Welcome!

Project: Materials & Manufacture Design Coursework

Lunch Box Design Project

Consumer Group F: Gourmet Consumers (Anvay, Shuban, Manoj, Julius)



A deep dive into materials and manufacturing for a premium lunch box designed for the discerning gourmet consumer.



Targeting the Gourmet Consumer

This project investigates materials and manufacturing methods suitable for a premium lunch box targeting gourmet consumers who value quality, aesthetics, and performance in every aspect of their culinary experience. Key material requirements include superior thermal insulation properties, high-quality surface finish capability, and structural integrity balancing technical performance with the aesthetic refinement this market segment demands.

Target Market:

- ***Professionals aged 30-55 with high disposable income***
- ***Quality over quantity, aesthetics matter, willing to pay premium for excellence***
- ***Food enthusiasts, appreciate fine dining, Instagram their meals, care about presentation***
- ***Current lunch boxes look cheap, don't keep food at proper temperature, lack sophistication***

Why Our Product Matters

Elevated Experience

Matches their high culinary standards.

Refined Taste

Reflects their sophisticated personal style.

Reliable Performance

Maintains food quality and temperature.

Pride in Ownership

A product they are proud to carry and display.



Design Specifications & Challenges

Essential Features

- *3-4hr thermal performance*
- *Premium tactile feel*
- *Elegant refined finish*
- *BPA-free and food-safe*
- *Daily use durability*
- *Leak-proof seal*

Desirable Features

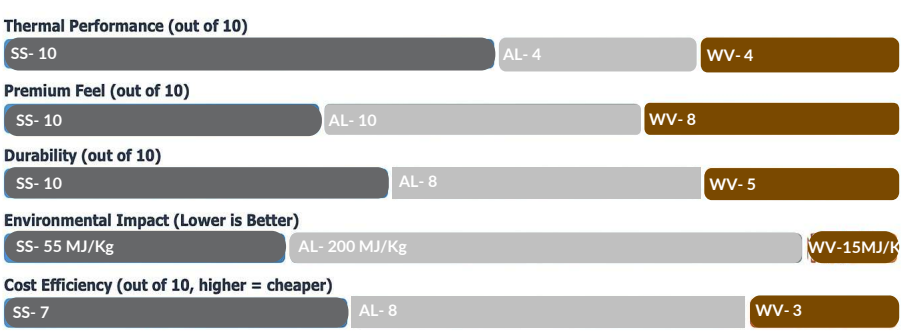
- *Compartments*
- *Dishwasher-safe*
- *Light with solid feel*
- *Condensation control*
- *Stackable design*

The challenge is to select materials and processes that deliver 3-4 hour thermal performance, an elegant finish, and durability while meeting food safety standards and justifying premium pricing.



Material Research

Property	316 Stainless Steel	Anodised Al 6061	Walnut Wood Veneer	Food-Grade Silicone
Density (g/cm³)	7.9	2.7	0.6-0.7	1.1-1.3
Tensile Strength (MPa)	515	310	35-45	7-10
Young's Modulus (GPa)	193	69	10-12	0.001-0.05
Thermal Conductivity (W/m·K)	16.3	167	0.15-0.20	0.15-0.20
Max Service Temp (°C)	425	200	120	230
Corrosion Resistance	Excellent	Very Good	Poor (needs coating)	Excellent
Embodied Energy (MJ/kg)	55	200	10-20	110-130
CO_2 Footprint (kg CO_2/kg)	6.15	11.5	0.7-1.5	5.5-7.0
Recyclability	100% infinitely	100% infinitely	Biodegradable	Limited
Material Cost (£/kg)	4.00-6.00	3.50-5.00	15.00-20.00	8.00-12.00
Microstructure	Austenitic FCC	FCC + Al_2O_3 layer	Cellulose fibers	Polymer chains



🏆 **Selected Materials: 316 Stainless Steel (Body) + Walnut Wood Veneer (Lid/Accent) for optimal luxury, thermal performance and aesthetic appeal.**

Material Microstructure & Performance

316 Stainless Steel



- Austenitic FCC microstructure for excellent formability.
- Cr + Mo provides exceptional resistance to acids and salts.
- Tensile strength ~515 MPa for dent and impact resistance.
- Density 7.9 g/cm³ for a premium "luxury-weight" feel.
- Non-porous surface for hygiene and mirror-polish capability.
- Low thermal conductivity (~16.3 W/m-K) for heat retention.

Walnut Wood Veneer Lid



- Natural cellular structure with air voids for low density (0.6-0.7 g/cm³).
- Heartwood tannins provide rich brown color and premium aesthetic.
- Anisotropic strength (35-45 MPa) strongest along fiber direction.
- Thermal conductivity 0.15-0.20 W/m-K for insulation.
- Low embodied energy (10-20 MJ/kg) and biodegradable for sustainability.

Quick Comparison

Property	Stainless Steel	Anodised Aluminium	Walnut Wood Veneer
Thermal Conductivity	16.3 W/(m·K) - Excellent with vacuum insulation ⭐	237 W/(m·K) - High, requires insulation	0.15 W/(m·K) - Natural insulator
THERMAL CONDUCTIVITY = How fast heat travels through material. Lower = keeps food hot/cold longer!			
Corrosion Resistance	Excellent (Cr_2O_3 passive layer) ⭐	Very good (anodized Al_2O_3 layer)	Moderate (requires food-safe coating)
Surface Finish	Brushed, satin, mirror - premium ⭐	Matte anodized, colored options ⭐	Natural grain, warm elegant finish ⭐
Recyclability	100% recyclable, no quality loss ♻️	100% recyclable, energy-intensive ♻️	Biodegradable, renewable resource 🌱
🌎 RECYCLABILITY = Can be melted down & reused forever! / BIODEGRADABLE = Naturally breaks down like leaves			
Weight	~395g (solid premium feel)	~135g (lightweight, portable) ⭐	~35g (decorative accent only)
Food Safety	FDA approved, ASTM A240, ISO 10993 ⭐	FDA approved, no metal leaching ⭐	Requires food-safe coating/sealing
FDA/ASTM/ISO = Official safety certificates proving it's safe to touch your food (like a food safety passport!)			
Durability	Highly durable, scratch-resistant ⭐	Good, anodized layer protects	Moderate, vulnerable to scratches
Maintenance	Easy clean, dishwasher-safe ⭐	Easy clean, dishwasher-safe ⭐	Requires gentle hand cleaning
Premium Aesthetic	★★★★★ (5/5) - Solid luxury feel	★★★★★ (5/5) - Modern minimalist	★★★★☆ (4/5) - Artisanal warmth
Best Application	Main body, vacuum-insulated walls 🏆	Lid frame, alternative body option	Decorative lid panel, accents 🏆

Decision Matrix

CRITERIA	WEIGHT	SCORE	WEIGHTED	SCORE	WEIGHTED	SCORE	WEIGHTED
		OPTION 1: 316 SS + WALNUT		OPTION 2: AL + BAMBOO		OPTION 3: WALNUT + SILICONE	
1. Material Feel & Appearance	20%	10	2.00	8	1.60	7	1.40
2. Thermal & Condensation Performance	25%	10	2.50	6	1.50	3	0.75
3. Durability & Scratch Resistance	15%	9	1.35	7	1.05	5	0.75
4. Weight	10%	6	0.60	9	0.90	10	1.00
5. Food Safety & Ease of Cleaning	15%	10	1.50	9	1.35	7	1.05
6. Leak-Proof Design	10%	10	1.00	8	0.80	9	0.90
7. Cost	5%	5	0.25	8	0.40	7	0.35
TOTAL WEIGHTED SCORE		9.20 / 10 🏆		7.60 / 10		6.20 / 10	

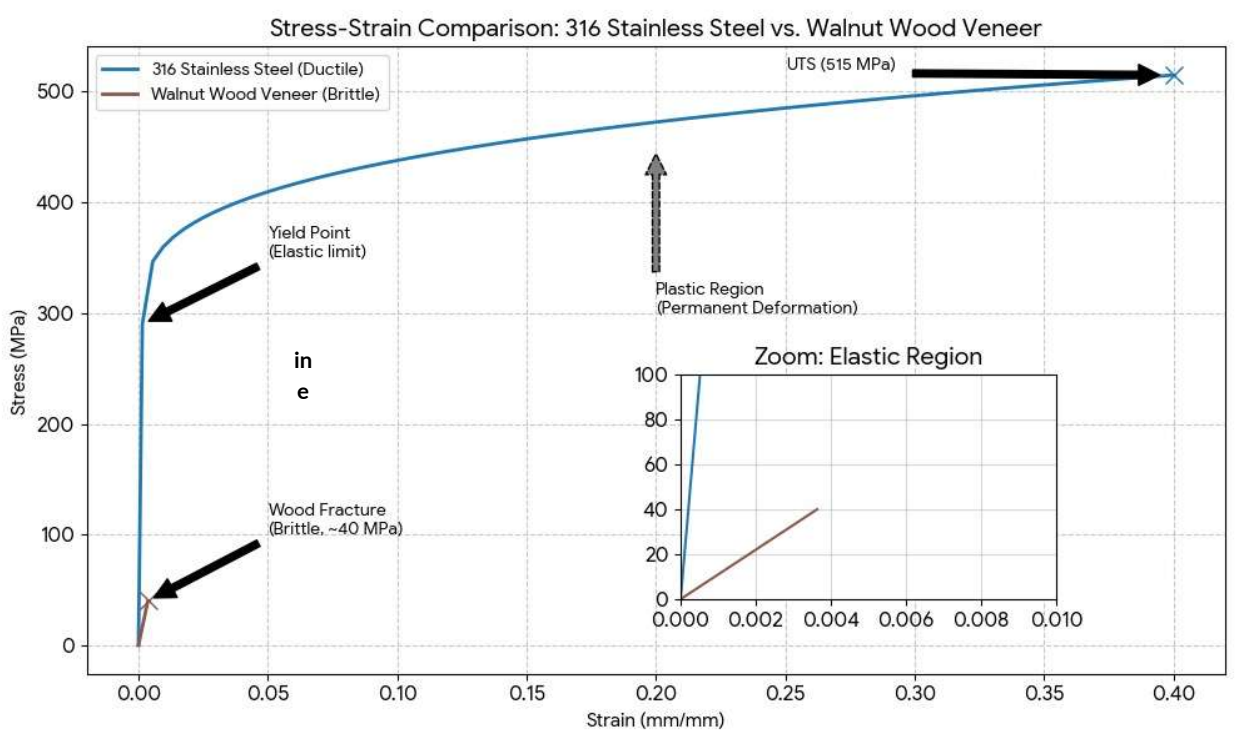
METHODOLOGY: A scoring table that helps us choose the best option by giving points to different features. Each material scored 1-10 per criterion. Scores multiplied by weight percentages to get weighted scores. Higher weights assigned to criteria most important for gourmet consumers (thermal performance 30%, premium feel 25%).

Material Behaviour

We mapped these stress-strain curves to validate our safety strategy.

If you look at the Blue Curve, you see that 316 Stainless Steel is highly ductile. Its large plastic region means that if a user drops the lunchbox, the steel will dent rather than shatter, absorbing the impact energy.

In contrast, the Brown Line shows that Walnut is brittle and snaps suddenly under low stress(40MPa).



This confirms our hybrid design is structurally sound. We use the steel chassis to take 100% of the mechanical load , which allows us to safely use the walnut solely as a premium aesthetic accent without risking breakage

316 Stainless Steel Body Manufacturing



Option 1: Sheet Metal Fabrication

Process: Cut blanks → Press brake bending → TIG welding → Polishing

Tooling: Press dies (£5K-15K), TIG welder, polishing equipment

Advantages:
- Fast cycle time (5-10 min)
- Cost-effective (£8-12/unit)
- Scalable (1000+ units)

Limitations:
- Visible weld lines
- Limited complex curves
- Surface finish Ra 1.6-3.2 µm

✓ SELECTED: CNC Machining

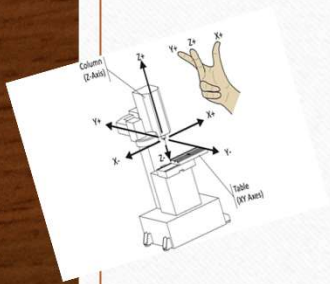
Process: CAD design → CNC milling from solid billet → Precision boring → Surface finishing

Tooling: CNC mill (3-axis), carbide endmills, boring bars, surface grinder

Advantages:
- Exceptional surface finish: Ra 0.4-0.8 µm (mirror polish capable)
- Tight tolerances: ±0.05mm for seamless lid fit
- Complex 3D geometry: intricate curves, undercuts, decorative features
- No weld marks: monolithic construction
- Consistent quality: minimal operator variation

Limitations:
- Higher cost: £25-40/unit (material + machining)
- Slower: 30-60 min cycle time
- Material waste: 40-50% removed as chips
- Energy: 15-25 MJ per unit

Justification: Premium market prioritizes aesthetics and precision over cost. Mirror finish and seamless construction justify luxury positioning.



Option 2: Deep Drawing

Process: Sheet blank → Multiple draw stages → Trimming → Polishing

✓ Good for hollow shapes, high volume

✕ Limited depth-to-diameter ratio, requires annealing between stages

Walnut Wood Veneer Lid Manufacturing



Option 1: Rolling/Pressing

Process: Adhesive application → Roller pressure → Air drying

Tooling: Pressure rollers, adhesive applicator

Advantages:
- Fast (2-5 min)
- Good for flat/simple curves
- Low energy (1-2 MJ/m²)

Limitations:
- Potential bubbling/wrinkles
- Less precise on complex shapes

✓ SELECTED: Cold Press Lamination

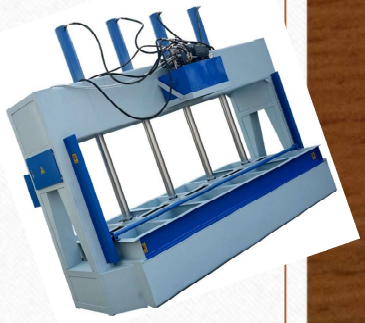
Process: Substrate prep → PVA adhesive application → Veneer layup → Vacuum bag → Heat press (60-80°C, 0.5-1 MPa) → Cooling → UV coating

Tooling: Vacuum press (£8K-20K), heated platens, vacuum pump

Advantages:
- Preserves natural grain: No compression damage to wood structure
- Smooth finish: Pressure eliminates voids, uniform adhesion
- Complex curves: Conforms to 3D substrate shapes
- Uniform thickness: 0.6-0.8mm veneer layer
- Durable bond: PVA creates strong wood-substrate interface
- Low energy: 5-8 MJ/m² (vs rolling 1-2 MJ/m²)

Limitations:
- Careful handling required: Thin veneer susceptible to cracking
- Cycle time: 15-30 min per part
- Requires coating: UV lacquer for moisture/scratch protection

Justification: Best preserves walnut aesthetics critical for luxury appeal. Smooth finish and conformability essential for premium lid design.



Option 3: Hot Press Lamination

Process: Higher temp (120-140°C) + pressure

✓ Faster cure, stronger bond

✕ Risk of veneer scorching, grain darkening reduces premium appearance

Process



CNC Machining for Body

Process 1. CAD Design 3D model in SolidWorks → 2. G-Code Generation Convert to machine language → 3. Material Setup Clamp 316 SS block in vice 4. Roughing Pass Remove 80% material quickly → 5. Finishing Pass Smooth surface Ra 0.8-3.2 µm → 6. QC & Polish Inspect + brushed finish

🛠️ TOOLING SPECIFICATIONS:

- Machine: 3-axis CNC mill (Haas VF-2 or equivalent), 7,500 RPM spindle
- Roughing Tool: 12mm carbide end mill, 4-flute, TiAlN coated (£45 each, lasts 100 parts)
- Finishing Tool: 6mm ball nose end mill, 2-flute (£35 each, lasts 150 parts)
- Cutting Parameters: 150 m/min surface speed, 0.15mm depth of cut (finish)
- Coolant: Water-soluble cutting fluid (prevents heat buildup + tool wear)
- Tooling Cost per Unit: £0.80 amortized (£160 tooling ÷ 200 parts per set)



Cold Press Lamination for lid

Process 1. Veneer Prep Cut + condition to 8% moisture → 2. Adhesive Apply Food-safe PVA roller-applied → 3. Press & Cure 100-150 PSI, 70°C, 30min → 4. Finish Coat 3× polyurethane layers

🛠️ TOOLING SPECIFICATIONS:

- Equipment: Pneumatic veneer press (50-ton capacity, £12,000)
- Press Bed: Heated aluminum platens with silicone cushioning
- Adhesive: Food-safe PVA (£8/liter, covers 200 lids)
- Finish: Water-based polyurethane (£15/liter, 150 lids)
- Production Capacity: 30 lids/day (2 operators)
- Energy Use: 1.5 kWh per lid (heating platens)

Tolerance & Material Testing

Fracture Toughness Testing (316 Stainless Steel)
Test Method: ASTM E399 (Standard)
Parameter: Fracture Toughness (KIC)
Result: 515 MPa

This high fracture toughness means:

- Excellent resistance to crack propagation
- Can withstand impacts/drops without fracture
- Superior to cast iron (15-50 MPa√m)
- Comparable to aerospace-grade materials

Drop Test Performance:

- Can Survive 1.5m drop onto concrete without denting or cracking
- Can withstand typical handling abuse in daily use
- High toughness prevents catastrophic failure

Test Method: ASTM E466 (S-N Curve)
Endurance Limit: ~40 MPa @ 10^7 cycles
Operating Stress: ~20 MPa (thermal cycling)

Fatigue life calculation:

- Daily thermal cycles: ~2-3 per day
- Annual cycles: ~1,000 cycles/year
- At 515 MPa limit: infinite life expected
- At operating stress: >15 years service life

Hot Fill (95°C) → Cold (5°C):
Temperature differential causes expansion/contraction
Stress Analysis:
Thermal stress = $E \times \alpha \times \Delta T$ = 193 GPa × 17.3×10^{-6} × 90
= 30 MPa
Safety Factor:
240 MPa / 30 MPa = 8:1 safety factor

Component/Feature	Tolerance	Process	Reason
Threaded Lid Connection	±0.05 mm	CNC Threading	Leak-proof seal, smooth operation
Vacuum Wall Gap	±0.02 mm	CNC Machining	Thermal insulation performance
Silicone Gasket Groove	±0.08 mm	CNC Milling	Proper compression seal
External Body Dimensions	±0.15 mm	CNC + Polish	Premium appearance, stackability
Veneer Lid Thickness	±0.10 mm	Cold Press	Flush fit with lid recess

Expected Product Lifespan:
With daily use (2 thermal cycles/day × 365 days × 15 years = ~11,000 cycles), the lunch box will operate well below fatigue limits, ensuring 15-20 year service life with no material degradation.

Service life prediction:

- 2 thermal cycles per day (hot lunch, then cold storage)
- 2 × 365 days × 15 years = 10,950 cycles
- Operating stress (30 MPa) is WAY below fatigue limit (240 MPa)
- Expected life: 15-20 years with no material degradation

Carbon & Energy

EMBODIED ENERGY (MJ) =

Total energy used to make the product from start to finish.

Material (316 SS):	27.5 MJ
CNC Machining:	18.5 MJ
Walnut Veneer:	3.0 MJ
Lamination:	1.5 MJ
Surface Finishing:	4.5 MJ
TOTAL:	55.0 MJ

CARBON DIOXIDE EQUIVALENT

316 Stainless Steel (500g):	2.20 kg CO_2e
CNC Machining Energy:	1.30 kg CO_2e
Walnut Veneer (20g):	0.02 kg CO_2e
Lamination Process:	0.15 kg CO_2e
Surface Treatment:	0.33 kg CO_2e
Total Carbon Footprint:	**4.0 kg CO_2e**

Total Product Carbon Footprint: 4.0 kg CO_2e

This represents the lifecycle emissions from raw material extraction through manufacturing. This is competitive with premium reusable containers in the market

Material Phase

3.31 kg
83% of total footprint
- Steel: 0.300 kg × 11.0 = 3.30 kg
- Walnut: 0.020 kg × 0.72 = 0.01 kg

Manufacturing

0.49 kg
12% of total footprint
- CNC: 9 kWh × 0.233 = 0.42 kg
- Press: 1.5 kWh × 0.233 = 0.07 kg
- Steel: 0.300 kg × 11.0 = 3.30 kg
- Walnut: 0.020 kg × 0.72 = 0.01 kg

Transport + Use

0.20 kg
5% of total footprint
- Transport: 200 km regional
- Use: minimal (hand-wash)

Compared to single-use plastic containers (0.40 kg CO_2e each), this lunch box breaks even after just 10 uses. Over its 15-year lifespan (5,475 uses), it prevents 2,186 kg CO_2e compared to disposables.

Net Environmental Impact (with Production) = 4.0 kg CO_2e
Recycling Credit = -1.98 kg CO_2e
Net Impact = 2.02 kg CO_2e (recycling)

Assuming 90% steel recycling rate at end-of-life (industry standard)

Disassembly
- **Threaded connection (no permanent adhesives)**
- **Removable silicone gasket**
- **Separable veneer panel**
- **Single-material components**
- **No mixed-material welds**
- **Easy material sorting for recycling**

Recycling Analysis

♻️ **Stainless Steel** (300g / 95% mass)

Recyclability: 100% Infinite
Stainless steel can be recycled indefinitely without quality loss

Recycling Process:

- Collection & sorting (magnetic separation)
- Shredding into small pieces
- Melting at 1,510°C
- Refining & alloying adjustment
- Casting into new products

Economic Value:
Scrap value: £1.20/kg × 0.300 kg = £0.36/unit

Energy Savings:
Recycled steel uses 60% less energy than virgin production
End-of-life credit: -1.98 kg CO_2e

🌱 **Walnut Veneer** (20g / 5% mass)

Biodegradability: 100% Natural
Wood is fully biodegradable and carbon-neutral

End-of-Life Options:

- Composting: Breaks down in 6-12 months
- Incineration: Energy recovery (no toxic emissions)
- Mulch: Garden/agricultural use

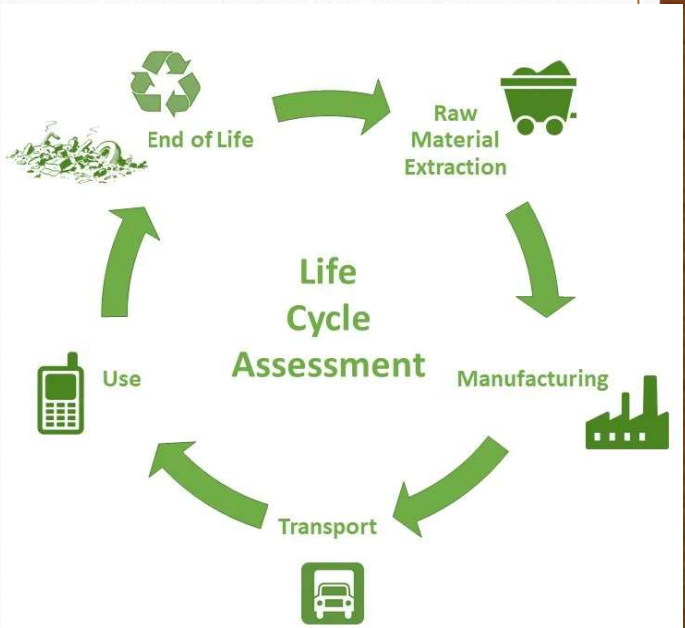
Carbon Balance:
Wood absorbed CO_2 during growth, making it carbon-neutral over lifecycle

Environmental Impact:

- No leachate toxins
- No microplastics
- Renewable resource
- FSC-certified sustainable harvest

📊 **Lifecycle Summary:**

- **Embodied Energy: 55 MJ**
- **Service Life: 15-20 years**
- **Recyclability: 95%+**



Down-Cycling

Why stainless steel is exceptional:

- **Infinite recycling**: Can be melted and reused indefinitely
- **Zero quality loss**: Recycled steel has identical properties to virgin steel
- **Chemical composition maintained**: Cr, Ni, Mo percentages stay constant through refining
- **No degradation**: Mechanical properties (strength, corrosion resistance) unchanged

Recycling process maintains quality:

1. Shred → Melt (1,510°C) → Refine → Cast
2. Quality testing ensures 316 grade specifications
3. Result: "New" stainless steel indistinguishable from virgin material

Comparison to down-cycling materials:

- Plastic (PET): Degrades each cycle → bottles become carpet → then unusable
- Paper: Fibers shorten → 5-7 cycles maximum before too weak
- Aluminum: Can recycle infinitely BUT surface treatments degrade
- Stainless Steel: TRUE circular economy - no degradation ever

Biodegradation as down-cycling:

- Wood naturally breaks down: Wood → Sawdust → Compost → Soil nutrients
- Each stage has lower material value BUT creates ecological value
- Final form: CO_2, H_2O, and organic matter enriching soil
- Carbon-neutral: CO_2 released = CO_2 absorbed during tree growth

End-of-life pathways:

1. Composting (6-12 months): Returns nutrients to soil
2. Incineration: Energy recovery (heating value ~18 MJ/kg)
3. Mulch: Agricultural/gardening use

Not traditional down-cycling because:

- Wood isn't meant to be recycled into wood products again
- Natural biodegradation is the intended end-of-life
- This is a biological cycle, not industrial recycling



Energy (MJ)
500
400
300
200
100
0
-150
27.5 MJ
55.0 MJ
18.5 MJ
3.0 MJ
1.5 MJ
-4.5 MJ
Material
Manufacture
Transport
Use
Disposal
End of Life credit

Eco Audit



Business Outlook & Profitability

Cost Per Unit Breakdown

- 316 Stainless Steel: £2.50
- Walnut Veneer: £0.35
- Adhesive & Coating: £0.45
- CNC Machining: £11.25
- Cold Press Lamination: £1.25
- Finishing & Polishing: £2.80
- Labor (assembly & QC): £1.80
- Silicone seal & hardware: £1.50
- Tooling amortization: £1.20
- Packaging & Branding: £2.40
- Overheads & Utilities: £3.75

Total Manufacturing Cost: *£29.25*

Profitability Analysis

- Retail Price: £89.99
- Manufacturing Cost: -£29.25
- Marketing & Distribution: -£18.00
- Retail Markup: -£13.20

Net Profit Per Unit: £29.54

This yields a 33% net margin, competitive in the premium segment with 67% gross margin.

Assumptions

- Labour (operator) wage: £15.00 / hour
- Overhead rate: £20.00 / hour (power, admin, rent, supervision—applied as £/h × time)
- Energy price: £0.20 / kWh
- Finishing tool purchase (brushes, jigs, pads) amortisation: example values (shown below)
- Per-part times (typical small-batch manual + machine assisted finishing):
  - Stainless-steel (deburr, surface smoothing, brushed-satin finish): 20 min = 0.33 h
  - Walnut veneer (sanding, sealing, 3× polyurethane coats — labour only; drying handled in parallel/batch): 15 min = 0.25 h
- Consumables / materials per part: abrasives, sanding discs, polishing compound, polyurethane, masking tape, thinner, etc (itemised below).
- These are cradle-to-assembly finishing costs only (no tooling for CNC body manufacture, no capital recovery for CNC mill unless you ask to include it).

Post-Processing

Process Cost (per unit)
Deburring £0.40 – £0.80
Surface smoothing £1.20 – £2.00
Brushed finish £1.50 – £2.50
Veneer sanding £0.30 – £0.60
PU sealing + 3 coats £1.20 – £1.35
Total £4.60 – £7.25

SS finishing — £7.64
Veneer finishing — £9.60
Energy/misc — £0.15
Total — £17.40

If finished in batches of 50+, estimated cost falls by ~30% due to reduced per-part labour/overhead.

All values are estimated — get 2–3 supplier quotes for validation.

Further Breakdown

Cost Category	Assumption Used	Value (£)
Production Volume	1,000 units/year	-
Material – Stainless Steel	300 g at £4.00/kg	£1.20
Material – Walnut Veneer + Seals	Veneer + silicone sealing components	£0.50
Total Material Cost (Cm)	As above	£1.70
Machining Time	18 minutes per part (0.30 hr)	–
Machine Hourly Rate	Outsourced CNC machining at £45/hr	£13.50
Tooling Cost (Ct)	£160 tooling, 200-part life	£0.80
Finishing (Brushed Steel + Veneer Coating)	Labour + consumables	£14.56
Energy Cost (Ce)	CNC energy & finishing equipment	£0.27
Assembly Labour	0.10 hr at £15/hr	£1.50
Capital Cost (Cc)	Outsourced – included in hourly CNC rate	£0.00
Overhead (Coh)	Included fully in outsourced machining rate	£0.00
R&D / Design (Ci)	£1 amortised per unit	£1.00
Packaging	Minimal cardboard sleeve	£0.75
Quality Assurance	Basic inspection	£0.50

Market

S'well (£45-75)

Zojirushi (£60-95)



Our Product (£89.99)

Our Approach

Premium pricing justified by superior thermal performance, luxury materials, and artisanal manufacturing. Competitive with high-end brands while offering unique walnut aesthetic.

- **Annual capacity**: **2,000 units** with **single** CNC = **£59,080 profit**
- Scalability: Transition to sheet metal at >5,000 units/year (reduces cost ~35%)
- Cost vs Quality: Chose CNC machining for superior finish despite 40% higher cost than sheet metal fabrication. Justified by gourmet market's quality-first mentality - £11.25 machining cost insignificant in £89.99 retail price.
- Weight vs Premium Feel: 395g unit weight provides solid luxury feel but sacrifices portability vs aluminum (135g). Accepted because target consumers prioritize "heft = quality" perception over lightweight convenience.
- Material Waste vs Surface Quality: CNC 40% waste vs sheet metal 20% waste. Trade-off accepted because: (a) 100% recyclable, (b) mirror-smooth finish impossible with stamping, (c) waste cost £0.08/unit negligible.
- Production Scale vs Artisanal Appeal: Limited to 2,000 units/year with current CNC setup. Intentional constraint - low volume reinforces "premium handcrafted" positioning. Can scale to sheet metal at >5,000 units if demand grows.

Investment 😍😍💕

Ask for £45,000 for 15% equity

Funding Needs:
-Tooling: ~£1,020
-Inventory (500 units): 500 units × £29.25 cost = £14,625.
-Marketing & Distribution: We allocated £18.00 per unit for this.
500 units × £18.00 = £9,000.
-Buffer/Contingency: ~£20,000 (for website, packaging, shipping, and unexpected costs)

TOTAL CASH NEEDED: ~£45k





Conclusion

Primary Material: 316 Austenitic Stainless Steel (body) - Superior thermal insulation via double-wall vacuum construction, premium tactile feel, excellent durability and hygiene

Accent Material: Walnut Wood Veneer (lid panel) - Luxurious warm aesthetic, artisanal appearance, complements metallic body elegantly
Manufacturing Method: CNC Machining (body) + Cold Press Lamination (veneer) - Prioritizes premium finish and precision over production speed

Key Features: Vacuum insulation maintains temperature 3-4 hours | Leak-proof silicone seal | Internal compartments | Brushed satin finish

Environmental Impact: 55 MJ embodied energy, 4.0 kg CO_2e per unit, fully recyclable materials, minimal waste with proper end-of-life processing

Economic Viability: £29.25 manufacturing cost, £89.99 retail price, £29.54 net profit per unit (33% net margin), competitive in premium segment!



Thank You!

References

1. *Callister, W.D. and Rethwisch, D.G., 2020. Materials Science and Engineering: An Introduction. 10th ed. Hoboken: Wiley.*
2. *Ashby, M.F., 2013. Materials and the Environment. 2nd ed. Oxford: Butterworth-Heinemann.*
3. *Ashby, M.F., 2017. Materials Selection in Mechanical Design. 5th ed. Oxford: Elsevier.*
4. *Granta Design, 2022. CES EduPack. Cambridge: Granta Design.*
5. *ASTM International, 2016. ASTM A240/A240M – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications. West Conshohocken: ASTM International.*
6. *ISO, 2018. ISO 10993 – Biological Evaluation of Medical Devices. Geneva: International Organization for Standardization.*
7. *Davis, J.R., 1998. Metals Handbook Desk Edition. Materials Park, OH: ASM International.*
8. *Forest Products Laboratory, 2010. Wood Handbook: Wood as an Engineering Material. Madison: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.*
9. *Lazonby, J., 2019. Food Packaging Technology. Cambridge: Woodhead Publishing.*