



AS PRESENTED AT STAINLESS STEEL WORLD ASIA 2026 • SINGAPORE • 15 OCTOBER 2026

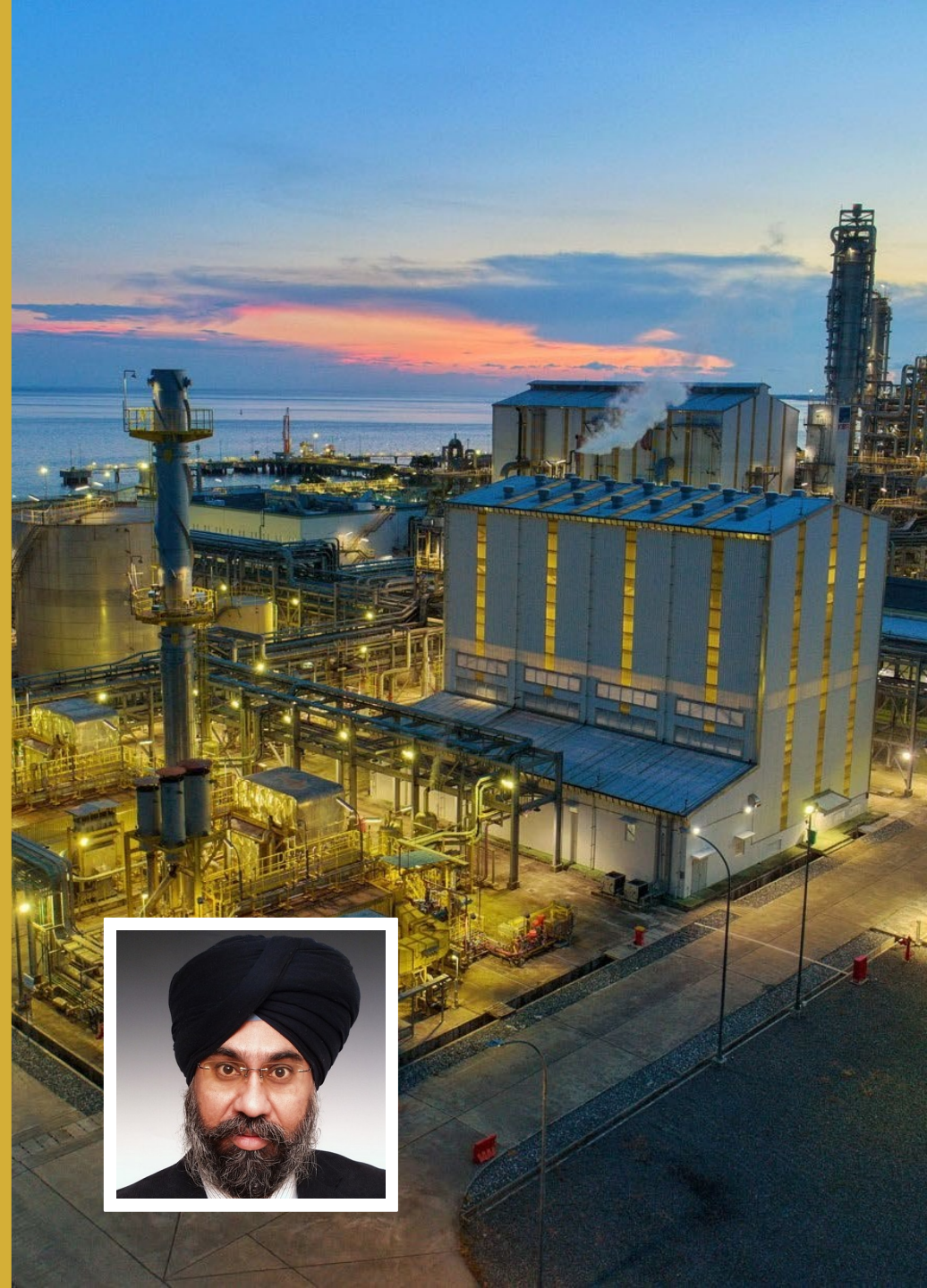
Materials for the biofuel transition

why stainless steels matter

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Namindo Pty Ltd • Bridging Science & Technology



Two weeks before this talk, in Singapore...

1 Oct 2026

Singapore began collecting the world's first SAF levy, on every ticket sold from 1 October.

- Levy applies to flights departing from 1 Jan 2027; cargo follows in 2028
- Economy S\$1.00 to S\$10.40 by distance band; premium cabins pay 4 times
- 1% SAF uplift target rising to 3–5% by 2030; first levy-funded SAF tender due by end-2026

15 minutes' drive from the venue

Neste Tuas: the world's largest SAF production site

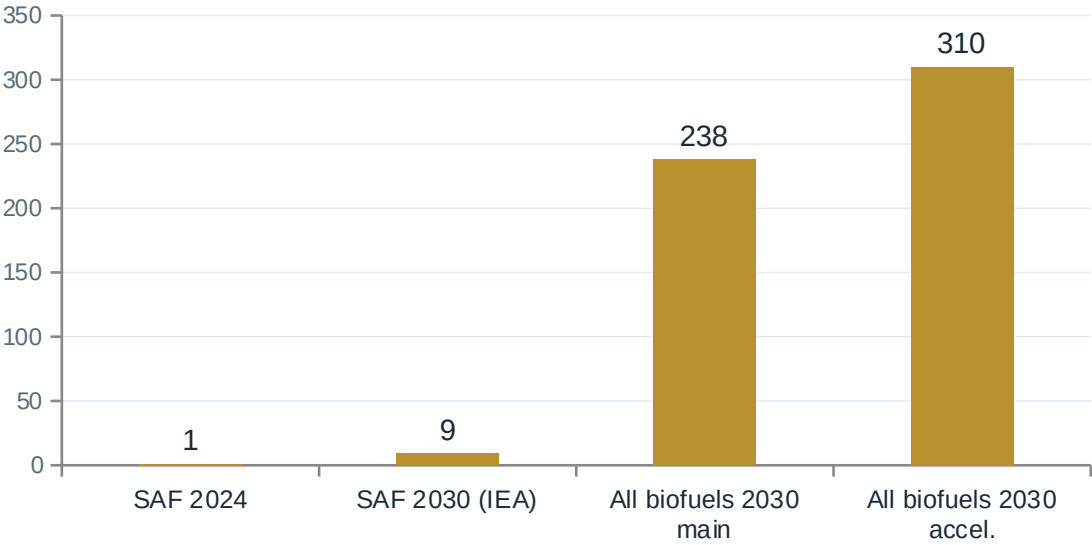
- 2.6 Mt/yr renewable products; up to 1 Mt/yr SAF; 2026 supply deals with SIA, Scoot and DHL at Changi
- The €1.6 bn expansion added a hydrogen unit and extra pretreatment for "more challenging wastes and residues"
- The pretreatment unit is what buys cheap feedstock. It is a metallurgy problem.

The biofuel transition is not a Brussels story. It is happening in this region's home market.

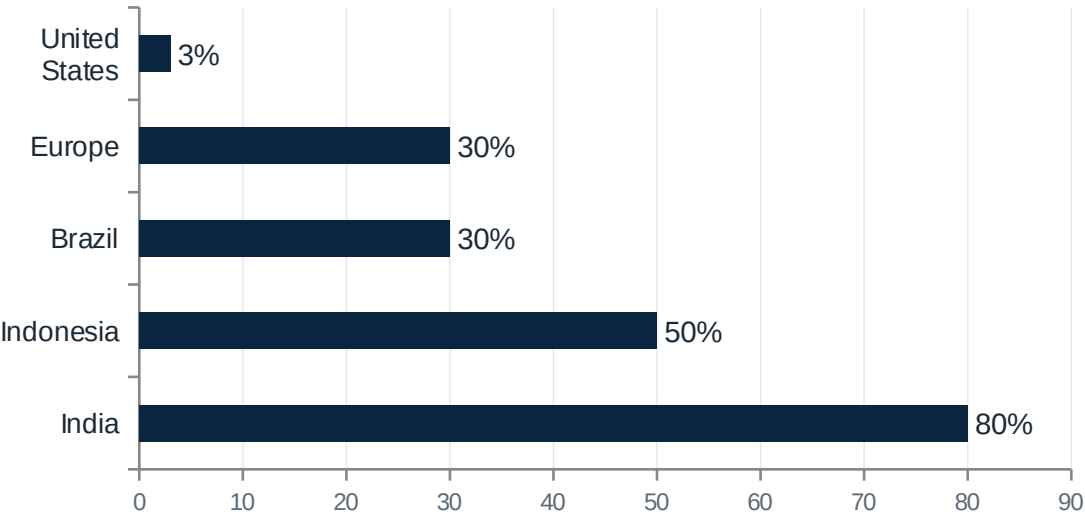
Source: CAAS / S&P Global, Sep 2026 (levy collection from 1 Oct 2026, flights from 1 Jan 2027); Neste Singapore.

The wave in numbers; and inside each plant, stainless is the default

Global biofuel demand, billion litres (SAF grows 9 times)



Biofuel demand growth to 2030 (IEA); ~75% of it is Brazil, Indonesia, India



80–90%

of the process equipment in ethanol and biodiesel plants is stainless; 304L leads

15–30 km

of stainless pipe and exchanger tube in each ethanol or biodiesel plant

≈ 1/3

of plant capex is equipment and piping: €500–650 m in one Neste-class refinery

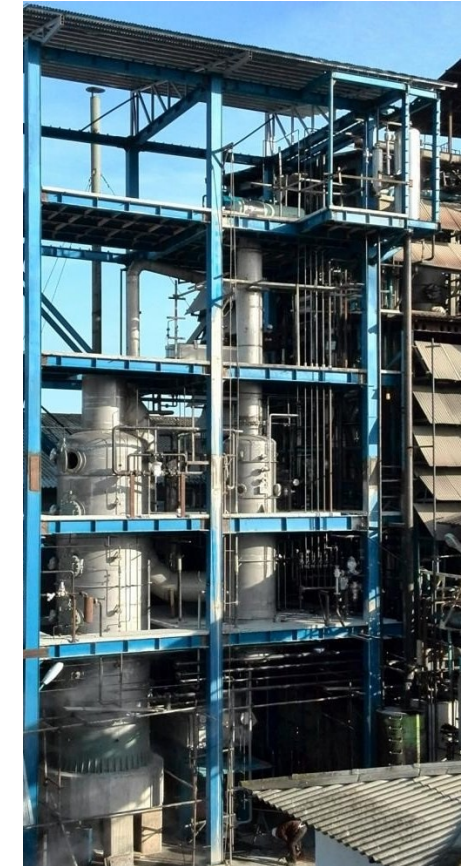
+5%

stainless output H1 2026 (33 Mt); Asia makes 86% of it. This wave lands in Asia.

Source: IEA Renewables 2025; IATA 2026 (SAF 2.4 Mt, 0.8% of jet fuel); Nickel Institute 10 090; Peters & Timmerhaus; worldstainless, Aug 2026.

The Asian mandate wall: guaranteed offtake, bankable plants

Market	Mandate / target	Timing	What gets built
Indonesia	B50 in force since 1 Jul 2026 (16.75 M kL; 94% of stations by Sep); E10 to E20 ethanol	B50 now; E10 2027-28; E20 2029	2 of 5 new biodiesel plants still to come; ethanol capacity must grow ~9 times
India	E20 achieved 5 years early; studies under way beyond E20; SAF 1–2%; CBG blending 1 to 5%	2025 to 2028-29	~480 distilleries, 20 bn L; 5,000-plant CBG target; first ethanol-to-SAF plants (LanzaTech, NTPC)
Malaysia	B10 now; rise to B15 agreed, starting with B12; B20/B30 ambitions	2026 onward (13th Malaysia Plan)	2.36 Mt capacity at 41% use; POME and UCO feeds; Sabah SAF project
Thailand	SAF 1% in force since 1 Jan 2026, rising to ~8% by 2036; E20 and B7 road fuels	2026 to 2036	Ethanol surplus goes to alcohol-to-jet; Bangchak SAF unit
Singapore	SAF 1% to 3–5%, funded by the levy now being collected	2026 to 2030	Neste Tuas 1 Mt/yr SAF; regional hub
Japan / Korea	SAF 10% (JP) • SAF 1% (KR)	2030 • 2027	Cosmo Sakai ATJ; Idemitsu; refiner JV plant
EU (for reference)	ReFuelEU 2% / 6% / 20% / 70%	2025 / 2030 / 2035 / 2050	The e-SAF sub-mandate drives e-fuel plants



Process towers, biodiesel plant. Photo: Namindo Pty Ltd.

Source: Argus; Antara; PIB India; The Star (MY); CAAT Thailand; CAAS; S&P Global; InfluenceMap. Verified Oct 2026.

Every biofuel molecule is made in a wet, acidic, chloride-bearing, biologically active environment.

That is stainless steel's home ground.



1G / 2G ethanol

organic acids • chlorides • hot dilute H_2SO_4



Biodiesel (FAME)

HCl / H_2SO_4 • free fatty acids • methanol



HVO / HEFA SAF

hot FFA + H_2 • organic chlorides • wet CO_2



Biogas / Bio-CNG

H_2S • NH_3 • MIC • condensate



e- / bio-methanol

wet CO_2 • KOH • high-pressure H_2

Ethanol: mild on paper, relentless in practice

The environment

- pH 5.8 down to 2; up to 115 °C; lactic and acetic acid from contamination; CO₂
- Chlorides concentrate in stillage, evaporators, column bottoms
- CIP cycling every batch: hot caustic, then acid
- Ethanol aggravates chloride pitting of 316L: pitting potential falls from 489 to 239 mV as ethanol concentration rises

The grade map

- 304L is the default (~90% of the stainless): fermenters, columns, mixers, tanks, most pipe
- 316L: evaporators, exchanger tubes, decanters, CIP, wet-mill steep (SO₂)
- Alloy 20 on sulfuric-acid skids; ferritic 444 in Brazil's evaporators
- Lean duplex 2101 for large tanks; duplex castings for pumps

Carbon steel's trap: ethanol stress-corrosion cracking (API 939-D/E)

More than 30 cracking failures documented at fuel-ethanol blending and user terminals since the mid-1990s; none at production plants. The recipe is dissolved oxygen, water in the 0.1–4.5% band, a few mg/L of chloride. General corrosion under 1 mpy gives no warning. Austenitic stainless is immune. Carbon steel needs oxygen exclusion, PWHT, coatings and inspection.

Source: Nickel Institute 10 090; Frontiers in Chemistry 2020; API TR 939-D / Bull. 939-E; PHMSA SCC report.

2G cellulosic: where the alloy ladder climbs above stainless

The pretreatment reactor is the metallurgical pinch point

Dilute-acid pretreatment

Incoloy 825 clad · C-276 · Alloy 625 · ~1% H₂SO₄ at 160–240 °C under pressure; beyond any stainless

Steam-explosion routes

304L / 316L / duplex · acetic acid, furfural; manageable at <0.1 mm/yr

Flash / neutralisation

316L · 2205 · 904L · dilute acid, falling temperature, chlorides

Balance of plant

304L / 316L · acid service under 100 °C; fermentation; distillation

The numbers

- NREL design: Incoloy 825-clad reactor at 158 °C with 1.1% H₂SO₄; the pretreatment system costs about US\$20 m and adds \$0.14/gal to ethanol cost
- Lab data: 347, 316L and lean duplex all corrode actively in hot dilute H₂SO₄; only high-Mo and nickel alloys survive
- India already runs two 2G refineries (Panipat, Numaligarh); nickel-alloy demand follows



Process column in fabrication. Photo: Namindo Pty Ltd.

Source: NREL/TP-5100-47764 (158 °C design); NREL/TP-510-32438 (190 °C design); MS&T 2019; AMPP 2020; BSSA; Nickel Institute 10 090.

Biodiesel: the reactor is mild, the glycerine circuit is not

Step	Chemistry	Materials logic
Transesterification	Methanol + NaOH/methylate, 60–65 °C	304L / 316L; mild duty
High-FFA esterification (UCO, POME, fats)	FFA + methanol + H ₂ SO ₄ , 60–90 °C+	316L minimum; upgrade at acid injection
Methanol recovery	Hot methanol/water, traces of glycerol	304L / 316L
Acidulation / glycerine	HCl 1.5–2%, 7% NaCl, pH 1.5–5.5, 95–160 °C	2205 / 2507 / 904L (the killer zone)
Acid water wash	pH 1.5–5.5	316L pits; duplex or 904L advised

A documented plant failure

Built in 316L, 904L, 2205 and 2507, and still had 11 failures: through-wall pitting next to welds at acid-injection spools and static mixers in 23–29 months; crevice attack at high-heat-input welds. The verdict: "material specification alone is not sufficient."

The market being built

Indonesia B50 is in force: 16.75 M kL allocated, 94% of fuel stations supplied by September, and 2 of 5 new plants still to build. Malaysia heads from B10 toward B15 and B30. POME and UCO feeds bring more FFA and more chlorides, so more 316L and duplex. About 80% of a biodiesel plant is stainless; the carbon steel is mostly storage.



FAME biodiesel plant. Photo: Namindo Pty Ltd.

Source: Nickel Institute 10 090; SciELO Matéria; Antara / KabarBursa, Sep 2026; Argus. Verified Oct 2026.

HVO/SAF: three surprises for a refinery metallurgist



Hot free fatty acids

- Over 1 mm/yr on carbon steel and 1.25Cr at 220 °C on high-acid feeds; rate scales with TAN, and TAN runs up to 200
- Needs molybdenum: 316L, then 317L, 317LM, 6Mo, 625
- The classic 321/347 hot-loop grades are the wrong answer for FFA



Organic chlorides

- Water wash removes over 90% of inorganic Cl; organic Cl "cannot be washed out"
- Converts to HCl in the reactor, then NH_4Cl deposits and under-deposit pitting
- Mitigate by blending feeds, water wash, inspection



The effluent is $\text{CO}_2 + \text{H}_2\text{O}$

- Deoxygenation makes carbonic acid, not H_2S ; it attacks anything below 12% Cr
- REAC tubes, cold separators, sour water: carbon steel loses 1–18 mm/yr when wet
- Upgrade to 316L or duplex; water-wash design carries over

The constants still apply: HTHA per API RP 941 (Tesoro, 2010); DMDS sulfiding keeps $\text{H}_2/\text{H}_2\text{S}$ sulfidation alive downstream; PASCC at shutdown. The PTU is 304/316 base, and Sanicro 35 is qualified at pH 2, 500 ppm Cl, 275 °C. Neste's Tuas expansion added pretreatment for harder wastes. The PTU is what buys cheap feedstock.

Source: IFPEN (Andari 2022); E2G / Inspectioneering; Alfa Laval PTU FAQ; Becht; Alleima; IEAGHG; HSE HTHA bulletin; Neste.

Test the feedstock first: the corrosive components travel with it

Feedstock	Acidity (FFA / TAN)	Chlorides & salts	P, metals, other
Crude palm oil (CPO)	FFA low single digits	low; inorganic Cl washes out	P 30–50 ppm; dry degumming
POME oil / palm residue oils	very high FFA; TAN toward the ~200 of pure fatty acid	mill-water salts	high P and metals; acid esterification duty
Used cooking oil (UCO)	FFA a few %	organic Cl; it cannot be washed out	P usually <50 ppm; polyethylene traces
Animal fats / tallow	high FFA	variable	metals and polymer residues; higher S and N
Sewage-sludge biocrude (HTL)	TAN ≈ 59	chlorides + ammonium salts	N 4.8%, O 4.7%, S 1.2%

What to ask the lab for, every time

TAN (ASTM D664) • total and organic chloride (combustion ion chromatography) • P and metals by ICP (Na, K, Ca, Mg, Fe) • sulfur and nitrogen • water (Karl Fischer). The pretreatment target is P at 3 ppm and metals at 5–10 ppm into the hydrotreater.

The sixth route: sewage to SAF

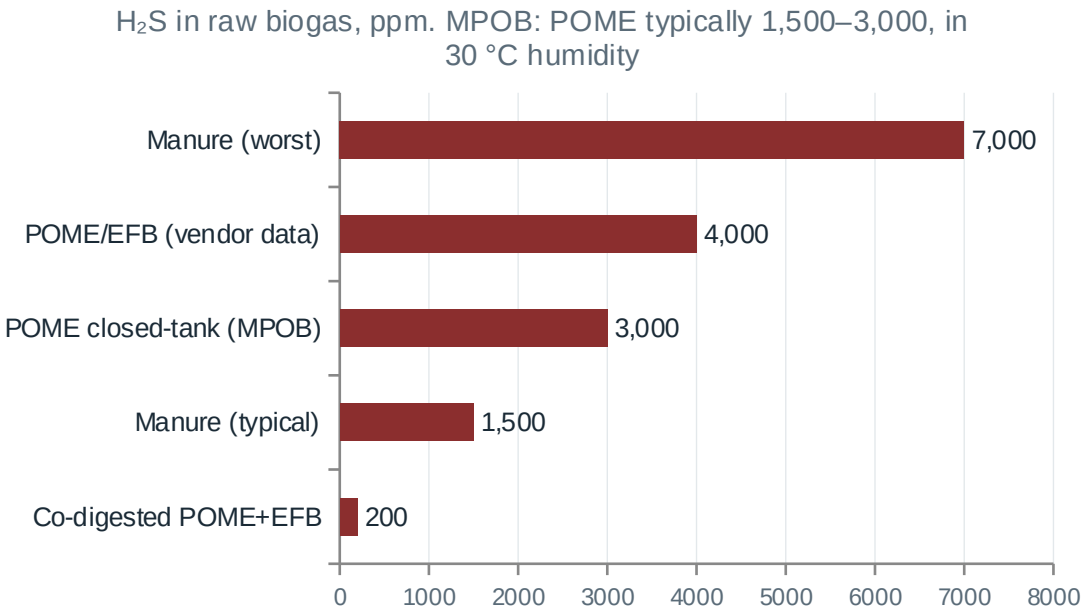
- Hydrothermal liquefaction: wet sludge in hot compressed water at 347 °C and 205 bar
- Biocrude is harsher than any lipid feed: TAN 59, N 4.8%, O 4.7%, S 1.2% (PNNL)
- Hydrogen demand is heavy: ~4.4–4.6 kg H₂ per 100 kg biocrude at 400 °C; HTHA rules apply in full
- PNNL pilot: 316L coupons held for 1,000 h; the bench reactor itself is Inconel; the cold train still sees ammonium salts and chlorides
- Watch this route. It is the most corrosive biofuel service yet proposed.

Source: Alfa Laval PTU FAQ; IFPEN (Andari 2022); MPOB; PNNL-27186, Hydrothermal Liquefaction of Wet Waste to Fuels.

Biogas: three zones in one tank; POME sits high on the H₂S range

Headspace	H ₂ S + condensate makes biogenic H ₂ SO ₄ , pH below 3	316Ti / 316L
Interface	wet/dry cycling; "uniquely destructive"	316L / duplex
Liquid	NH ₄ ⁺ , Cl ⁻ , VFAs, MIC; heat tint at welds becomes a MIC site	304 (low Cl) / 316L

The zone rule from ISSF practice: 304 in the liquid, 316Ti in the gas zone, 316L for wet-gas piping; 904L or 6Mo at high H₂S with chlorides.



Failures and the market

A 2016 ARIA corrosion bulletin records a 2012 case: a 7,000 m³ carbon-steel digester lost 2.6–4 mm of wall, with microbial attack suspected; a separate 2013 cast-iron pipe failure released 24,000 m³ of biogas. Concrete is "hard to avoid corrosion, even with a special coating". Only ~30% of Malaysia's mills and under 10% of Indonesia's capture biogas. India CBG: 160 running, 244 building, 5,000 targeted.

Source: ISSF / worldstainless; MPOB Palm Oil Engineering Bulletin; DTI H₂S review; SARE; ARIA 2016; PNGRB 2025.

e-Methanol: impurities and water fossil syngas plants never saw

1	Biogenic CO₂ feed	H ₂ S, O ₂ and VOC residues from biogas or fermentation; catalyst poison and pitting risk. Topsoe: "impurity profiles that simply do not exist in natural-gas plants."
2	Compression & capture	Wet CO ₂ is carbonic acid: carbon steel loses 1–18 mm/yr. All wetted compressor parts stay austenitic until the gas is dry (~250 ppmv H ₂ O); 304L/316L in rich amine.
3	Synthesis loop	CO ₂ + 3H ₂ → CH ₃ OH + H ₂ O makes far more water than syngas, so carbonic acid in loop condensate. Separators, let-down and crude storage in 304L/316L; austenitics, never duplex, for high-pressure H ₂ .
4	Distillation & storage	Crude methanol with CO ₂ and formic/acetic traces: 304L/316L overheads and reboilers. Storage in 300-series or carbon steel; linings last under 7 years, and methanol picks up water.
5	Electrolysis BoP	30% KOH at 80–90 °C gives caustic SCC of 304L/316L near boiling, so duplex 2304/2205/2507 on the caustic side; 316L/Ti on PEM water loops; O ₂ -clean practice.

Reference: Kassø, Denmark. 42,000 t/yr, the first commercial e-methanol plant, running since 2025 on biogenic CO₂ from a nearby biogas plant; shipping to Maersk, LEGO, Novo Nordisk and OMV.

Source: Topsoe; IEAGHG 2010/03; Methanol Institute storage guide; Hydrogen Tech World; European Energy Kassø.

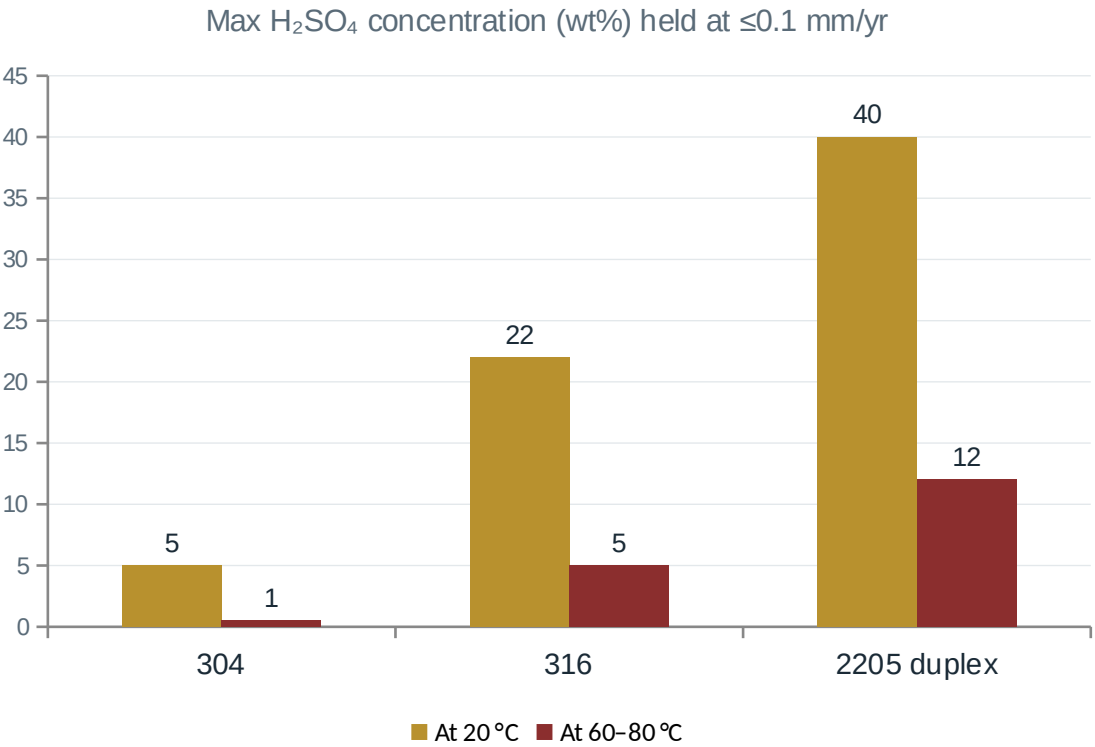
80% of the plant is 304L/316L. The other 20% is the career risk.

Route	Default grade (bulk)	Hot-spot grade	What fails if you cheap out
1G ethanol	304L; 316L evaporators/exchangers	2205 columns/pumps; Alloy 20 acid skids; LDX 2101 tanks	Chloride pitting in evaporators; eSCC of CS in loadout
2G ethanol	304L / 316L balance of plant	Incoloy 825 / C-276 / 625 clad pretreatment; 904L, 2205 downstream	Active corrosion of any stainless in hot dilute H ₂ SO ₄
Biodiesel	304L (alkaline) / 316L (acid)	2205 / 2507 / 904L glycerine and acid-water; Alloy 20 hot H ₂ SO ₄	Weld-adjacent pitting in 2 years at acid injection
HVO / SAF (incl. HTL)	304/316 PTU; Cr-Mo + 347 overlay reactor	317L / 6Mo / Sanicro 35 hot FFA; 316L/duplex REAC	FFA corrosion over 1 mm/yr; NH ₄ Cl under-deposit; carbonic acid
Biogas / Bio-CNG	304 liquid zone; 316L piping	316Ti gas zone; 904L / 6Mo high H ₂ S+Cl; 2205 amine	MIC and biogenic H ₂ SO ₄ in headspace; CS digester wall loss
e-/bio-methanol	CS dry gas; 304L/316L wet & MeOH	2205/2507 caustic BoP; austenitic H ₂ ; martensitic impellers	Wet-CO ₂ attack of CS at 1–18 mm/yr; caustic SCC

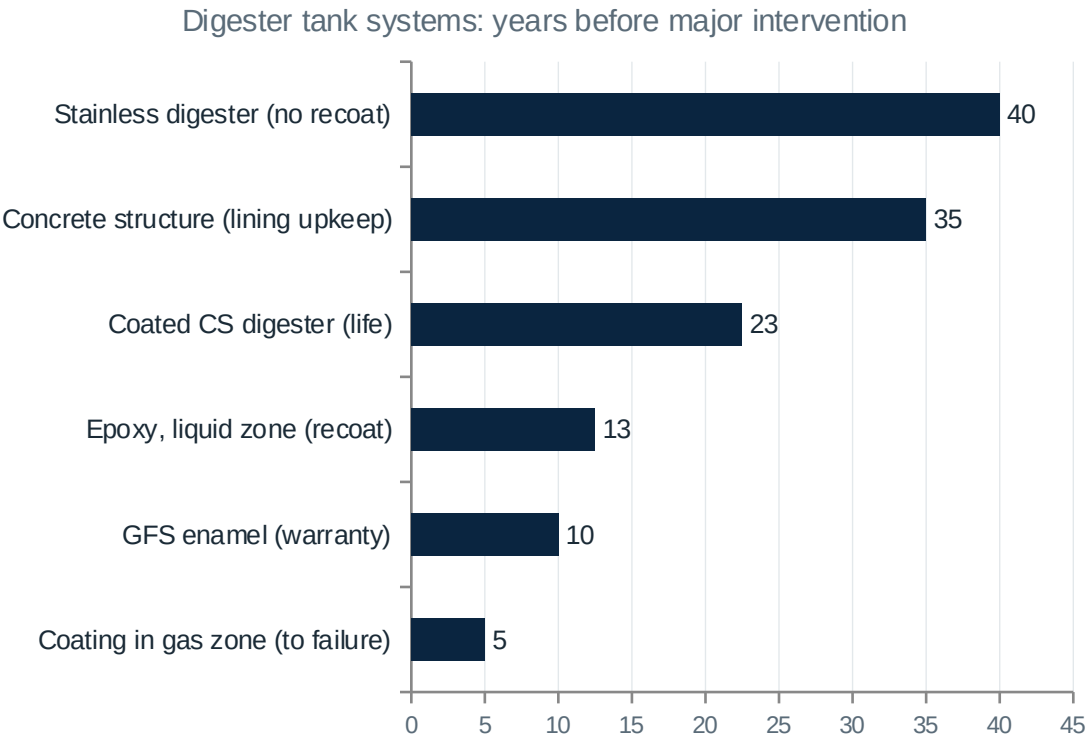
The ladder: 304L → 316L/316Ti → lean duplex 2101/2304 → 2205/2507/904L → superaustenitic / 825 / 625 / C-276

Source: Synthesis of the research pack and Nickel Institute 10 090 / ISSF / Rolled Alloys.

What the published long-term data says



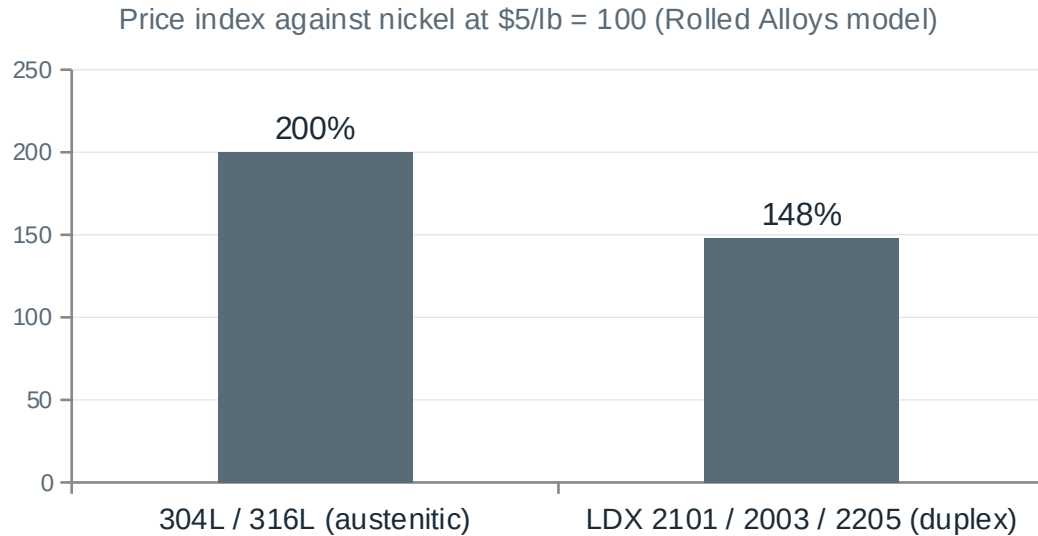
Acid tolerance collapses with temperature. 904L covers the full acid range, at 35 °C or below. Above ~100 °C every stainless fails; that duty is clad with 825 or C-276.



The 35 years belongs to the concrete structure, not its coating. Liquid-zone epoxy runs 10-15 yr to recoat, but gas-zone linings have failed in 1-2 yr; ~5 yr is a realistic field allowance. No coated system matches a stainless tank with no recoat cycle.

Source: BSSA iso-corrosion data for H₂SO₄; ISSF biogas publications; anaerobic-digestion.com lifecycle survey; WaterWorld digester-lid lining case; GFS vendor warranties. Charts redrawn from the cited data.

The cost case: lifecycle wins, and duplex compounds it



Nickel sits near US\$15,000–16,000/t with record LME stocks; the Indonesian surplus still caps prices. That keeps austenitics cheap today. It is a window, not a guarantee.

The 25-year arithmetic

Zero corrosion allowance and no coatings. Epoxy lasts 10–15 years in the liquid zone but as little as 5 in the gas zone, so a coated tank buys two to four recoat shutdowns in a 25-year life; stainless buys none, and scraps at value.

25%

less material: LDX 2101 tanks against 304L (Greenmills)

30%

less material: 2304 biodiesel plant, over 120 t of plate

2×

yield strength of LDX 2101 against 304L/316L, at about 304L price

PREN 35

2205: slightly above 316L price, immune to chloride SCC, no coating under insulation

Where duplex is NOT the answer

High-pressure hydrogen: ferrite embrittles, use austenitics. Hot dilute H₂SO₄: even 625 corrodes, clad with 825 or C-276. And duplex needs qualified welders.

Design beats grade: the fabrication lessons

- 1

Right alloys, wrong geometry

A biodiesel plant in 316L/904L/2205/2507 still had 11 failures at acid-injection spools and hot welds. Fix: emissary-tube injection, weld procedure, dosing control.

- 2

Heat tint is a MIC site

In digesters and wastewater, heat tint near welds invites biocorrosion. Fix: remove tint, pickle and passivate.

- 3

Crevices under deposits

Stainless H₂S-removal vessels pitted where iron-sponge media sat against the wall. Fix: crevice-free internals, drainage, inspection.

- 4

Condensate is the enemy

Wet biogas, low velocity and cold spots make biogenic acid. Fix: 2% slope minimum, traps every 60–75 m, insulation.

- 5

The feed is a spec

Organic chlorides in UCO cannot be washed out. Fix: blend feedstocks, set Cl limits, inspect more often.



Stainless reactor vessel in fabrication. Photo: Namindo Pty Ltd.

Proven at scale: PAU ammonia complex, Sulawesi

On the US\$850 m PAU project the speaker helped bring Indonesia its first super-duplex seawater intake pumps and titanium once-through seawater exchangers, with fibre-optic leak detection on the cryogenic ammonia tanks. The plant runs at 112% of rated capacity with 97% availability. Materials selection, done early, pays for itself.

To fabricators: weld procedure, finish and drainage are part of the material.

Source: SciELO Matéria; Wastewater Digest; J. Failure Analysis & Prevention 2021; BioCycle; Alfa Laval PTU FAQ.

What a biofuel developer needs from the stainless industry



Stock it close

Regional inventory of lean duplex plate and 316L/316Ti pipe in Southeast Asia and India. Lead time kills projects on mandate timetables.



Certify the welders

Duplex-qualified fabricators in Indonesia, Malaysia and India. The alloy is only as good as the shop.



Publish the data

Hot FFA with chlorides, biogenic CO₂, POME H₂S: corrosion data for the new environments, open rather than gated.



Sit at the FEED table

Materials selection belongs at licensor evaluation, not at procurement. By then the killer zones are already drawn.



Be transparent on nickel

Lay out surcharge against duplex economics plainly, so owners can hedge instead of over- or under-specifying.

Every biofuel molecule is made in stainless steel's home ground.

Asia is building the plants

IEA: ~75% of growth is Brazil, Indonesia, India · mandates from Jakarta to Tokyo

The mandates are live

Singapore levy collecting now · Indonesia B50 at the pumps · India past E20

The alloys already exist

Specify by zone · fabricate right · stock close

Thank you

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Grade reference: PREN, strength, cost signal

Grade	UNS / EN	PREN	Yield MPa	Cost signal	Typical biofuel duty
304L	S30403 / 1.4307	~19	~205	baseline	Fermenters, columns, tanks, most pipe; digester liquid zone
316L	S31603 / 1.4404	~24–25	~205	+20–30%	Evaporators, exchangers, acid service, wet biogas piping, PTU
316Ti	S31635 / 1.4571	~25	~220	near 316L	Digester gas zone (European practice)
444 ferritic	S44400 / 1.4521	~23	~310	near 304L, no Ni	Sugar-cane ethanol evaporators (Brazil); SCC-immune
LDX 2101	S32101 / 1.4162	~26	~450	near 304L	Large tanks; 25% less material than 304L
2304	S32304 / 1.4362	~26	~400	near 316L	Biodiesel plate; 30% less material
2205	S32205 / 1.4462	~35	~450	316L +20%	Acid and glycerine circuits, columns, pumps, amine, caustic BoP
2507	S32750 / 1.4410	>40	~550	well below 6Mo	Biodiesel decanters and reactors; replaces 904L
904L	N08904 / 1.4539	~34	~220	2–3× 316L	H ₂ SO ₄ service; high-H ₂ S biogas; hot FFA
6Mo / Sanicro 35	S31254 · N08367 · S32035	~43 / ~52	~300	high	Hot FFA with Cl (275 °C, pH 2, 500 ppm Cl); high-Cl biogas
Alloy 825 / 625 / C-276	N08825 / N06625 / N10276	n/a	n/a	Ni-alloy	2G dilute-acid pretreatment cladding; hot H ₂ SO ₄ ; HTL hot spots

Source: BSSA PREN formula ($Cr + 3.3Mo + 16N$); Rolled Alloys; Nickel Institute 10 090; Alleima; Sandmeyer.

Sources

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- worldstainless · 2025 and H1 2026 melt-shop production
- Argus, Antara, S&P Global, PIB India, The Star, CAAT Thailand · Asian mandates, verified Oct 2026
- BSSA · PREN and sulphuric acid selection guides; Alleima corrosion tables
- Contact for the full reference pack: Namindo Pty Ltd · supritpal@gmail.com