Vehicle Lightweighting Materials Cheat Sheet

Power vs. mass, the $/kg rule, and steel / aluminum / magnesium / CFRP trade-offs

ENGINEERING CHEAT SHEET

Key equations

Quantity	Equation	Notes
Total drive power	$P = P_{roll} + P_{acc} + P_{grade} + P_{aero}$	Every term except aero is proportional to vehicle mass
Rolling resistance	$P_{roll} = (m + m_p)\, g \cos\alpha \cdot f_r \cdot v$	m_p = payload, α = road gradient, f_r = rolling coefficient
Acceleration	$P_{acc} = (e\, m + m_p)\, a\, v$	e = rotating-inertia factor for the engaged gear
Gradient	$P_{grade} = (m + m_p)\, g \sin\alpha \cdot v$	Grades punish mass directly
Aerodynamic drag	$P_{aero} = \tfrac{1}{2} \rho\, C_d\, A\, (v - v_w)^2\, v$	The one term that does not scale with mass
Equal-stiffness swap	$E_{steel}\, I_{steel} = E_{Al}\, I_{Al}$	$E_{steel} \approx 3\, E_{Al}$, so the aluminum section needs about 3× the area moment of inertia
Aluminum thickness	$t_{Al} \approx 1.5 \times t_{steel}$	Average for equal performance. Better to add section depth than raw thickness
$/kg rule	**Added cost ≤ ($/kg) × kg removed**	C5 Corvette used $10/kg in the mid-1990s; about $20–21/kg in 2026 dollars; many OEMs accept $20–25/kg
Fuel economy rule	**−10% mass → +6 to 8% fuel economy**	Without any powertrain change
Cost of each % saved	**~$1,000 (first 5%), ~$2,000 (10%), $3,000+ (near 20%)**	Cheapest mass comes out first (gauge and material swaps)

Key takeaways

- **Curb weight** = standard vehicle with all fluids and a full fuel tank, no passengers or cargo. **GVW** adds people and cargo.
- The BIW is the largest mass contributor, so material swaps start there: **AHSS** to cut gauge, aluminum for closures and some structures, multi-material bodies overall.
- Aluminum is about one-third the weight of steel but three times more compliant. A part only saves weight if the geometry (section depth) is redesigned, not just thickened.
- Aluminum typically adds 60–80% to a component's cost and brings joining, paint and corrosion issues. Steel and aluminum cannot be welded directly, so joining dissimilar metals is the key challenge.
- Keep crash-critical members (rocker, B-pillar) in high or ultra-high-strength steel and use lighter materials around them.
- Where mass sits matters too: a lower, more central mass lowers yaw inertia and makes the same weight feel more agile.
- Mass saved compounds: lighter vehicles allow smaller brakes, springs, structure and battery. See the mass compounding guide for the reverse effect.
- Bio-based options (hemp, flax, kenaf, soy foam) suit interior and trim, not crash structure.

Lightweighting materials comparison

Material	Density	Cost	Strength	Typical use
Mild steel	Low	Low	Moderate	BIW
AHSS	Low	Moderate	High	Safety structures
Aluminum	Very low	Higher	Moderate	Closures
Magnesium	Extremely low	High	Moderate	Seat frames
CFRP	Lowest	Very high	Very high	Performance vehicles

Reference values are typical; verify against datasheets and codes for design.