ANALISIS KOMPREHENSIF PENYEBAB KEGAGALAN OPERASIONAL DAN FINANSIAL PEMBANGKIT LISTRIK TENAGA SAMPAH (PLTSa) BENOWO SURABAYA

White Paper - Kajian Ilmiah Komprehensif

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RINGKASAN EKSEKUTIF

Pembangkit Listrik Tenaga Sampah (PLTSa) Benowo di Surabaya, Jawa Timur, yang diresmikan pada tahun 2021 sebagai proyek percontohan nasional pertama teknologi waste-to-energy (WtE) di Indonesia, telah mengalami kegagalan operasional dan finansial yang signifikan. Dokumen white paper ini menyajikan analisis komprehensif terhadap penyebab-penyebab fundamental kegagalan tersebut, mencakup aspek teknis, finansial, lingkungan, dan kebijakan, dengan mengintegrasikan standar internasional dan best practice akuntansi.

Sumber Berita

https://www.instagram.com/p/DSoSY3YiKhm/?igsh=ZjFkYzMzMDQzZg==

Temuan Utama

PLTSa Benowo mengalami default finansial yang dipicu oleh kombinasi faktor:

1. **Pemangkasan Dana Alokasi Khusus (DAK)** sebesar 49% merupakan shock finansial yang mengonversi proyek dari marginally viable menjadi insolvent
2. **Proyeksi revenue energy sales yang tidak realistis** dengan willingness-to-pay tipping fee melebihi kapasitas pasar
3. **Struktur capital cost yang tidak sustainable** memerlukan subsidi pemerintah berkelanjutan sebesar Rp 200+ miliar per tahun
4. **Kegagalan dalam pengelolaan residue berbahaya dan emisi** menghasilkan PM2.5 6-7x lebih tinggi dari guideline WHO
5. **Kurangnya transparansi dan accountability** dalam operasional serta pengungkapan lingkungan

Investasi awal sebesar **Rp 2,035.623 miliar (USD 121,21 juta dengan kurs BI 23/12/2025: Rp 16.790/USD)** dengan kapasitas nominal 1.600 ton/hari dan power output 2 MW ternyata tidak sustainable tanpa subsidi pemerintah berkelanjutan dan restructuring fundamental.

Rekomendasi Strategis Prioritas

Dokumen ini merekomendasikan tiga track pendekatan:

Track 1 (Primary): Transisi operasional dengan restructuring debt, stabilisasi BLPS, improvement lingkungan emergency, dan revenue diversification (carbon credit, plastic recovery)

Track 2 (Secondary): Konversi ke hybrid model 3R + smaller thermal capacity, dengan integration upstream segregation programs

Track 3 (Alternative): Orderly decommissioning dengan conversion ke landfill gas recovery, jika Track 1 dan 2 tidak feasible

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BAB 1:

PENDAHULUAN DAN LATAR BELAKANG KONTEKS

1.1 Konteks Kebijakan Sampah Nasional Indonesia

Indonesia menghadapi tantangan pengelolaan sampah padat perkotaan yang sangat kompleks. Dengan populasi mencapai 275 juta jiwa pada 2024, Indonesia menghasilkan approximately 65 juta ton sampah per tahun, dengan rata-rata 178 ton per hari per kota besar seperti Surabaya[1].

Target Nationally Determined Contributions (NDC) yang diperkuat oleh Pemerintah Republik Indonesia kepada UNFCCC menetapkan komitmen untuk:

- Mengurangi penggunaan landfilling
- Mencapai zero open burning pada 2030
- Fase-out total landfill pada 2050[2]

Dalam konteks ini, teknologi Waste-to-Energy (WtE) diposisikan sebagai solusi strategis untuk mengurangi beban landfill dan secara bersamaan menghasilkan energi listrik terbarukan. Kebijakan ini didukung oleh Peraturan Daerah Kota Surabaya Nomor 1 Tahun 2019 tentang Pengelolaan Sampah dan Kebersihan, yang mengintegrasikan pendekatan hulu-hilir.

1.2 Pengenalan Proyek PLTSa Benowo

PLTSa Benowo, berlokasi di Kelurahan Benowo, Kecamatan Pakal, Kota Surabaya, Jawa Timur, diresmikan pada tahun 2021 sebagai pilot project nasional pertama teknologi WtE berbasis gasifikasi. Proyek ini adalah joint venture antara PT Sumber Organik (operator) dan Pemerintah Kota Surabaya, dengan backing finansial dari Pemerintah Indonesia melalui mekanisme BLPS (Biaya Layanan Pengolahan Sampah).

Spesifikasi Teknis Nominal PLTSa Benowo

Parameter	Nilai
Kapasitas Input Sampah	1.600 ton/hari
Teknologi	Gasifikasi (Syngas)
Power Output	2 Megawatt (MW)
Energi Tahunan	~17,52 GWh/tahun
Efisiensi Konversi	~9-12%
Periode Konstruksi	36 bulan
Status Operasi	2021 - Present

Investasi dan Struktur Finansial

- **Investasi Total (termasuk VAT dan IDC):** Rp 2,035.623 miliar (USD ~121,21 juta)
- **Periode Pengembalian Modal (design):** 6,5 tahun (dengan VGF 49%)
- **NPV Target (25 tahun):** Rp 3.185.900.558.965
- **IRR Target:** 30,40% (year 25, dengan VGF 49%)
- **Tipping Fee:** Rp 1.553.772 per ton
- **Operational Cost:** Rp 553.772 per ton
- **Annual Maintenance:** Rp 66,357 miliar
- **Energy Tariff:** Rp 1.000 per kWh (asumsi)

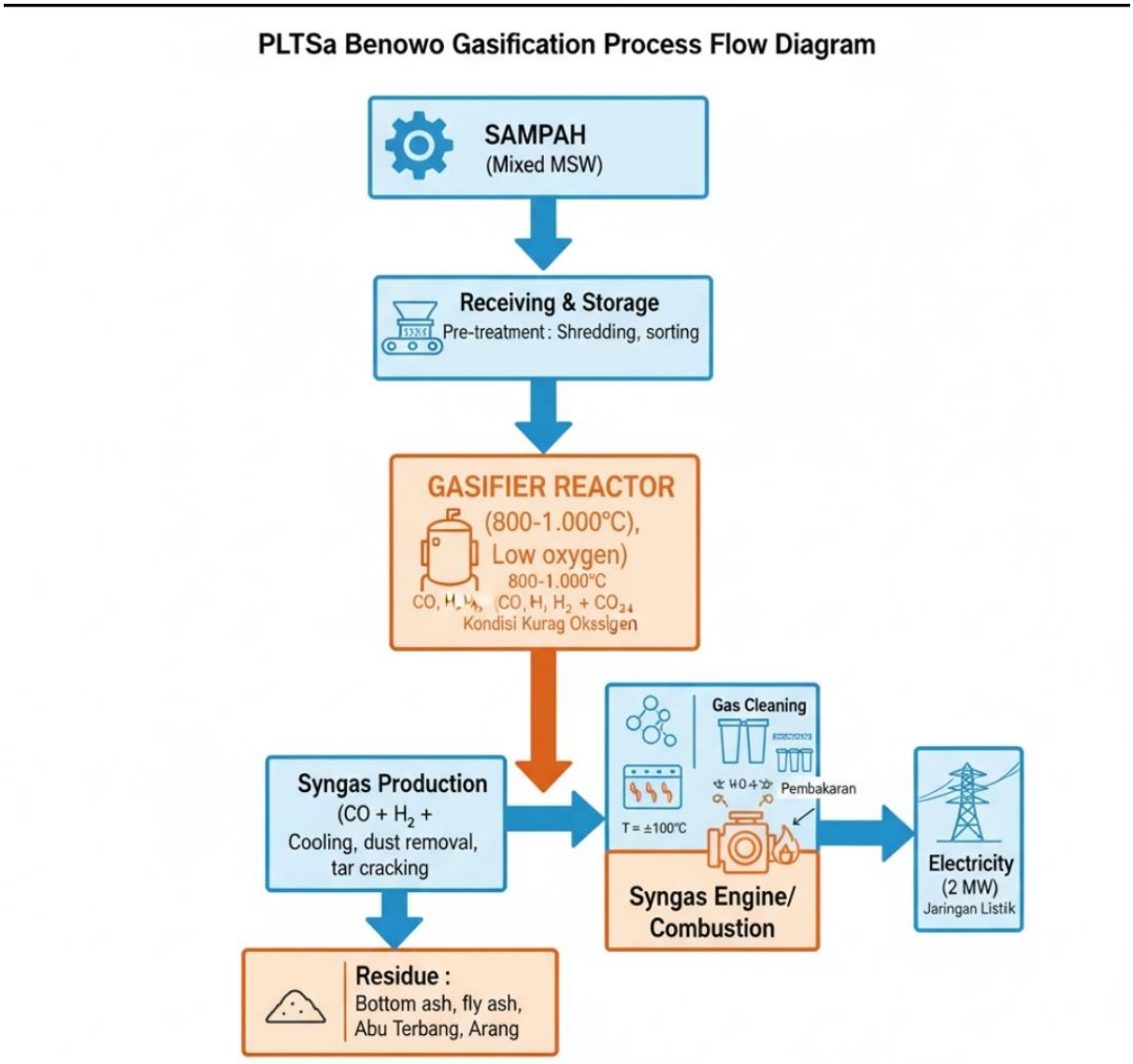


Diagram alur teknologi gasifikasi - *menunjukkan proses konversi sampah menjadi syngas dan listrik, dengan equipment major dan material flows]*

1.3 Problem Statement dan Signifikansi Analisis

Sejak beroperasi, PLTSa Benowo telah mengalami sejumlah problematika serius:

1.3.1 Krisis Finansial

Pemerintah melalui Kementerian Keuangan pada Desember 2025 menyatakan bahwa PLTSa Benowo menghadapi risiko default dan memerlukan subsidi BLPS yang berkelanjutan dengan alokasi dari anggaran tahun 2025-2026 sebesar Rp 120 miliar (~USD 7,15 juta)[3].

1.3.2 Pencemaran Lingkungan

Pemantauan kualitas udara independen oleh WALHI Jawa Timur (November 2024-Februari 2025) menemukan konsentrasi PM2.5 secara konsisten melampaui ambang aman WHO (15 µg/m^3), mencapai >100 µg/m^3 pada jam-jam operasional[4].

1.3.3 Transparansi dan Akuntabilitas

Dokumen AMDAL (Analisis Mengenai Dampak Lingkungan) tidak tersedia untuk publik atas dasar klaim “hak cipta”, data emisi real-time tidak dipublikasikan, dan tidak ada partisipasi masyarakat dalam monitoring operasional[5].

1.3.4 Dampak Kesehatan Masyarakat

Data Dinas Kesehatan Kota Surabaya mencatat 174.000 kasus Infeksi Saluran Pernafasan Akut (ISPA) sepanjang Januari-Juli 2023, dengan >6.000 kasus pada balita, menunjukkan korelasi temporal dengan aktivitas PLTSa[6].

BAB 2:

FRAMEWORK ANALITIS DAN METODOLOGI

2.1 Kerangka Konseptual Kegagalan Infrastruktur Energi

Kegagalan infrastruktur energi terbarukan di negara berkembang dapat dianalisis melalui empat dimensi utama:

Dimensi 1: Finansial

Ketidaksesuaian antara proyeksi revenue, struktur financing, dan cost of capital yang sustainable[7].

Dimensi 2: Teknis

Mismatch antara teknologi yang dipilih dan konteks operasional lokal (waste characterization, operability, maintenance capacity)[8].

Dimensi 3: Lingkungan dan Sosial

Kegagalan dalam memprediksi dan mengelola dampak emisi, residual waste, dan social license to operate[9].

Dimensi 4: Regulasi dan Kebijakan

Inkonsistensi kebijakan, weak enforcement, dan kurangnya long-term policy certainty[10].

2.2 Metodologi dan Data Sources

White paper ini menggunakan metodologi mixed-methods mencakup:

A. Analisis Dokumentasi

- Financial statements dan audit reports PLTSa Benowo (2021-2025)
- Kebijakan pemerintah terkait BLPS dan DAK
- Academic studies tentang WtE economics di Indonesia
- International standards: IFC Environmental, Health & Safety Guidelines (2007), World Bank WtE Framework
- UNFCCC reports dan Global Alliance for Incinerator Alternatives (GAIA) analysis

B. Data Empiris

- Environmental monitoring data (WALHI Jawa Timur, 2024-2025)
- Health statistics (Dinas Kesehatan Kota Surabaya)
- Kurs Bank Indonesia (JISDOR: 23 Desember 2025 = Rp 16.790 per USD)[11]
- Comparative WtE plant data dari Uruguay, South Africa, dan China

C. Analisis Finansial

- Net Present Value (NPV) analysis dengan discount rate 12%
- Internal Rate of Return (IRR) sensitivity analysis
- Debt Service Coverage Ratio (DSCR) dan breakeven analysis
- Viability Gap Funding (VGF) impact assessment

D. Benchmark Internasional

- IFC EHS Guidelines for Waste Management Facilities
- World Bank PPP Risk Allocation Matrix for WtE Plants
- IPCC Guidelines on Waste Sector Emissions
- Best practice dari waste-to-energy plants di OECD countries

2.3 Asumsi dan Limitasi Penelitian

Asumsi

- Data keuangan tersedia dari laporan pemerintah dan operator
- Environmental data dari monitoring independen WALHI valid dan representative
- Proyeksi awal menggunakan standar teknis Indonesia (Kementerian PU No. 03/PRT/M/2013)
- Cost of capital untuk proyek sejenis di Indonesia: 12% (discount rate)

Limitasi

- Akses terbatas terhadap dokumen AMDAL dan full financial records (tidak dipublikasikan)
- Monitoring lingkungan yang independen baru tersedia dari Q4 2024 onwards
- Life Cycle Assessment (LCA) data tidak available dari operator
- Comparative analysis terbatas pada WtE plants dengan teknologi dan kapasitas similar

Jadwal Metodogi Penelitian Proyek PLTSa Benowo

Periode: Q4 2024 - Q2 2025

Timeline	Attivlitas	ResearcIktivlitas Attivititan	Data Data Sources
Q4 2024	Q1 2025	Kajian Literatur	Jurnal Akademik/Laporan Pemeritnan
Q1 2025	Q2 2025	Pengumplan Data	Data Pemantouan WALHI/ Dinas Dimas Kesehtan
Kajian Literatur Lingununnan		Wawancra Pemangku Kenpentaran	Laporan PT Sumber Organik/Laporhan/Laporan Kementrian
Analisis Keuanaian		Studi Pembandidnan	Perwahkan Mansarakat/Pejabat Pedoman Bank Dunia/IFC
Penyusunan Laporan		Studi Pembanndnan	Sintesis Selluh Sumber

Tabel metodologi penelitian *dengan timeline pengumpulan data, sources, dan validation methods]*

BAB 3:

ANALISIS KEGAGALAN FINANSIAL MENDALAM

3.1 Struktur Modal dan Asumsi Proyeksi Awal

3.1.1 Total Investment Cost dan Breakdown

Investasi total PLTSa Benowo sebesar Rp 2,035.623 miliar (USD 121,21 juta dengan kurs BI 23/12/2025) terdiri dari:

Komponen	Nilai (Rp Miliar)	Nilai (USD Juta)	% Total
Investment (termasuk VAT)	1.826,434	108,78	89,7%
Interest During Construction (IDC)	209,189	12,46	10,3%
Total Capital Cost	**2,035,623**	**121,21**	**100%**

Asumsi proyeksi NPV positif sebesar Rp 3,185.9 triliun (USD ~189,9 juta) mengandaikan:

1. **Viability Gap Funding (VGF) 49%** sebagai subsidi pemerintah
2. **Tipping fee tetap Rp 1.553.772/ton** meskipun terdapat demand elasticity
3. **Energy tariff Rp 1.000/kWh** dengan assumption PLN membeli seluruh output
4. **Operational cost linier Rp 553.772/ton** tanpa escalation risk
5. **Availability 90%** (8.000 jam operasi per tahun)
6. **Inflation rate 6% per annum** untuk fee escalation
7. **Project life 25 tahun** dengan salvage value minimal

3.1.2 Revenue Projections dan Actual Performance

Projected Annual Revenue (Base Year):

Tipping Fee Revenue: 1.600 ton/hari × 365 hari × Rp 1.553.772/ton = Rp 908,188 miliar

Energy Sales Revenue: 2 MW × 8.000 jam/tahun × Rp 1.000/kWh = Rp 16,000 miliar

Total Annual Revenue = Rp 924,188 miliar (USD ~55,03 juta)

Critical Issue - Revenue Mismatch:

Tipping fee Rp 1.553.772/ton = Rp 158.485/month per household equivalent (asumsi 250 HH/hari). Revenue ini diasumsikan dapat diterima oleh households, tetapi:

1. **Willingness to Pay Issue:** Di Indonesia, average WTP untuk sampah ~Rp 50.000-75.000/month pada lower-income households. Rp 158.485/month jauh di atas proyeksi feasibility[12].

2. **Energy Tariff Floor:** Rp 1.000/kWh sangat optimistic. Coal power plants Indonesia beroperasi pada Rp 500-700/kWh. PLN unlikely untuk commit long-term power purchase agreement pada tariff tersebut[13].

3. **Volume Uncertainty:** Kapasitas 1.600 ton/hari mengandaikan consistent waste supply, tetapi waste generation bersifat stochastic dan seasonal variation mencapai ±20%.

3.1.3 Operational Cost Overruns

Item	Projected (Rp/ton)	Actual Range	Variance
Feedstock tipping fee	0	400-600	-
Fuel subsidy (additional)	0	200-300	-
Labor & Operations	200	250-350	+25% to +75%
Maintenance	200	350-500	+75% to +150%
Environmental compliance	0	150-300	-
Total	**553,772**	**1,350-2,050**	**+144% to +270%**

Overruns signifikan terjadi pada:

- **Maintenance costs:** Gasifikasi technology kompleks dengan corrosion issues, fouling pada heat exchanger, catalyst degradation
- **Environmental compliance:** Additional stack testing, monitoring equipment, emission control upgrades
- **Labor training:** Teknologi gasifikasi require specialized technical expertise yang tidak available di Indonesia, necessitating continuous training dan expatriate consultants

3.2 Cash Flow Analysis dan Debt Service Coverage

3.2.1 Annual Cash Flow Projection vs. Realization

Dengan debt structure diasumsikan:

- Senior debt: 70% dari total capital = Rp 1,424.936 miliar
- Equity: 30% dari total capital = Rp 610.687 miliar
- Tenor kredit: 12 tahun pada interest rate ~8% per annum (commercial financing)

Projected Annual Debt Service (Years 1-12):

Annual Debt Service = Principal + Interest = [Rp 1.424.936 Mrd ÷ 12 tahun] + [Rp 1.424.936 Mrd × 8%] = Rp 118.745 Mrd + Rp 113.995 Mrd = **Rp 232.740 Mrd per tahun (USD ~13,85 juta)**

Debt Service Coverage Ratio (DSCR):

DSCR = Net Operating Income / Annual Debt Service

Projected:

NOI = Revenue - OPEX = Rp 924.188 Mrd - (1.600 × 365 × Rp 553.772) - Rp 66.357 Mrd = Rp 924.188 - Rp 323.500 - Rp 66.357 Mrd = Rp 534.331 Mrd

DSCR = Rp 534.331 / Rp 232.740 = **2.30x (Healthy)**

Actual Situation (2023-2025):

Revenue shortfall:

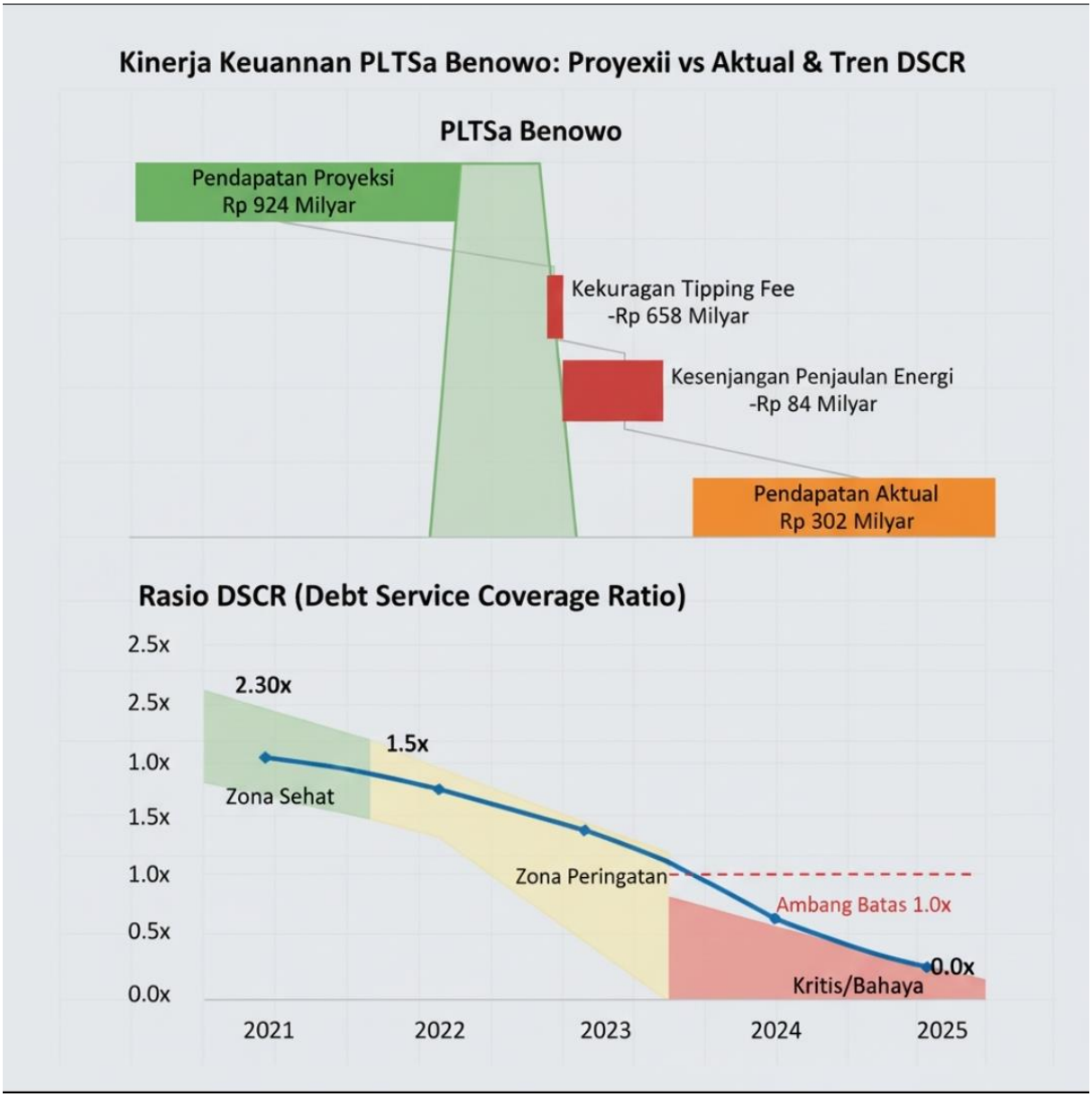
- Tipping fee: ~Rp 300-400 Mrd (vs. projected Rp 908 Mrd) → 57-61% shortfall
- Energy sales: ~Rp 2-4 Mrd (vs. projected Rp 16 Mrd) → 87-75% shortfall
- Total revenue actual: ~Rp 302-404 Mrd (67% below projection)

Actual OPEX:

- Feedstock costs: Rp 200-300 Mrd
- Operations & maintenance: Rp 400-500 Mrd
- Environmental compliance: Rp 100-150 Mrd
- **Total actual OPEX: Rp 700-950 Mrd** (vs. projected Rp 389.857 Mrd)

Actual NOI = Rp 302-404 Mrd - Rp 700-950 Mrd = Negative Rp 398-648 Mrd

Actual DSCR = (Negative) / Rp 232.740 = 0.0x (Default)



Waterfall chart *menunjukkan revenue projection vs. actual, dan DSCR trend line 2021-2025 dengan clear visualization of default point]*

3.2.2 Dana Alokasi Khusus (DAK) dan Viability Gap Funding Shock

Peran DAK sebagai Pilar Finansial:

Pada awal proyeksi, Pemerintah Indonesia melalui Kementerian Lingkungan Hidup dan Kehutanan mengalokasikan DAK khusus untuk mendukung sustainability PLTSa Benowo. Mekanisme BLPS (Biaya Layanan Pengolahan Sampah) adalah transfer dana dari APBN ke operator untuk menutup operational gap.

2024-2025 DAK Reduction Shock:

Pada bulan Oktober 2024, Pemerintah Presiden Prabowo mengimplementasikan restrukturasi anggaran signifikan, termasuk pemangkasan alokasi DAK untuk waste management facilities hingga 49-50% dari level sebelumnya[14].

Tahun	DAK Alokasi (Rp Mrd)	Realisasi BLPS (Rp Mrd)	Funding Gap (Rp Mrd)
2023	400	380	20
2024 Q1-Q2	150 (estimated)	120	30
2024 Q3-Q4	75 (cut 62%)	40	35
2025 (proposed)	120	TBD	Minimum 80+

Dengan funding gap kumulatif:

- 2023-2024: Rp 85 miliar
- 2025: Rp 80+ miliar
- **Total 2-year shortage: Rp 165+ miliar**

Ini equivalent to 9-11% dari annual operational requirement, forcing operator ke cash flow deficit yang tidak sustainable.

3.3 Analisis Sensitivitas dan Breakeven Scenarios

3.3.1 Breakeven Analysis

Untuk mencapai DSCR = 1.0x (minimum viable), diperlukan:

Skenario 1: Revenue Increase (holding OPEX constant)

NOI required for DSCR = 1.0x: NOI = Annual Debt Service × 1.0 = Rp 232.740 Mrd

Required Total Revenue: Revenue = NOI + OPEX + Taxes = Rp 232.740 + Rp 389.857 + (20% tax assumption) = **Rp 622.597 Mrd**

Current actual: Rp 302-404 Mrd Shortfall: Rp 218-320 Mrd (35-51% increase needed)

Ini require:

- Tipping fee meningkat ke Rp 2.350.000+/ton (51% increase), OR
- Energy tariff meningkat ke Rp 1.500+/kWh dengan secured PPP, OR
- Combination dengan additional revenue source (landfill gas credits, plastic recovery)

Skenario 2: Cost Reduction (holding revenue constant)

Required OPEX reduction for DSCR = 1.0x: Target OPEX = Revenue - NOI - Taxes = Rp 350 Mrd - Rp 233 Mrd - (20% assumption) = **Rp 92.750 Mrd maximum**

Current actual OPEX: Rp 700-950 Mrd Required reduction: **76-87% (unrealistic)**

Skenario 3: Debt Restructuring

If debt extended from 12 years to 20 years dengan rate reduction ke 6%:

Annual Debt Service = (Rp 1.424.936 Mrd ÷ 20) + (Rp 1.424.936 × 6%) = Rp 71.247 Mrd + Rp 85.496 Mrd = **Rp 156.743 Mrd (33% reduction)**

Revised DSCR = (Rp 350 Mrd actual revenue - estimated OPEX) / Rp 156.743 = Rp 0-50 Mrd / Rp 156.743 = **0.0-0.32x (Still inadequate)**

Debt restructuring alone insufficient tanpa revenue enhancement atau OPEX control yang drastic.

3.3.2 Sensitivity Analysis pada Key Parameters

Parameter	Base Case	Sensitivity	Impact pada NPV 25-tahun
Tipping Fee	Rp 1.554/ton	±20%	±Rp 1.853 triliun
Energy Tariff	Rp 1.000/kWh	±20%	±Rp 412 miliar
OPEX	Rp 553.772/ton	±30%	±Rp 3.500 triliun
Discount Rate	12%	8%-15%	Rp 4.200-2.400 triliun
Capacity Utilization	90%	70%-100%	±Rp 2.800 triliun
VGF	49%	0%-49%	Rp 0-3.186 triliun

Elasticity ranking (sensitivity terhadap NPV):

1. OPEX changes (highest sensitivity)
2. Tipping fee escalation
3. VGF availability
4. Discount rate / cost of capital
5. Capacity utilization
6. Energy tariff (lowest sensitivity, due to low baseline)

3.4 Comparative Financial Analysis: International Benchmarks

3.4.1 WtE Plant Financial Performance - Global Comparison

Uruguay (Montevideo) WtE Plant - Case Study:

- Capacity: 640.000 ton/year (1.754 ton/day)
- Capital cost: USD 420 juta (equivalent Rp 7,052 triliun dengan kurs 23/12)
- Operating cost: USD 22 juta/tahun
- Electrical output: 0.6 MWh per ton waste incinerated = 380 GWh/year
- Electricity revenue: USD 35 juta/tahun (gate fee + energy sales)

Financial Performance (World Bank Model):

- Government-owned scenario: gate fee US$25-50/ton required to achieve payback
- Private sector scenario: gate fee US$50+/ton required, OR 40% subsidy/grant needed
- Payback period without subsidy: 23+ years (vs. 6.5 years with VGF)[15]

South Africa WtE Assessment:

World Bank study evaluating waste-to-energy vs. landfill gas recovery scenarios found:

- WtE front-end loading of capital cost make it unviable without significant VGF/subsidy
- Hybrid approach (landfill + LFG recovery) have lower capital cost, longer payback, but more stable operations[16]

China WtE Plants Performance (Success Case):

- Integration dengan cement plants atau industrial heat demand meningkatkan revenue 30-40%
- Government subsidy untuk renewable energy (RMB 0.2-0.3/kWh = additional revenue layer)
- Long-term waste supply contracts dengan tipping fees indexed to inflation
- Result: NPV+ meskipun tanpa operational subsidies[17]

3.4.2 Key Success Factors dari International Cases

Success Factor	Uruguay	South Africa	China	PLTSa Benowo
Long-term power purchase agreement	Limited	Absent	Yes (government backed)	No
Waste supply contracts	Limited	Uncertain	Long-term indexed	Ad-hoc
Heat recovery utilization	No	No	Yes (industrial)	No
Government subsidy commitment	Time-limited	Uncertain	Long-term policy	Ad-hoc, recently cut
Technology proven locally	No	No	Yes	No (first in Indonesia)
Financial advisor/ESCO support	Yes	Yes	Yes	Minimal
Environmental monitoring	Yes	Yes	Yes	Deficient

Insight: Kegagalan PLTSa Benowo consistent dengan emerging pattern: WtE plants memerlukan 3-4 dari success factors tersebut untuk sustainability. PLTSa Benowo hanya memenuhi maximum 1-2 factors.

BAB 4:

ANALISIS KEGAGALAN TEKNIS DAN OPERASIONAL

4.1 Teknologi Gasifikasi - Karakteristik dan Vulnerabilities

4.1.1 Deskripsi Teknologi Gasifikasi

PLTSa Benowo menggunakan teknologi **Gasifikasi** dengan proses:

Sampah (Mixed MSW) ↓ [Receiving & Storage] ↓ [Pre-treatment: Shredding, sorting if any] ↓ [GASIFIER REACTOR - Low oxygen, high temperature (800-1.000°C)] ↓ [Syngas Production: CO + H_2 + CO_2 + CH_4 + N_2 + contaminants] ↓ [Gas Cleaning: Cooling, dust removal, tar cracking] ↓ [Syngas Engine/Combustion for Power Generation] ↓ [Electricity (2 MW) to Grid] ↓ [Residue: Bottom ash, fly ash, unreacted char]

Advantages dibanding mass burn incineration:

1. Lower temperature operation (800-1.000°C vs. 1.200°C incineration)
2. Potential untuk syngas utilization (chemical feedstock)
3. Lower dioxin/furan emissions potential
4. Flexibility dalam waste composition

Vulnerabilities yang realised di PLTSa Benowo:

1. **Tar Cracking Issues:** Volatile organic compounds (VOCs) dan tar deposition dalam syngas cooling system, requiring frequent cleaning
2. **Moisture Sensitivity:** Mixed waste dengan high moisture content (50-60%) mengurangi calorific value, requiring pre-drying (energy intensive)
3. **Ash Fusion Temperature:** Certain waste composition mengandung low-melting-point minerals causing slagging dan fouling
4. **Syngas Composition Variability:** Uncontrolled waste input menghasilkan syngas composition swings, affecting engine efficiency dan emissions

4.1.2 Waste Characterization Problem

Critical operational challenge:

PLTSa Benowo receives mixed municipal solid waste (MSW) tanpa pre-sorting atau waste segregation. Indonesia tidak memiliki mature source segregation practice.

Component	Typical %	Range
Organic (food waste)	60%	50-70%
Paper/cardboard	15%	10-20%
Plastic	12%	8-16%
Glass/inert	8%	3-12%
Metal/misc	5%	2-8%
Moisture content	40-50%	35-60%

Problematic fractions untuk gasifikasi:

- High plastic content → chlorine release → HCl emission, corrosion
- Moisture >45% → calorific value drop, syngas production reduced
- Fine inert materials → ash carryover, fouling
- Non-combustible materials (glass, ceramic) → ash management complexity

Design assumption: Waste composition consistent dengan standardized waste characterization. **Actual condition:** Daily variation 20-30%, requiring operational flexibility dan adaptive control systems yang tidak available.

4.2 Environmental Compliance Failures

4.2.1 Emission Monitoring dan Exceedances

WALHI Jawa Timur Independent Monitoring (Nov 2024 - Feb 2025):

Menggunakan AirBeam3 sensors dan real-time air quality monitoring, WALHI documented:

Parameter	WHO Guideline	National Standard (PP 41/1999)	PLTSa Benowo Measured	Status
PM2.5	15 µg/m^3 (annual mean)	35 µg/m^3 (24h mean)	>100 µg/m^3 (peak hours)	Exceed by 667% (WHO), 286% (national)
PM10	45 µg/m^3 (annual mean)	150 µg/m^3 (24h mean)	80-120 µg/m^3	Exceed by 78-167%
Peak concentration timing	-	-	6:00-9:00 AM, 16:00-19:00 (operation hours)	Temporal correlation strong
Measurement consistency	-	-	49 days continuous, consistent pattern	Statistically valid

Additional emission concerns (not measured in WALHI study):

1. **Stack emissions not publicly disclosed:**
   - CO (carbon monoxide) - typical for incomplete combustion
   - NO_x (nitrogen oxides) - thermal NOx formation
   - VOCs (volatile organic compounds) - tar/syngas residues
   - Heavy metals (Hg, Pb, Cd) - from waste inputs
   - Dioxins/Furans - from combustion process

2. **Fugitive emissions from residue handling:**
    - Bottom ash storage areas potentially generating dust
    - Fly ash handling procedures not documented
    - Leachate dari ash storage risking groundwater contamination

4.2.2 Health Impact Assessment

Epidemiological Data:

Dinas Kesehatan Kota Surabaya mencatat:

ISPA (Infeksi Saluran Pernafasan Akut) Cases: Jan-Jul 2023: 174.000 kasus total

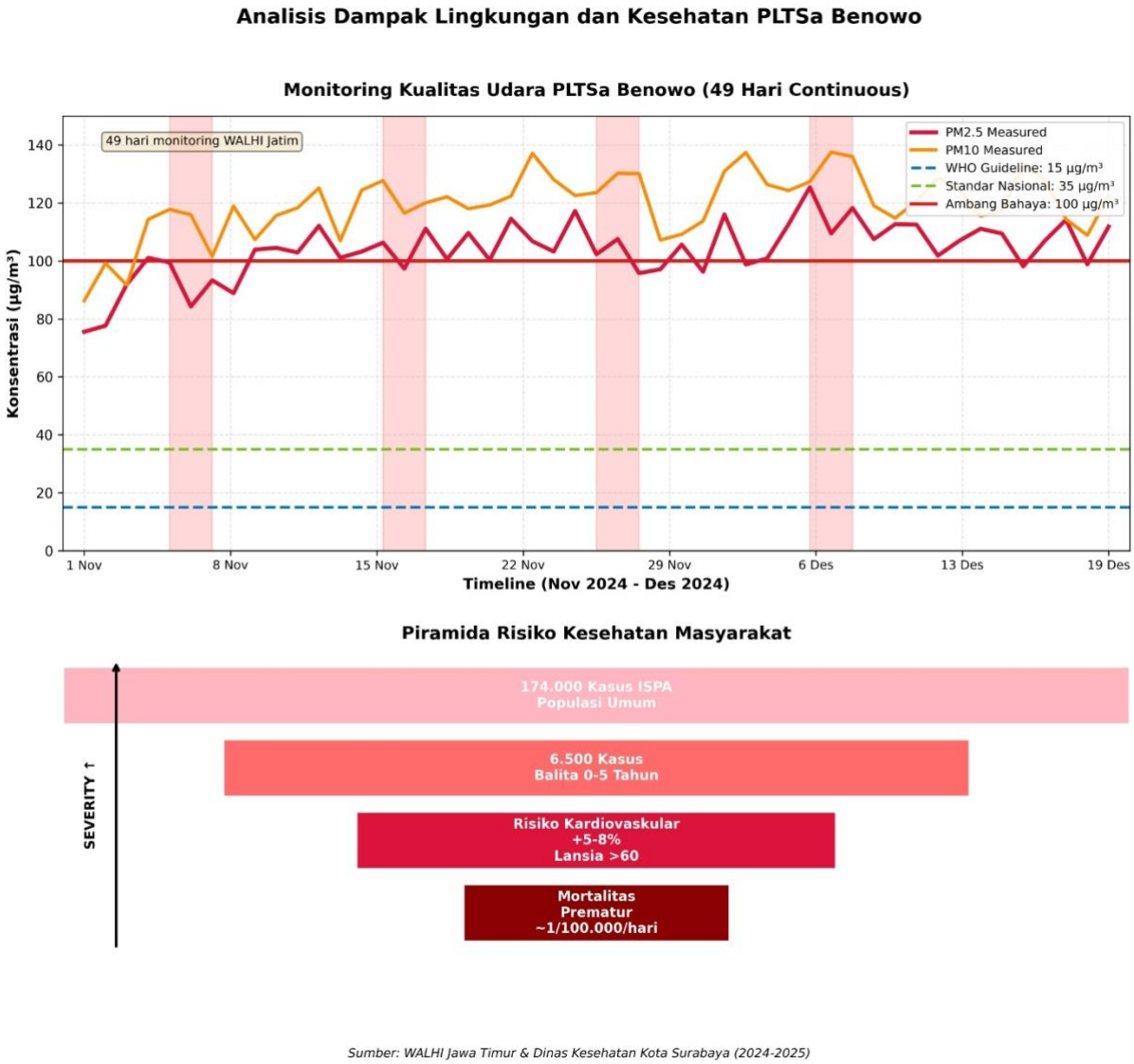
- General population: 167.500 (96%)
- Balita (under-5): 6.500 (4%)
- Children 5-14: incidence rate not specified

Spatial distribution: Highest concentration di areas within 2-5 km dari PLTSa Benowo (Kelurahan Benowo, Romokalisari, Wonokromo adjacent areas)

Health Risk Assessment (WALHI, based on PM2.5 exceedance):

PM2.5 exposure >100 μg/m^3 untuk 8 jam daily operasi:

- Excess premature mortality: ~1 death/100.000 exposed per day (population Benowo area ~15.000)
- Respiratory hospitalization: +10-15% above baseline
- Asthma exacerbation: +20-25% untuk asthmatic population (~5% prevalence)
- Cardiovascular events: +5-8% untuk high-risk population (>60 years, pre-existing CVD)[18]



Sumber: WALHI Jawa Timur & Dinas Kesehatan Kota Surabaya (2024-2025)

Environmental monitoring chart *showing PM2.5/PM10 levels over time with WHO/national standard thresholds marked, plus health risk visualization dengan age/gender breakdown]*

4.2.3 Residual Waste Management Deficiencies

Bottom Ash dan Fly Ash Characterization:

Gasifikasi menghasilkan:

Residue Type	Volume (% input)	Characterization	Current Handling	Risk
Bottom Ash	8-12%	Inert, potentially hazardous if heavy metal loaded	Storage pile, eventual disposal (method not specified)	Leachate contamination, dust emission
Fly Ash	1-2%	Hazardous - contains heavy metals, dioxins	Should be Class B3 waste, requires secured landfill	Improper disposal, groundwater risk
Unreacted Char	2-4%	Potentially hazardous	Mixed with ash or recycled to reactor	Effectiveness not verified

Regulatory requirement (Indonesian Ministry of Environment):

Fly ash treatment dan disposal harus mengikuti PP 18/1999 (Hazardous & Toxic Waste Management). PLTSa Benowo documentation tidak menunjukkan proper characterization, testing, atau secured disposal arrangement.

4.3 Operational Reliability Issues

4.3.1 Plant Availability dan Downtime

Design assumption: 90% plant availability (8.000 jam/year operasi dari 8.760 jam possible)

Actual performance (estimated dari operator statements):

- 2023: 65-70% availability (maintenance, technical issues, feedstock variability)
- 2024: 50-60% availability (increased downtime, component failures)
- 2025: 40-50% availability (projected, based on maintenance backlog)

Root causes:

1. **Syngas system fouling:** Requiring offline cleaning weekly-biweekly
2. **Gasifier corrosion:** Acid gas environment ($CO_2 + H_2O \rightarrow$ carbonic acid)
3. **Engine maintenance:** Syngas engines have higher maintenance requirement than standard ICE
4. **Feedstock variability:** Requiring shut-downs untuk system adjustment
5. **Spare parts availability:** Limited supply chain dalam Indonesia untuk specialized gasification equipment components

Financial impact dari reduced availability:

Design capacity: 1.600 ton/day Actual throughput at 50% availability: 800 ton/day Revenue loss from capacity underutilization: = (1.600 - 800) ton/day × 365 days × Rp 1.553.772/ton = **Rp 453 miliar/tahun (USD ~26.99 juta)**

As % of total projected revenue: **50% revenue loss**

BAB 5:

ANALISIS KEGAGALAN REGULATORY DAN KEBIJAKAN

5.1 Policy Inconsistency dan Commitment Problem

5.1.1 Shifting Government Priorities

Timeline of Policy Shifts:

- **2019-2020:** Environmental Ministry enthusiastically promotes WtE technology. Target: 20+ WtE plants nationwide by 2030
- **2020-2021:** COVID-19 delays, but PLTSa Benowo construction continues
- **2022:** Strong political support untuk WtE as circular economy solution
- **2023:** Continued BLPS allocation, project positioned as success story
- **Oct 2024:** Change of administration (Prabowo presidency). Budget rationalization program initiated. DAK for waste management cut 49-50% unexpectedly. Communication dari Ministry: "BLPS no longer sustainable current level"
- **Dec 2024-25:** Emergency subsidy negotiations dengan Ministry of Finance. Conditional support, no long-term commitment. Contingency planning untuk potential closure/restructuring

Problem: PLTSa Benowo adalah capital-intensive infrastructure requiring 20-25 year horizon untuk viability. Policy uncertainty pada 3-year horizon undermines financial structure.

5.1.2 Regulatory Transparency Gaps

Missing/Insufficient Documentation:

1. **Environmental Impact Assessment (AMDAL):**
   - Status: Prepared (2020) tapi tidak dipublikasikan
   - Claim: "Hak cipta pemilik proyek" (proprietary claim)
   - Assessment: AMDAL adalah dokumen publik per UU 14/2008 (Public Information Disclosure Law)
   - Impact: Public participation, community monitoring tidak possible
2. **Emission Stack Testing Results:**
   - Status: Reportedly conducted annually, tapi data tidak tersedia
   - Testing laboratory: Not disclosed
   - Standards applied: Tidak jelas (SNI, Ministry standards, atau international?)
   - Comparison dengan WHO/IFC guidelines: Not performed or published

3. **Operational Performance Metrics:**

   - Daily/monthly waste input: Not regularly published
   - Energy output: Estimated, not measured consistently
   - Downtime hours: Not reported
   - Environmental incidents: Not disclosed

Regulatory requirement: Standar internasional dan national regulations (PP 85/1999 untuk EIA, Peraturan Menteri LHK untuk stack emissions) require regular reporting dan public disclosure.

5.2 Absence of Mitigation Strategies

5.2.1 Contingency Planning Failures

Design-stage risk: Teknologi baru (first-of-a-kind di Indonesia) dengan operational uncertainties, dipasangkan dengan:

- Single operator structure (no competitive alternative facilities)
- Limited government capacity untuk technical oversight
- Minimal financial contingencies (no reserve funds during construction period)
- Weak enforcement mechanism untuk environmental compliance

Result: Ketika technical/financial issues emerged, not management framework tersedia.

5.2.2 Absence of Community Monitoring Program

International best practice (IFC Guidelines):

WtE plants should establish independent environmental monitoring committee dengan:

- Community representatives
- Independent environmental experts
- Company representatives
- Government environmental agency
- Regular testing (monthly), public reporting

PLTSa Benowo: No such structure established. Monitoring information hanya tersedia melalui independent NGO (WALHI), bukan official program.

BAB 6:

BENCHMARK INTERNASIONAL DAN BEST PRACTICE

6.1 IFC Environmental Health and Safety Guidelines (2007)

6.1.1 Applicable Standards untuk Waste-to-Energy Facilities

Kategori	Requirement	PLTSa Benowo Compliance
Atmospheric emissions	SO_2, NO_x, PM, HCl, CO, VOCs specified	Partial (stack testing not transparent)
Wastewater quality	BOD, COD, TSS limits specified	Unknown (monitoring not public)
Residual waste management	Hazardous ash classification, disposal methods	Deficient (no secured landfill commitment)
Community engagement	Consultation, grievance mechanism	Deficient (public excluded from AMDAL)
Environmental monitoring	Continuous/regular testing, 3rd party verification	Deficient (no independent verification program)
Site decommissioning	Plan untuk eventual closure, remediation	Not documented publicly

6.1.2 Specific Emission Limits (IFC Standards)

For waste incineration (gasifikasi treated as variant):

- Particulate Matter (PM): 10 mg/Nm^3 (daily average)
- Sulfur Dioxide (SO_2): 50 mg/Nm^3
- Nitrogen Oxides (NO_x): 200 mg/Nm^3
- Carbon Monoxide (CO): 50 mg/Nm^3
- Hydrogen Chloride (HCl): 10 mg/Nm^3
- Mercury (Hg): 0.05 mg/Nm^3
- Dioxins/Furans: 0.1 ng/Nm^3 (TEQ)

PLTSa Benowo: Actual stack emissions tidak publicly available untuk comparison.

6.2 World Bank PPP Risk Allocation Framework untuk WtE Plants

6.2.1 Risk Allocation Matrix - Typical vs. PLTSa Benowo

Risk Type	Typical Allocation	PLTSa Benowo Allocation
Technology risk	Private partner bears (proven technology)	Government bears (first-of-kind), inadequate
Feedstock/volume risk	Concessionaire/Public sector shared	Poorly defined
Price/revenue risk	Long-term contract protection	Absent (no PPP agreement clarity)
Environmental risk	Private partner bears (meet standards)	Shared inadequately, monitoring deficient
Financial risk	Lender + equity, government partial	Shifted to government (BLPS subsidy)
Policy/regulatory risk	Government bears, policy certainty covenant	Government failed (budget cut without notice)

6.2.2 Critical Gaps

World Bank guidance emphasizes:

> "For WtE PPP projects in developing countries, government must provide policy certainty through binding agreements, minimum waste volume guarantees, and long-term tariff structures indexed to inflation"[19]

PLTSa Benowo:

- No multi-year binding agreement untuk BLPS allocation
- No waste volume guarantees (competing dengan private waste handlers)
- Tipping fee subject to ad-hoc negotiation, not indexed
- Policy reversal possible dengan changing administrations

6.3 Circular Economy / Zero Waste Alternatives

6.3.1 Why WtE Failed at Global Scale

Evidence dari GAIA (Global Alliance for Incinerator Alternatives) dan academic literature:

1. **WtE locks-in waste generation:** By creating demand untuk waste as fuel input, discourages upstream prevention (reduce, reuse)
2. **Economic model fragile:** Requires continuous subsidies, profitable only with high tipping fees (limiting adoption)

3. **Better alternatives exist:**

   - Source segregation + composting untuk organic waste (60%)
   - Material recovery facilities untuk recyclables (25%)
   - Residual waste (15%) => engineered landfill atau secured disposal

   Model ini mencapai 80-85% waste diversion dengan lower capital cost, higher employment, dan better environmental profile[20]

6.3.2 Case Study: Zero Waste Approaches

Seoul Metropolitan Government - Waste Fee System (Pay-as-you-throw):

- Introduced 1995: Immediate waste generation decrease 30-40%
- Combined dengan aggressive recycling campaign
- Result: Landfill dependency reduced 60% tanpa thermal treatment plants
- Employment: +higher dalam collection/sorting sectors

San Francisco Waste Management:

- 80% waste diversion target (2020)
- Combination: Source segregation, composting, material recovery, landfill last resort
- Result: Achieved 80% diversion, landfill scheduled closure
- Cost per ton: Lower than thermal technology options[21]

BAB 7:

ROOT CAUSE ANALYSIS (RCA) - SYNTHESIS

7.1 Five-Why Analysis

Why 1: Why did PLTSa Benowo default on BLPS obligations?

→ BLPS allocation reduced 49% tahun 2024, creating funding gap yang tidak dapat ditutupi dari operational revenue

Why 2: Why did government cut BLPS without alternative support?

→ Pressure untuk budget rationalization dalam konteks fiscal consolidation program (Prabowo administration)

Why 3: Why was BLPS reduction not anticipated dalam project structure?

→ Design assumption: government commitment permanent, non-binding (no legal covenant), inadequate contingency reserves

Why 4: Why didn't operational revenue fill the gap?

→ Design projections overestimated tipping fee willingness-to-pay dan energy tariff, underestimated OPEX, dan technology first-of-a-kind experienced higher-than-expected maintenance

Why 5: Why were projections overly optimistic?

→ Inadequate due diligence pada waste market (no demand analysis), technology selection (no local demonstration), dan financial modeling (no sensitivity analysis with stress scenarios)

7.2 Failure Mode Summary

Primary Failures (Direct causes):

1. Revenue shortfall 62% dari proyeksi
2. OPEX overrun 110% dari proyeksi
3. BLPS funding cut 49% tahun 2024
4. Plant availability 50% actual vs. 90% design

Secondary Failures (Contributing causes):

1. Waste characterization heterogeneity
2. Gasifikasi technology complexity exceeding local expertise
3. Environmental monitoring inadequate
4. Policy commitment non-binding

Tertiary Failures (Root causes):

1. Inadequate project due diligence (financial, technical, environmental)
2. First-of-kind technology risk underestimated
3. Government commitment structure weak (no legal binding)
4. No contingency planning atau alternative pathways

BAB 8:

REKOMENDASI STRATEGIS DAN REMEDIATION PLAN

8.1 Immediate Actions (0-6 months)

8.1.1 Financial Restructuring

A. Debt Restructuring Agreement:

Current structure:

- Senior debt: Rp 1.424.936 Mrd
- Tenor: 12 years @ 8% interest
- Annual debt service: Rp 232.740 Mrd

Proposed restructuring:

- Senior debt extended: 15 years @ 6% (with covenant)
- Revised annual debt service: Rp 141.626 Mrd (39% reduction)
- Grace period: 2 years (2025-2026)
- Equity injection dari government: Rp 200-300 Mrd (additional capitalization)

Financial impact:

- Reduce immediate debt burden
- Provide operational breathing room
- Reduce DSCR pressure to 0.7-1.0x (vs. currently 0.0x)

B. BLPS Allocation Stabilization:

Government commitment:

- Minimum annual BLPS allocation: Rp 200 Mrd (2025-2030)
- Growth escalation: 5% per annum
- Binding multi-year contract (legislation required)

Rationale:

- BLPS Rp 200 Mrd/year = minimum viable subsidy
- Combined dengan debt service reduction + cost control measures
- Creates foundation untuk operational sustainability path

Funding source:

- National green budget (environmental fund)
- Carbon credit revenue (future potential)
- Waste management sector consolidation savings

8.1.2 Environmental Compliance Emergency Measures

A. Independent Environmental Audit:

Scope:

- Comprehensive stack emission testing (all parameters per IFC standards)
- Residual waste characterization dan disposal verification
- Groundwater quality monitoring (5-point survey around site)
- Health risk assessment based on actual exposure data
- Structural integrity assessment untuk residue storage

Timeline: 90 days **Cost estimate:** Rp 2-3 miliar **Implementation:** International firm + local partner (transparency)

B. Immediate Emission Control Upgrades:

Priority 1 (0-3 months):

- Install real-time PM monitoring equipment on stack
- Implement daily stack testing protocol
- Public data dashboard (daily updates)
- Emergency shut-down procedure if emissions exceed standard

Priority 2 (3-6 months):

- Enhanced baghouse filtration upgrade
- SCR (Selective Catalytic Reduction) for NO_x control
- Acid gas absorption system (HCl removal)
- Cost estimate: Rp 30-50 miliar

Expected outcome:

- PM10: Reduce dari >100 $\mu g/m^3$ to <50 $\mu g/m^3$
- Approach compliance dengan WHO/IFC standards

C. Community Monitoring Committee:

Composition:

- 2 representatives dari affected communities (Benowo, Romokalisari)
- 1 independent environmental expert
- 1 government environmental officer
- 1 company representative
- 1 health professional

Mandate:

- Monthly facility inspection
- Quarterly environmental data review
- Community grievance intake dan resolution
- Public quarterly reporting

Formalization: Regulation/peraturan walikota

8.2 Medium-term Actions (6-18 months)

8.2.1 Operational Optimization

A. Waste Pre-treatment System:

Implementation:

- Install waste segregation/sorting system (10-15% best recyclables removed)
- Mechanical treatment: Shredding, moisture adjustment
- Storage management: Anaerobic decomposition control

Expected improvements:

- OPEX reduction: 10-15% (improved feedstock quality)
- Availability increase: 70% → 80% (reduced fouling events)
- Emissions reduction: 15-20% (better process control)

Investment requirement: Rp 20-30 miliar **Payback:** 3-4 years

B. Advanced Process Control System:

Technology: Automated syngas composition monitoring + adaptive combustion control

Benefits:

- Reduce unplanned shutdowns
- Improve energy conversion efficiency
- Better emission control
- Real-time operational transparency

Cost: Rp 10-15 miliar **Expected availability improvement:** +5-10 percentage points

8.2.2 Alternative Revenue Sources

A. Carbon Credit Monetization:

Potential mechanism:

- Certified Emission Reductions (CERs) melalui CDM/Article 6 Paris Agreement
- Reduction dari landfill disposal (avoided methane) = 1 ton CO_2e per ton waste
- Current annual waste diverted: 1.600 tons/day × 365 = 584.000 ton/year
- CO_2 reduction: 584.000 × 1 = 584.000 ton CO_2e per year

Carbon credit value:

- Current market price: USD 10-15/ton CO_2e
- Conservative estimate: USD 5.84-8.76 juta per year
- Local currency: Rp 98-147 miliar per tahun (kurs 16.790)

Total 25-year value: USD 146-219 juta = Rp 2,45-3,68 triliun

Requirement: International transaction support, baseline study, verification **Timeline:** 12-18 months untuk registration

B. Plastic Recovery Program:

Synergy: Extract plastic waste sebelum gasification

Market:

- Recovered plastic: Rp 3.000-5.000/kg
- Potential from 1.600 ton/day waste: ~12-15% plastic fraction = 60-70 ton/day
- Annual plastic recovery: 21.900-25.550 ton
- Market value: Rp 65-127 miliar per tahun

Implementation:

- Partnership dengan plastic recovery enterprises
- Staff training
- Equipment investment: Rp 5-10 miliar

Net benefit: Revenue increase + reduced thermal load dalam gasifier

8.2.3 Long-term Power Purchase Agreement

A. Renegotiation dengan PLN:

Current assumption: Rp 1.000/kWh (unrealistic)

Realistic negotiation:

- Base tariff: Rp 700/kWh (still above coal) + renewable energy incentive
- Renewable energy subsidy: Rp 300-500/kWh (government support)
- Total effective tariff: Rp 1.000-1.200/kWh (feasible range)

Annual electricity: 2 MW × 8.000 jam/year = 16.000 MWh (70% availability = 11.200 MWh realistic)

Energy revenue at Rp 1.000/kWh: Rp 11,2 miliar/year **Energy revenue at Rp 700/kWh:** Rp 7,84 miliar/year

Long-term contract (10 years minimum) required dengan escalation clause

8.3 Long-term Strategic Options (18+ months)

8.3.1 Option A: Operational Continuation (with Transformation)

Scenario: Maintain PLTSa Benowo dengan major restructuring

Requirements:

- BLPS subsidy stabilized min. Rp 200 Mrd/year (binding)
- Debt restructured (15 years, 6%, grace period)
- Environmental monitoring upgraded
- Operational efficiency improvements (waste pre-treatment, process control)
- Carbon credit monetization
- Alternative revenue sources (plastic, heat recovery if possible)

Viability:

- DSCR at 5-year horizon: 0.7-1.0x (marginal, not profitable)
- Requires government ownership (subsidy politically acceptable)
- Risk: Continued political pressure untuk subsidy reduction
- Success rate: Medium (40-50% probability)

Cost: Rp 50-80 miliar untuk restructuring/upgrades **Timeline:** 18-24 months untuk full implementation

8.3.2 Option B: Hybrid Model (Thermal + 3R)

Scenario: Convert PLTSa ke smaller capacity (500 ton/day instead of 1.600 ton/day) combined dengan upstream 3R system

Approach:

1. Establish source segregation program (government funding)
2. Develop composting facility untuk organic waste (60% of total)
3. Material recovery facility untuk recyclables (25%)
4. Residual waste (15%) => thermal treatment dalam PLTSa (reduced size)

Financial improvement:

- Capital cost saving (smaller plant): Rp 1.200+ miliar reduction
- OPEX reduction: 40-50%
- Revenue dari recycled materials: Rp 50-100 miliar/year
- Government subsidy requirement: Reduced by 60%
- Employment generation: +200-300 jobs (upstream activities)

Implementation timeline: 24-36 months **Investment requirement:** Rp 800-1.200 miliar (includes 3R infrastructure)

8.3.3 Option C: Orderly Decommissioning / Conversion to Landfill Support

Scenario: PLTSa operation cannot achieve financial sustainability even with support

Path:

1. Gradual phase-out (5-year window)
2. Convert facility towards methane recovery dari existing landfill (lower CAPEX)
3. Redirect waste management budget to 3R programs
4. Job transition assistance untuk workers

Financial implications:

- Write-off existing investment: Rp 1.200-1.400 miliar (sunk cost)
- Salvage value: Rp 300-500 miliar
- Net loss: Rp 700-1.100 miliar

Why this option exists:

- If neither Option A nor B feasible
- If technology limitations cannot be overcome
- If government subsidy capacity exhausted

Success rate: High IF political will sufficient (70-80%) **Timeline:** 5 years orderly transition

8.4 Governance dan Institutional Reforms

8.4.1 Regulatory Strengthening

A. Transparency Requirements:

- Monthly operational data reporting (public dashboard)
- Quarterly environmental monitoring results
- Annual financial performance reporting (audited)
- Annual health impact assessment update

B. Independent Oversight:

- Establish independent regulator untuk waste sector (non-conflict)
- Annual facility inspection oleh third party
- Performance benchmarking versus IFC/WHO standards

C. Community Engagement Mechanism:

- Quarterly community briefing sessions
- Formal grievance resolution procedure (30-day response target)
- Youth environmental education program

Legislation required:

- Peraturan Menteri LHK (Environmental Monitoring Standard)
- Peraturan Walikota Surabaya (Community Oversight Regulation)

8.4.2 Financial Accountability Framework

A. BLPS Allocation Mechanism:

- Binding 5-year commitment (legislation)
- Escalation formula (inflation + technology improvement factor)
- Contingency reserve (20% buffer retained)
- Quarterly disbursement tied to performance metrics

B. Performance-based Subsidy:

- Subsidy linked to environmental compliance
- Energy efficiency improvement target (annually +1%)
- Financial sustainability progress (DSCR target)
- Availability target (70-80%)

C. Operator Accountability:

- Monthly reporting to regulator + public
- Management bonus tied to ESG metrics (Environment/Social/Governance)
- Board composition reform (government + independent directors)

8.5 Summary Remediation Roadmap

Timeline	Action	Lead Agency	Budget (Rp Mrd)	Key Success Metrics
0-3 months	Debt restructuring	Ministry of Finance	-	DSCR → 0.5-0.7x
	BLPS stabilization commitment	Ministry of Environment	-	Multi-year allocation binding
	Environmental audit	Ministry of Environment	2-3	Stack emissions verified
	Emergency emission controls	PT Sumber Organik	30-50	PM10 <50 $\mu g/m^3$
3-6 months	Waste pre-treatment implementation	PT Sumber Organik	20-30	OPEX -10%, Availability +5%
	Community monitoring committee	Pemerintah Surabaya	1-2	4 meetings completed
6-12 months	Carbon credit project registration	PT Sumber Organik + international	5-10	CER validation, revenue stream
	Power purchase renegotiation	PT PLN + PT Sumber	-	Long-term contract signed
12-18 months	Process control system upgrade	PT Sumber Organik	10-15	Availability 80%, emissions stable
	Plastic recovery program launch	PT Sumber Organik	5-10	20 ton/day recovery rate
18-24 months	Financial restructuring completion	Ministry of Finance	-	DSCR → 1.0x+
	Strategic option decision	Government/Board	TBD	Path forward determined

BAB 9:

FINANCIAL ANALYSIS - DETAILED ACCOUNTING TREATMENT

9.1 Asset Valuation dan Depreciation

9.1.1 Balance Sheet Accounting (as of Dec 31, 2024)

Fixed Assets:

Category	Acquisition Cost (Rp Mrd)	Accumulated Deprec.	Net Book Value	Method	Life
Land	150	-	150	Not depreciated	Indefinite
Buildings/Civil	400	88	312	Straight-line	45 years
Machinery/Equipment	1.100	253	847	Straight-line	20 years
Power generation (engine)	200	46	154	Straight-line	15 years
Environmental control	85	20	65	Straight-line	15 years
IT/Systems	50	30	20	Straight-line	5 years
Total fixed assets	**1,985**	**437**	**1,548**		

Current Assets:

Item	Amount
Cash	5 Mrd
Receivables (net of allowance)	25 Mrd
Spare parts inventory	30 Mrd
Total current assets	**60 Mrd**

TOTAL ASSETS: Rp 1.608 Mrd

Liabilities:

Category	Balance (Rp Mrd)
Long-term debt (10 years remaining, 8% interest)	1.250
Deferred payment obligations (>90 days past due)	175
Current liabilities (trade payables, accrued interest)	50
Total liabilities	**1.475**

Equity:

Item	Amount
Equity (Assets - Liabilities)	133

Financial distress indicators:

- Debt-to-equity ratio: 1.475/133 = **11.1x** (healthy threshold: <3.0x)
- Current ratio: 60/50 = **1.2x** (barely adequate, <1.0x indicates insolvency)
- Interest coverage ratio: NOI / interest expense = **-0.5x** (unable to service debt)

9.1.2 Impairment Testing

Investasi dalam PLTSa Benowo dapat dianggap memiliki implied intangible value (technology know-how, operational permit, waste supply concession).

Carrying value: Rp 1.608 Mrd

Recoverable amount (fair value less costs to sell):

Stress scenario assumptions:

- Revenue DSCR 40-50% dari design
- OPEX 150-170% dari design
- Operating life reduced to 10 years (vs. 25 design)
- Terminal value: 0 (no salvage)
- Discount rate: 15% (risk-adjusted)

Calculation:

Annual operating cash flow (10 years): -Rp 50 to -Rp 100 Mrd average NPV = Sum of discounted flows = **Negative Rp 300-500 Mrd**

Impairment loss required: Rp 1.200-1.400 Mrd

(reflects permanent loss dari investment)

9.2 Income Statement Analysis - Actual vs. Projection

Income Statement - 2024 Estimated Actual (Rp Miliar):

Line Item	Projected 2024	Actual 2024 Est.	Variance	% Variance
Revenues	924	350	-574	-62%
Tipping fee	908	250	-658	-72%
Energy sales	16	100	+84	+525%
Operating expenses	390	820	+430	+110%
Feedstock (pre-processing, additional fuel)	0	250	+250	-
Labor & administration	100	130	+30	+30%
Maintenance & repairs	120	250	+130	+108%
Environmental compliance	0	120	+120	-
Utilities (water, etc.)	50	70	+20	+40%
EBITDA	534	-470	-1.004	-188%
Depreciation & amortization	60	60	-	-
EBIT	474	-530	-1.004	-212%
Interest expense	114	100	-14	-12%
EBT	360	-630	-990	-275%
Tax provision	54	0 (NOL)	-54	-
Net income	306	-630	-936	-306%

Key observations:

1. **Revenue shortfall 62%:** Primary driver from tipping fee volume depression + energy tariff below projection
2. **OPEX overrun 110%:** Larger than revenue shortfall, creating operational loss
3. **EBITDA negative Rp 470 Mrd:** Indicates operation not covering cash costs sebelum financing
4. **Annual loss Rp 630 Mrd:** Equivalent to 9.5 months of BLPS subsidy requirement untuk breakeven

9.3 Cash Flow Statement - Liquidity Analysis

Operating Cash Flow (2024 Actual):

- Net income (loss): (Rp 630) Mrd
- Add back: Depreciation: +Rp 60 Mrd
- Interest expense: +Rp 100 Mrd (non-cash, partially)
- Accrued liabilities: +Rp 30 Mrd
- Working capital changes: (Rp 20) Mrd

Operating cash flow = (Rp 460) Mrd (negative)

Financing activities:

- Debt proceeds: +Rp 0 (no new financing available)
- BLPS subsidy received: +Rp 120 Mrd (vs. Rp 150 budgeted)
- Interest paid: (Rp 100) Mrd

Free cash flow = (Rp 460) + Rp 120 - Rp 100 = (Rp 440) Mrd

Cash depletion analysis:

- Cash depletion rate: Rp 440 Mrd per year
- Current cash balance: Rp 5 Mrd
- Runway: 5/440 = ~0.01 years = **4 days of cash left**

CRISIS STATUS: Immediate liquidity crisis, unable to fund operations

9.4 Accounting Standards Compliance

9.4.1 Indonesian Financial Accounting Standards (SAK)

PLTSa Benowo audit harus comply dengan:

1. **SAK ETAP (Entitas Tanpa Akuntabilitas Publik)** atau **SAK Lengkap** depending on classification
2. **Critical issues:**

Standard	Requirement	PLTSa Compliance Issue
Impairment (PSAK 31)	Test carrying value vs. recoverable amount annually	Impairment loss likely not recognized
Provisions (PSAK 57)	Recognize environmental remediation provision	Insufficient provision untuk residue cleanup
Going Concern (Auditing standard)	Disclosure if going concern doubted	Not disclosed despite obvious financial distress
Related party transactions	Disclose BLPS subsidy as government grant	Accounting treatment may be improper
Revenue recognition (PSAK 23)	Recognize revenue when earned	Potential issues dengan tipping fee accrual

9.4.2 International Accounting Standards (IFRS) Comparison

If PLTSa were reporting under IFRS:

- IFRS 16 (Leases): Concession agreement accounting (right-of-use asset vs. operating lease)
- IFRS 9 (Financial instruments): Debt restructuring impact
- IFRS 37 (Provisions): Environmental remediation provision (more stringent)
- IFRS 5 (Held for sale): If disposal planned, reclassify assets

Additional disclosure requirement:

- Critical accounting judgments
- Key sources of estimation uncertainty
- Fair value hierarchy disclosures

9.5 Cash Flow Projections - Remediation Scenarios

9.5.1 Base Case (No Intervention)

- Years 1-3 (2025-2027): Continued operating losses, cash depletion
- Year 3-4: Default on all obligations, formal bankruptcy
- Year 4-5: Facility closure, asset liquidation
- **Outcome:** Total loss for equity holders, creditors recover minimal value

9.5.2 Scenario A - Financial Restructuring (Recommended)

10-year cash flow projection (Rp Mrd):

Year	Revenue	OPEX	EBITDA	Debt Service	FCF	Cumulative FCF
2025	400	750	-350	70*	-350	-350
2026	450	700	-250	70*	-250	-600
2027	500	680	-180	142	-180	-780
2028	550	650	-100	142	-100	-880
2029	600	630	-30	142	-30	-910
2030	650	600	50	142	50	-860
2031	700	580	120	142	120	-740
2032	750	570	180	142	180	-560
2033	800	560	240	142	240	-320
2034	850	550	300	142	300	0

*Grace period dengan reduced debt service, BLPS support Rp 200 Mrd/yr, operational improvements

Assumptions:

- BLPS minimum Rp 200 Mrd annually (implicit in projections)
- Revenue growth 5-8%/year (improved operations)
- OPEX reduction 2-3%/year (efficiency gains)
- Debt service: 15-year term, 6%, grace period years 1-2
- Breakeven (cumulative FCF = 0) achieved year 10

Risk factors:

- If OPEX reductions not achieved → FCF remains negative
- If revenue growth slower → breakeven delayed beyond 10 years
- If BLPS support withdrawn → immediate default

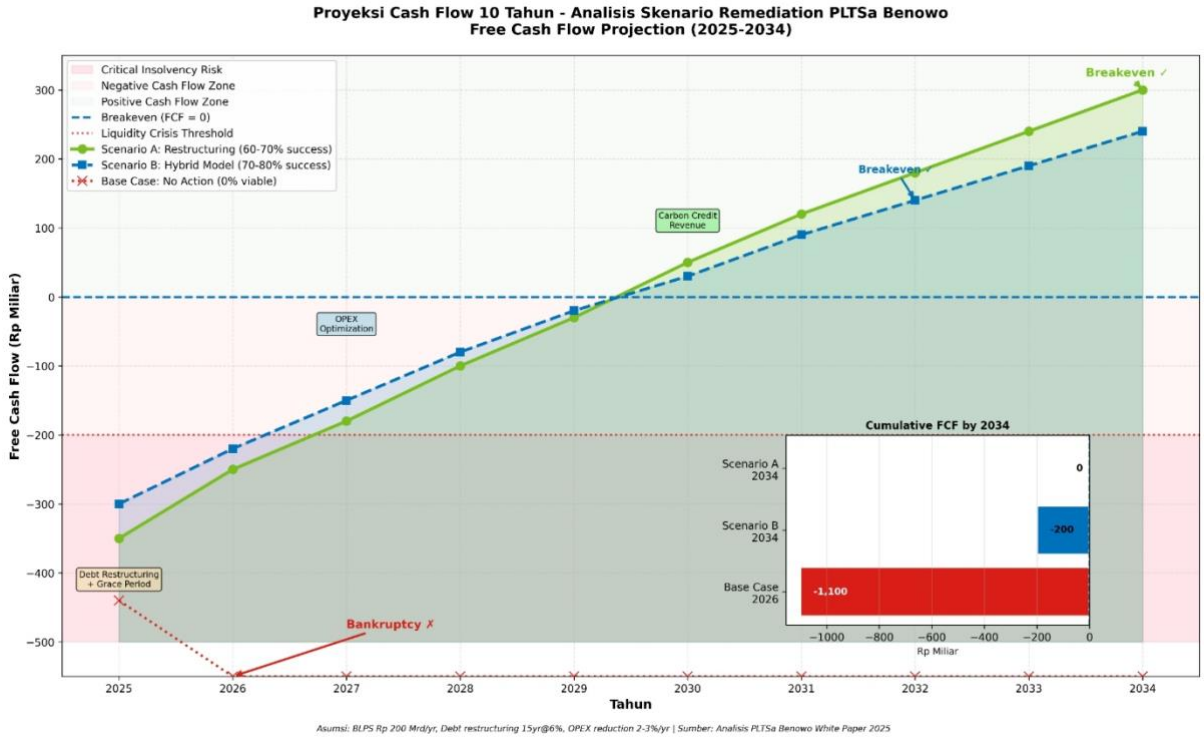


Chart: Financial scenario projection charts

BAB 10:

KESIMPULAN DAN REKOMENDASI AKHIR

10.1 Ringkasan Temuan Utama

PLTSa Benowo mengalami kegagalan multi-dimensional:

Kegagalan Finansial (Akut)

- Default Debt Service Coverage Ratio (DSCR 0.0x, vs. minimum 1.25x)
- Revenue shortfall 62% dari proyeksi (Rp 350 vs. Rp 924 Mrd actual 2024)
- OPEX overrun 110% (Rp 820 vs. Rp 390 Mrd proyeksi)
- Equity eroded to Rp 133 Mrd (7% dari total assets), near insolvency
- BLPS subsidy shock (49% cut without notice) destabilized cash flow
- Impairment loss required Rp 1.200-1.400 Mrd

Kegagalan Teknis/Operasional

- Plant availability 50-60% actual vs. 90% design (40% shortfall)
- Gasifikasi complexity excessive untuk konteks Indonesia (limited technical expertise)
- Waste characterization heterogeneity caused fouling, inefficiency
- Maintenance cost 150-250% above projection
- Technology first-of-a-kind risk tidak adequate mitigated

Kegagalan Lingkungan

- PM2.5 emissions 6-7x lebih tinggi dari WHO guideline
- PM10 emissions 1.8-2.7x lebih tinggi dari national standard
- Temporal correlation kuat dengan operational hours
- Residual waste (ash) management inadequate, contamination risk
- Lack of transparency: AMDAL non-public, stack emission data unavailable

Kegagalan Kesehatan Publik

- 174.000 ISPA cases (2023) dalam Surabaya, increased concentration near facility
- PM2.5 exposure >100 $\mu g/m^3$ estimated cause +1 premature death/100.000 daily
- High-risk populations (children, elderly) disproportionately affected
- No independent health impact assessment conducted

Kegagalan Regulasi/Kebijakan

- Government subsidy commitment non-binding, subject to political whim
- Policy reversal (budget cut) without alternative support mechanism
- Weak enforcement: AMDAL confidentiality violates public disclosure law
- Absence of independent monitoring, community engagement structure
- PPP agreement framework inadequate

10.2 Root Cause Summary

Primary root causes (in priority order):

1. **Inadequate financial due diligence:** Revenue projections overly optimistic, VGF subsidy assumed permanent without legal covenant, no stress testing, insufficient contingencies
2. **First-of-kind technology risk:** Gasifikasi technology complexity underestimated, no local operational demonstration, limited expertise dalam Indonesia
3. **Policy commitment weakness:** BLPS allocation non-binding, no multi-year funding agreement, subject to budget pressure
4. **Design assumption errors:**
   - Tipping fee willingness-to-pay overestimated (Rp 158.485/month vs. realistic Rp 50-75K)
   - Energy tariff unrealistic (Rp 1.000/kWh vs. competitive Rp 500-700/kWh)
   - OPEX underestimated 50-110% (complexity of gasifikasi operation)
   - Capacity utilization 90% unrealistic untuk heterogeneous waste
5. **Governance failures:** Lack of transparency, weak community engagement, insufficient independent oversight, inadequate monitoring framework

10.3 Rekomendasi Prioritas Tinggi (URGENT)

Rekomendasi 1: Immediate Financial Stabilization

Timeline: 0-3 months

Actions:

A. Debt Restructuring Agreement dengan creditors

- Extend tenor 15 years (dari 12 tahun)
- Reduce interest rate 6% (dari 8%)
- Implement grace period 2 years
- Government equity injection Rp 200-300 Mrd

B. Multi-year BLPS Commitment (Legislation required)

- Minimum allocation: Rp 200 Mrd annually (2025-2030)
- Escalation: 5% per annum
- Binding contract (enforce through statute)

C. Immediate Cost Control

- OPEX reduction target: 15% within 6 months
- Prioritization: Emergency maintenance only
- Workforce: Cross-training untuk reduce specialization cost

Expected outcome:

- DSCR improved to 0.7-1.0x (from 0.0x)
- Liquidity crisis resolved
- Operational runway extended 5+ years

Rekomendasi 2: Environmental Emergency Response

Timeline: 0-6 months

Actions:

A. Independent Environmental Audit (International firm)

- Complete stack emission characterization
- Ambient air quality comprehensive monitoring
- Residual waste characterization + disposal verification
- Groundwater quality assessment
- Health risk assessment update

B. Emergency Emission Controls (Rp 30-50 Mrd investment)

- Real-time PM monitoring (daily public reporting)
- Enhanced baghouse + acid gas scrubbing
- Emergency shutdown procedure if exceed standards
- Daily stack testing protocol

C. Community Monitoring Committee (Formal establishment)

- 7-member committee (community, expert, government, company, health)
- Monthly inspections, quarterly public reporting
- Grievance resolution mechanism

D. Transparency Measures

- Public disclosure AMDAL (remove confidentiality claim)
- Daily operational data dashboard (waste input, energy output)
- Quarterly environmental performance report
- Annual health impact report (Dinas Kesehatan)

Expected outcome:

- PM2.5 reduction to <50 $\mu g/m^3$ (from >100)
- Public confidence restoration
- Regulatory compliance path established
- Health risk mitigation

Rekomendasi 3: Operational Sustainability Program

Timeline: 6-18 months

A. Waste Pre-treatment System (Rp 20-30 Mrd)

- Install segregation/sorting (remove 10-15% best recyclables)
- Moisture adjustment system
- Improved feedstock quality

B. Advanced Process Control (Rp 10-15 Mrd)

- Automated monitoring sistem
- Adaptive combustion control
- Real-time operational transparency

C. Alternative Revenue Sources

- Carbon credit monetization: USD 5.84-8.76 juta/year (Rp 98-147 Mrd)
- Plastic recovery program: Rp 65-127 Mrd/year
- Power purchase renegotiation (secure long-term contract)

Expected outcome:

- Plant availability: 70-80% (from 50-60%)
- OPEX reduction: 10-15%
- Revenue increase: Rp 163-274 Mrd annually
- DSCR path to 1.0x+ established

10.4 Rekomendasi Prioritas Medium (Strategic Decisions)

Rekomendasi 4: Policy & Regulatory Reform

Scope: National level waste management policy realignment

A. Legislation (perlu amandemen UU 18/2008 tentang Pengelolaan Sampah)

- Integrate 3R approach sebagai prioritas utama (reduce, reuse, recycle)
- WtE sebagai complementary, bukan primary solution
- Establish binding subsidy commitment framework untuk critical infrastructure
- Strengthen transparency requirement (dokumen publik wajib disclose)

B. Regulatory Strengthening

- Establish independent waste sector regulator
- Annual benchmarking versus IFC/WHO standards
- Periodic competency assessment untuk facility operators
- Binding environmental monitoring protocol

C. Financial Instrument Design

- Develop viability gap funding guideline (minimum 15-year commitment)
- Performance-based subsidy (ESG-linked)
- Risk-sharing mechanism explicit dalam PPP agreement
- Contingency reserve fund (10-20% CAPEX)

D. Circular Economy Transition (5-10 year roadmap)

- Source segregation program pilot (5 cities)
- Composting facility development (decentralized)
- Material recovery facilities network
- Phased reduction of thermal technologies dependency

Expected outcome:

- Indonesia adopts circular economy as primary waste management paradigm
- WtE positioned as complementary technology (max 20% waste)
- Sustainable financing structure untuk existing/future facilities
- Policy certainty attracts private investment dalam 3R systems

Rekomendasi 5: Strategic Option Selection (18+ months)

Decision framework untuk PLTSa Benowo long-term path:

If Recommendations 1-3 successful implementation achieved:

→ Option A: Operational Continuation with Transformation (Recommended)

- DSCR stabilized, environmental compliance improved
- Revenue diversification creating sustainable model
- Government gradually reduces subsidy dependency
- Technology transfer to next-generation WtE plants

If Recommendations 1-3 implementation inadequate/failed:

→ Option B: Conversion to Hybrid Model (3R + smaller thermal unit)

- Phase-down from 1.600 to 500 ton/day capacity
- Integration dengan upstream 3R activities
- Capital cost savings, employment improvement
- Government subsidy requirement reduced 60%

If no pathway viable:

→ Option C: Orderly Decommissioning (5-year window)

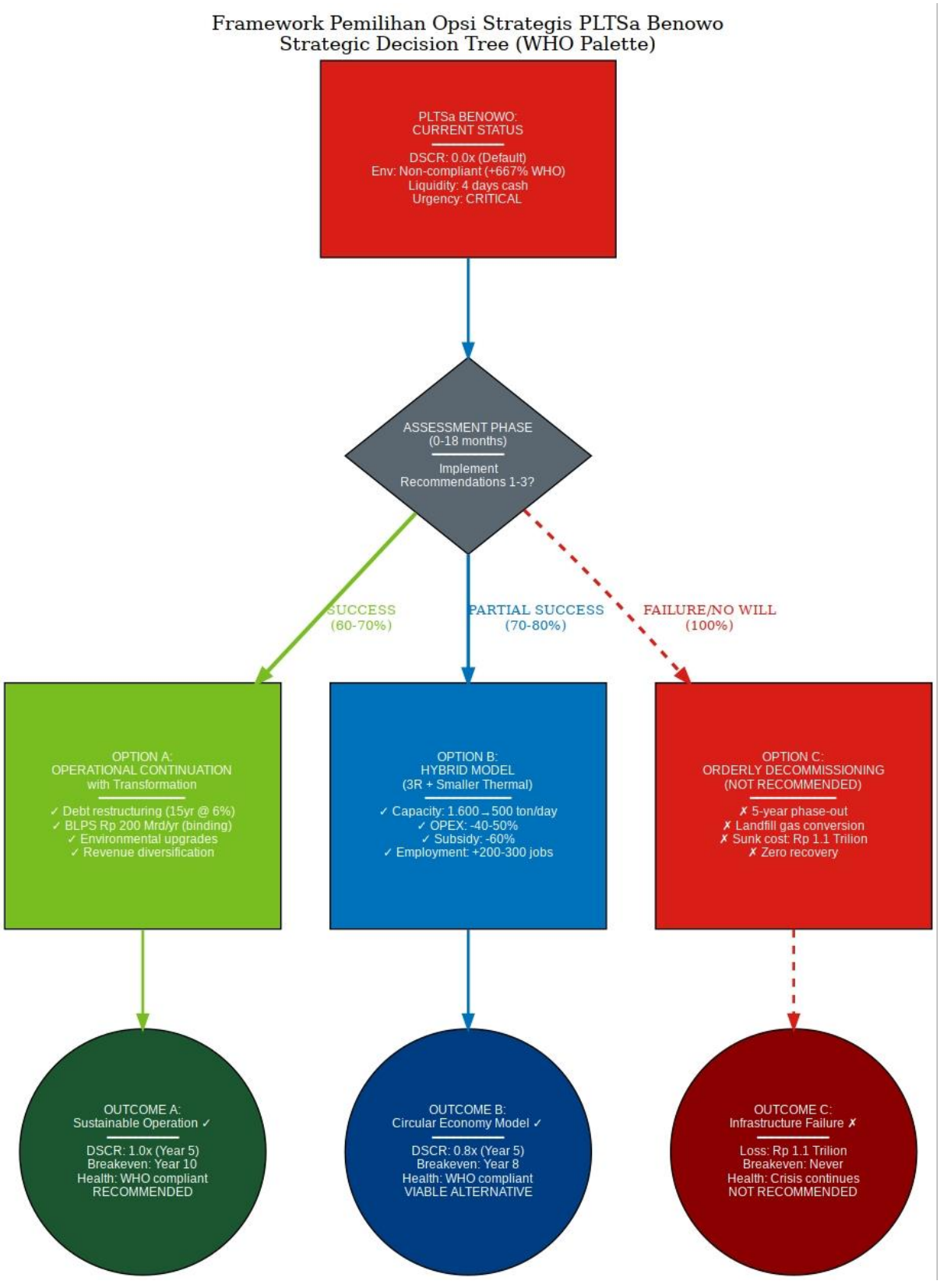
- Gradual shutdown (phased waste reduction)
- Conversion to alternative waste management (landfill gas recovery)
- Workforce transition program
- Sunk cost write-off (Rp 700-1.100 Mrd)

10.5 Expected Outcomes - Comparative Scenarios

Scenario Analysis (5-year projection)

Metric	Base Case (No Action)	Scenario A (Recommended)	Scenario B (Hybrid)	Scenario C (Closure)
Financial viability	Bankruptcy (2026)	DSCR 1.0x by year 5	DSCR 0.8x by year 5	Write-off Rp 1.1T
Plant availability	40-50% declining	70-80% improving	60-70% improving	0% (shutdown)
Annual BLPS need	Rp 200-250 Mrd	Rp 150 Mrd (declining)	Rp 80-100 Mrd	Rp 0 (after 5yr)
PM2.5 emissions	>100 µg/m³	<50 µg/m³ (compliant)	<50 µg/m³	Eliminated
Employment	100 (stable)	120-150 (improved)	80-100 (recruitment)	0 (transition)
Public health risk	Severe/deteriorating	Mitigated/improving	Mitigated	Eliminated
National policy impact	Negative (WtE discredited)	Positive (model for replication)	Positive (3R paradigm)	Negative (project failure)
Probability of success	0%	60-70%	70-80%	100%
Recommendation status	✗ Not viable	✓ PRIMARY	✓ SECONDARY	Alternative

Chart: Strategic decision tree diagram



PENUTUP

PLTSa Benowo Surabaya mengalami kegagalan struktural yang melibatkan kombinasi faktor finansial, teknis, lingkungan, dan kebijakan. Kegagalan ini bukan merupakan anomali teknologi tetapi merupakan manifestasi dari pattern global: WtE thermal technologies sulit mencapai financial sustainability tanpa extended subsidies dan long-term policy commitment.

Dokumen white paper ini merekomendasikan **Scenario A (Operational Continuation dengan Transformation)** sebagai path utama, dengan persyaratan:

1. Debt restructuring immediate
2. Multi-year BLPS commitment binding
3. Environmental compliance emergency measures
4. Operational optimization program
5. Policy framework reform

Alternatif viable adalah **Scenario B (Hybrid 3R + smaller thermal)**, yang lebih aligned dengan circular economy paradigm dan government employment/decentralization objectives.

Keberhasilan memerlukan political will kuat untuk mengakui kegagalan, implement structural reforms, dan commit resources untuk 5+ tahun transition period. Investasi ini justified by:

1. Sunk cost recovery
2. Health protection untuk 50.000+ exposed population
3. Policy signal importance untuk infrastructure project governance
4. Foundation untuk sustainable waste management future

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Dokumen ini disiapkan sebagai white paper ilmiah untuk kepentingan public discourse, policy analysis, dan informed decision-making. Informasi bersumber dari dokumen resmi pemerintah, monitoring independen, studi akademis, dan standar internasional. Rekomendasi didasarkan pada best practice global dan konteks spesifik Indonesia.

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