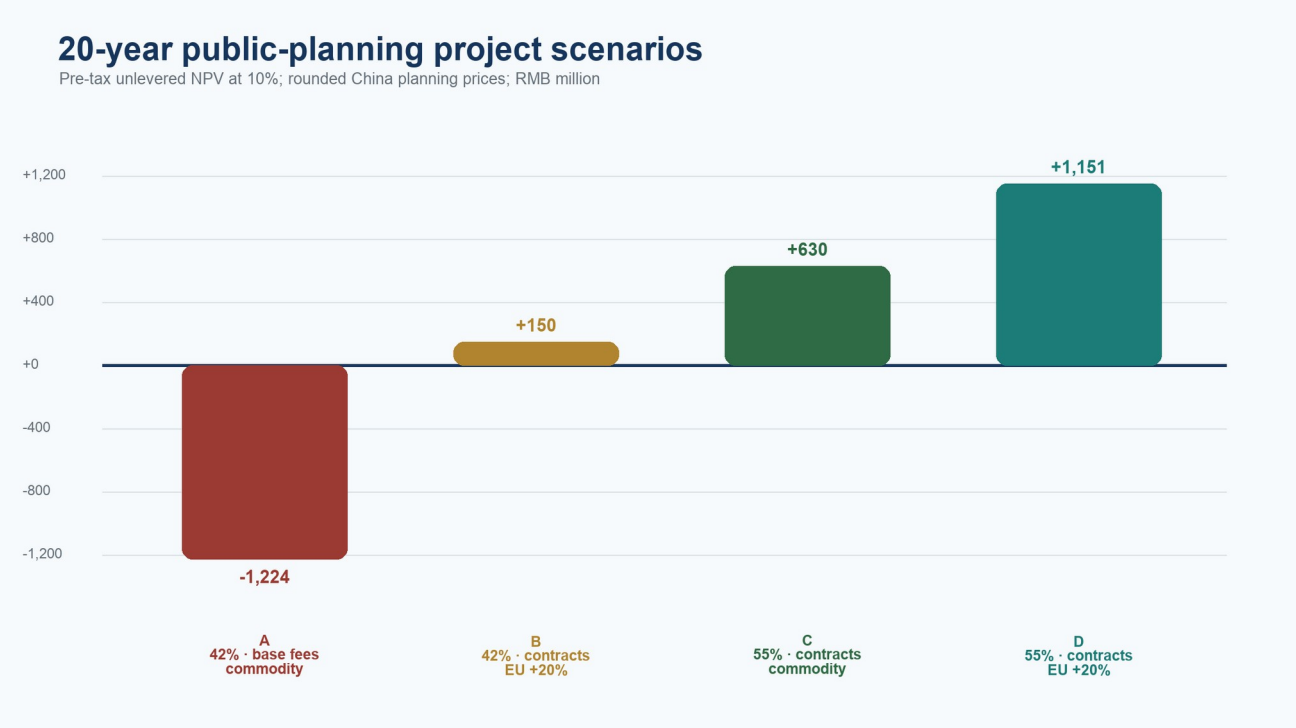

Figure 10.1 — Public-planning pre-tax unlevered NPV at 10% over 20 operating years. Electricity is screened at RMB 0.40/kWh and biomass pellets at RMB 650/t; assumptions are stated in Section 10.11.

Table 10.6 — Twenty-year economic results; no taxes, financing, ramp-up or terminal value.

Scenario	Olefin kt/y	Revenue RMB m/y	EBITDA RMB m/y	NPV RMB m	IRR	Simple payback
A — Current-performance commodity	42.35	406.2	186.8	-1223.8	2.9%	15.1 y
B — Current-performance + EU 20%	42.35	589.6	348.2	+150.2	10.8%	8.1 y
C — Improved conversion + contracts	55.45	624.4	404.5	+629.8	13.2%	7.0 y
D — Improved conversion + EU 20%	55.45	707.6	465.7	+1150.6	15.6%	6.0 y

10.5.1 Scenario A — current performance and base commercial terms

Scenario A is the reference case: 42% feed-carbon efficiency, 42.35 kt/y of olefins, a 7,500 RMB/t commodity netback, base service fees of RMB 83.6 million/y and public-planning OPEX of RMB 219.5 million/y. EBITDA is RMB 186.8 million/y and 20-year NPV is RMB -1223.8 million. Rounded Chinese utility assumptions improve the case, but weak product output and service income still cannot repay the hydrothermal capital at a 10% hurdle rate.

10.5.2 Scenario B — current conversion with stronger contracts and EU premium

Scenario B holds technical performance at 42%, so output remains 42.35 kt/y. Service fees rise to RMB 203.5 million/y, netback rises to 9,000 RMB/t and OPEX rises to RMB 241.5 million/y after the export/compliance increment. Level annual NPV becomes RMB 150.2 million; the two-year ramp screen reduces it to approximately RMB -15.1 million. The commercial package can therefore rescue current conversion only narrowly, leaving limited tolerance for capital overrun or lost availability.

10.5.3 Scenario C — improved conversion and contracts without premium

Scenario C is an alternative to B, not the next chronological step. Carbon efficiency rises to 55% and contracted service fees remain, but product sells at the 7,500 RMB/t commodity netback. Public-planning OPEX is RMB 219.9 million/y, level annual NPV is RMB 629.8 million and ramp-adjusted NPV is approximately RMB 444.4 million. The result shows that sustained carbon recovery is more robust than relying solely on an export premium.

10.5.4 Scenario D — improved conversion plus EU premium

Scenario D differs from C only by adding the 20% certified premium and RMB 22 million/y export/compliance increment. Level annual NPV rises to RMB 1150.6 million; the two-year ramp screen gives approximately RMB 943.5 million. This is the strongest case, but its premium and eligible volume still require a binding ISCC-aligned offtake rather than a generic market assumption.

10.6 Premium and conversion thresholds

Table 10.7 — Premium sensitivity with contracted circular-service fees.

Premium	Netback RMB/t	Break-even product kt/y	Break-even feed-C efficiency	NPV at 55% RMB m
0%	7,500	45.54	45.2%	+630
10%	8,250	43.82	43.5%	+814
20%	9,000	40.38	40.0%	+1151
30%	9,750	37.57	37.3%	+1479

Under the rounded public planning basis, the contracted case reaches level annual break-even at approximately 45.2% feed-carbon efficiency without a premium and about 40.0% with a 20% premium. This does not make 42% conversion comfortable: the two-year ramp, capital uncertainty and availability can consume the small positive margin in Scenario B. The 55% target remains the appropriate technical design point.

10.7 CAPEX and availability sensitivity

Table 10.8 — Capital, availability and contracts dominate smaller consumable optimisations.

Change from improved + EU 20% case	Approximate NPV effect	Interpretation
TCI rises from RMB 2.814bn to RMB 4.0bn	−RMB 1.186bn	Destroys project value unless grants/off-balance waste-service structures compensate
TCI falls to RMB 2.2bn	+RMB 0.614bn	Domestic modularisation and proven salt system are high-value
Availability falls 10% with largely fixed OPEX	Roughly −RMB 0.5–0.7bn	Salt separator and train turnaround are commercial variables, not maintenance detail
Olefin netback falls 1,000 RMB/t	About −RMB 472m NPV	55.45 kt/y × 1,000 × annuity factor
Weighted organic gate fee falls 100 RMB/t	About −RMB 680m NPV	799.2 kt/y eligible wet feed × 100 × annuity factor
Qualified ammonium sulfate adds RMB 30m/y net	+RMB 255m NPV	Useful upside but cannot rescue current 42% case alone

10.8 Economic conclusion

The original OXZEO route is not near-impossible, but it is not a normal commodity-chemical project. Ten trains create enough scale for a shared back end, yet scale alone cannot overcome low product carbon. A financeable configuration needs four conditions simultaneously: total capital near the central RMB 2.8 billion rather than the high end of the range; sustained feed-carbon efficiency above roughly 45–52% depending on premium; weighted long-term waste-service fees; and reliable online salt removal so annual production is actually achieved.

If those conditions cannot be contracted and demonstrated, the appropriate correction is a simpler product route—renewable methane or methanol—not another increase in slurry capacity. Direct methanol would remove OXZEO and deep olefin fractionation but would not remove SCWG, gas cleanup or the need to reform methane into CO/H2. It may reduce technical and market risk, but it also sells a lower-value product. The route decision should therefore compare complete licensed packages on the same feed, gate-fee, capital and 20-year basis.

10.9 Methanol and renewable-methane comparators

10.9.1 Why direct methanol does not automatically remove B6

A methanol loop consumes CO/CO2 and H2, not a methane-rich B2 gas. Replacing OXZEO with methanol synthesis therefore removes the bifunctional olefin reactor, synthesis recycle conditions and deep C2–C4 separation, but it does not automatically remove bi-reforming. B6 can be deleted only if SCWG or another upstream unit directly supplies a methanol-grade synthesis gas with the correct stoichiometric number, sulfur specification and acceptably low methane. Hotter SCWG may move the gas in that direction; the corrected methanation discussion in Section 5.2.3 explains why that result must be measured rather than assumed.

$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad and \qquad CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$$

Methanol nevertheless has practical advantages. The synthesis loop and distillation are mature, the liquid product is easier to store and ship than mixed light olefins, and marine/chemical buyers may accept certified renewable methanol. Its disadvantage is value density: the July 2026 NBS methanol observation was about 2,491 RMB/t, far below the 7,500 RMB/t mixed-olefin netback. Whether simpler equipment compensates for the lower price depends on carbon recovery, contracted gate fees and the actual renewable-methanol offtake.

10.9.2 Carbon-limited methanol capacity

The ten-train B1 feed contains 86,404 t/y carbon. Because methanol is 37.5 wt% carbon, the absolute stoichiometric maximum is 230.4 kt/y if every carbon atom becomes product. At a 60% overall feed-carbon efficiency, a more defensible route-screen basis is 138.2 kt/y. This is well below the owner's 300 kt/y Inner Mongolia comparator, so the RMB 1.5 billion benchmark still cannot be scaled solely by product name. Reaching 300 kt/y would require substantially more feed carbon or an external carbon/syngas source.

10.9.3 Screening comparison

Table 10.9 — Product-route comparison on the same B1 feed and contracted-fee basis. Methanol capital/OPEX and 60% carbon efficiency are route-screen assumptions, not vendor quotes.

Route screen	Product kt/y	Netback RMB/t	TCI RMB bn	OPEX RMB m/y	20-y NPV RMB m
OXZEO commodity, improved conversion	55.5	7,500	2.81	219.9	+630
OXZEO EU 20%, improved conversion	55.5	9,000	2.81	241.9	+1151
Reference methanol plant	300.0	Not disclosed	1.50 owner benchmark	Private cost breakdown omitted	Not calculable without revenue/feed/labour
Towngas-feed methanol screen	138.2	Scenario only	Vendor quote required	Vendor estimate required	Not asserted

A private commercial benchmark confirms that mature methanol production has a materially simpler and better-established cost structure than the proposed SCWG–OXZEO route. Its exact component breakdown is omitted from this public edition. The comparison still does not prove profitability for the Towngas feed because SCWG, gas cleanup, feed logistics and reforming duties differ from a conventional methanol plant. A comparable vendor scope, product offtake and complete feed/logistics cost are required before assigning a methanol NPV.

10.9.4 Renewable methane

A renewable-methane route is mechanically simplest because much of the B2 methane can be purified rather than reformed. B6 and B7 could be replaced by CO2 removal, drying, compression and gas-grid or LNG conditioning. This avoids the methane round-trip and should have the lowest conversion-island capital, but product value is tied to gas markets and certification, and methane slip becomes a critical greenhouse-gas risk. The route may be the best fallback where a nearby grid, industrial fuel buyer or bio-LNG terminal offers a firm premium.

Table 10.10 — Product-route decision should follow complete battery-limit economics.

Route	Units retained	Units removed / simplified	Commercial strength	Principal weakness
OXZEO olefins	B1–B6 plus B7	None	Highest product value and EU chemical-market differentiation	Catalyst/scale risk, reformer duty and product separation
Methanol	B1–B6 plus methanol loop	OXZEO and C2–C4 fractionation	Mature liquid synthesis and logistics; renewable-methanol buyers	Lower commodity price; B6 usually still required
Renewable methane	B1–B5 plus gas conditioning	B6/B7 largely removed	Lowest downstream complexity; avoids methane round-trip	Gas offtake/premium, compression and methane-emission control

10.11 Public cost basis and ramp sensitivity

The exact component cost breakdown from the private methanol reference is omitted from this public edition. The company-provided RMB 1.5 billion capital benchmark for a 300 kt/y methanol plant is retained as a high-level comparator. Towngas calculations use independent rounded public planning assumptions: RMB 0.40/kWh electricity, RMB 650/t biomass pellets, RMB 20/t purchased water and RMB 35/t provisional operating tax. These values are screening inputs rather than supplier quotations.

Table 10.11 — Rounded public planning inputs used in the Towngas economic screen; private methanol cost components are omitted.

Public planning input	Project quantity	Public unit basis	Comparator status	Annual RMB m
Electricity	50.9 GWh/y	0.40 RMB/kWh	—	20.36
Biomass thermal energy	682,650 GJ/y	650 RMB/t pellets	—	33.62
Purchased water	Site balance	20 RMB/t	—	Included in water OPEX
Maintenance	Towngas allowance	Vendor confirmation pending	—	70.00
Catalysts and chemicals	Towngas allowance	Vendor confirmation pending	—	32.00
Commercial methanol breakdown	—	Omitted from public edition	—	Not published

Table 10.12 — Effect of a two-year operating ramp. Fixed OPEX remains; revenue and variable OPEX scale with throughput.

Case	Level annual NPV RMB m	NPV with 70%/90% ramp RMB m	Interpretation
A	-1223.8	-1331.8	Commodity/base-fee case remains structurally negative
B	+150.2	-15.1	Current conversion becomes approximately break-even after ramp
C	+629.8	+444.4	Conversion plus contracts works without premium
D	+1150.6	+943.5	Strongest public case; premium still requires contract

11. Discussion and conclusions

11.1 What the feed strategy changes

The revised feed strategy does not abandon douzha. It treats douzha as the stable wet matrix and uses regional residues to adjust carbon, nitrogen and rheology. The balanced B1 design raises feed carbon from the douzha-rich control while preserving margin below the higher-carbon solids ceiling. This strengthens product output without making one speculative feedstock responsible for the plant. The same approach supports the website claim that many wet organic wastes can be converted: the core hydrothermal chemistry is shared, while the recipe and pretreatment respond to carbon density, pumpability and contaminant load.

11.2 What the bauxite-residue strategy changes

Bauxite residue is treated as a waste that needs an outlet, not only as a catalytic additive. Purposeful B3 precipitation and B4/B8 washing remove soluble species into controlled streams. The design no longer depends on complete one-pass dealkalization or a large permanent recycle. A one-pass qualified product leaves the plant; off-specification material receives a second wash or defined retreatment. This makes residue throughput, chloride and final responsibility auditable.

11.3 What remains scientifically difficult

Salt remains the largest technical availability risk. The project wants precipitation for residue treatment, but it must force that precipitation into B3 and keep H-101/B2 surfaces clean. The second difficulty is the methane round-trip. SCWG can produce methane efficiently, whereas OXZEO needs CO/H2; bi-reforming reverses methane formation with a large endotherm. The third difficulty is not a separate slogan but a consequence of the same integration: OXZEO laboratory selectivity must translate into long-duration conversion, catalyst life and product quality on real waste-derived gas.

11.4 Main financial conclusion

The plant remains capital-intensive because ten high-pressure, salt-resistant hydrothermal trains handle nearly one million tonnes per year of watery slurry while only 42–55 kt/y becomes saleable olefins. Rounded Chinese electricity and biomass-fuel assumptions reduce screened operating cost materially, but they do not remove the capital-dilution problem. Under the public assumptions, current conversion plus contracted service fees and a 20% certified premium remains only marginally positive after a two-year ramp; improved 55% carbon efficiency is substantially stronger. Profitability therefore still requires high availability, controlled capital, contracted waste-service revenue and verified product value together.

11.5 Final design position

Table 11.1 — Consolidated outcome of the complete rewrite.

Decision	Revised position
Feed	Keep douzha as anchor; use cassava, clean pulp/liquor and controlled straw as optional carbon adjustment; manure only after separate qualification
Location	Treat the Guangxi–Guangdong/Beibu Gulf corridor as an opportunity; decide from supplier-level delivered dry-carbon and utility/product logistics
Scale	Ten 300 t/d B1–B4 trains merging after B4 into shared B5–B7
Salt	Desired separation product and primary availability risk; twin continuous B3 separators with flush and underflow
Bauxite residue	One-pass product target plus off-spec second wash/retreatment; no blanket full-dealkalization claim
Chloride	Supplier segregation, washing, recycle limit and controlled aqueous purge based on measured inventory
Nitrogen	Recover aqueous ammonia to ammonium sulfate after qualification; do not leave protein nitrogen in indefinite water recycle
Bi-reforming	Retain; strongly endothermic; optimise B2 to reduce methane only when full carbon efficiency improves

Decision	Revised position
OXZEO	Use simplified chemistry narrative but require licensed real-gas conversion, selectivity and life
Certification	Standalone ISCC/ISO/market section; EU premium is contractual and olefins are not currently CBAM goods
Economics	Current 42% case is not financeable; improved 50–55% conversion plus contracts can make the ten-train case profitable

FINAL CONCLUSION: The process is technically coherent and can become commercially credible, but only as an integrated waste-service and certified-carbon project. It should not be presented as a commodity-olefin plant that happens to use waste.

References

1. International Aluminium Institute. Updated Sustainable Bauxite Residue Management Guidance. https://international-aluminium.org/iai-releases-updated-sustainable-bauxite-residue-management-guidance/
2. International Aluminium Institute. Bauxite Residue Use. https://international-aluminium.org/work-areas/bauxite-residue-use/
3. Current review of bauxite residue generation, storage, alkalinity and valorisation. Science of the Total Environment, 2024. https://www.sciencedirect.com/science/article/abs/pii/S0048969724049064
4. Hydrothermal/supercritical-water dealkalization of bauxite residue and structural sodium phases. Journal of Environmental Management, 2023. https://www.sciencedirect.com/science/article/pii/S0301479723012574
5. Bauxite-residue washing and removal of soluble components. Journal of Environmental Sciences, 2020. https://www.sciencedirect.com/science/article/pii/S1001074220300346
6. Marrone, P. A.; Hodes, M. Salt precipitation and deposition in supercritical water oxidation/gasification systems. General mixed-salt phase-behaviour basis.
7. Schubert, M. et al. Continuous salt separation concepts for supercritical-water systems. Industrial hydrothermal separation literature.
8. ISCC. ISCC PLUS certification scheme and alternative feedstock categories. https://iscc-system.org/certification/certification-schemes/iscc-plus/
9. ISO. ISO 14067:2018 Greenhouse gases — Carbon footprint of products. Confirmed 2024. https://www.iso.org/standard/71206.html
10. National Bureau of Statistics of China. Market prices of important means of production, mid-July 2026. https://www.stats.gov.cn/sj/zxfbhjd/202607/t20260723_1964185.html
11. European Commission. CBAM sectors. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-sectors_en
12. BASF. The Biomass Balance Approach and ISCC PLUS-certified products. https://www.basf.com/global/en/who-we-are/sustainability/our-contributions-to-enabling-the-green-transformation/circular-economy/circular-feedstocks/mass-balance/the-biomass-balance-approach
13. Pan, X.; Jiao, F.; Miao, D.; Bao, X. Oxide–zeolite-based composite catalyst concept that enables syngas chemistry beyond Fischer–Tropsch synthesis. Chemical Reviews, 2021. https://pubmed.ncbi.nlm.nih.gov/34032417/
14. Dalian Institute of Chemical Physics. Jiao Feng research profile; OXZEO concept and kilotonne-scale pilot participation. https://english.dicp.cas.cn/sourcedb/ra/cc/202310/t20231031_462539.html
15. Feng, J. et al. Stability of ZnMOx–SAPO-11 OXZEO composite catalysts. Catalysis Science & Technology, 2024, 14, 1209–1215. https://pubs.rsc.org/en/content/articlehtml/2024/cy/d3cy01166f
16. Olah, G. A. et al. Bi-reforming of methane with steam and carbon dioxide to metgas. Journal of the American Chemical Society, 2013. https://pubmed.ncbi.nlm.nih.gov/23256664/
17. Kumar, N.; Shojaee, M.; Spivey, J. J. Catalytic bi-reforming of methane. https://www.osti.gov/servlets/purl/1369696
18. Ammonia removal and recovery from hydrothermal aqueous streams with acid absorption to ammonium sulfate. Chemical Engineering Journal, 2024. https://www.sciencedirect.com/science/article/pii/S1385894724052045
19. Gas-permeable membrane recovery of ammonia nitrogen from hydrothermal-liquefaction aqueous phase. Journal of Environmental Management, 2023. https://pubmed.ncbi.nlm.nih.gov/37769474/
20. Hydrothermal conversion of protein and nitrogen distribution; ammonia from deamination. ACS Sustainable Chemistry & Engineering. https://pubs.acs.org/doi/10.1021/acssuschemeng.7b02854
21. Guangxi Department of Agriculture and Rural Affairs. Regional agricultural and processing-sector planning materials. https://nynct.gxzf.gov.cn/
22. Guangdong Provincial Bureau of Statistics. Provincial statistical data and industrial/agricultural activity. https://stats.gd.gov.cn/attachment/0/588/588488/4757585.pdf
23. Guangxi Department of Agriculture and Rural Affairs. Lingshan cassava area and processing report, 2025. https://nynct.gxzf.gov.cn/xwdt/gxlb/qz/t27187328.shtml
24. Guangxi sugar-industry planning document. https://nynct.gxzf.gov.cn/xxgk/jcxxgk/wjzl/gntf/P020221206603177735473.pdf
25. ISCC. Mass-balance requirements and transition information. https://contact.iscc-system.org/support/solutions/articles/103000349237-where-do-i-find-information-on-the-requirements-related-to-mass-balance-
26. European Commission. CBAM definitive regime from 2026. https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism/cbam-definitive-regime_en
27. ISCC. Mass Balance Guidance, 2026. https://iscc-system.org/wp-content/uploads/2026/02/Mass-Balance-Guidance-document.pdf
28. Ministry of Ecology and Environment of China. National carbon market and CCER information. https://www.mee.gov.cn/
29. ISO. ISO 14040 and ISO 14044 life-cycle assessment principles and requirements. https://www.iso.org/
30. National Bureau of Statistics of China. Explanatory notes for monitored production-material market prices, 2026.
31. Supercritical-water gasification of soybean straw: feed characterisation, gas yields and inorganic effects. Published SCWG literature used for the dry-fibre screen.
32. General reviews of supercritical-water gasification of wet biomass, reaction pathways, catalysts and process limitations.
33. Published bauxite-residue composition reviews covering Fe, Al, Ti, Si, sodium and trace-element variability.
34. Published corrosion literature for nickel alloys and high-alloy steels in hot pressurised water containing chlorides, sulfides and alkali.

35. Pressure filtration and cake washing of bauxite residue. Minerals Engineering, 2015. https://www.sciencedirect.com/science/article/pii/S0301751615001489

36. Restricted commercial benchmark. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

37. Industrial technical reference a. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

38. Industrial technical reference b. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

39. Industrial technical reference c. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

40. Industrial technical reference d. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

41. Industrial technical reference e. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

42. Industrial technical reference f. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

43. Industrial technical reference g. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

44. Industrial technical reference h. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

45. Industrial technical reference i. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.

46. Industrial technical reference j. Source identity, original document title, facility attribution and detailed source description are withheld from this public edition. Technical values are reproduced only where authorised.