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Quantifying Avoided Impact

Material, carbon and embodied water savings from extended vessel service life.

By Raul Ramos
Based on manufacturer-collected field data · Technical review: Impact Filtration Engineering

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> This is the reference paper for the quantification used across this platform. It sets out what is counted, the published factors each figure derives from, and the arithmetic in full — so that any number cited elsewhere can be reproduced here.

The argument for durability as a climate strategy is made in Vol. 06 <https://impactfiltration.com/insights/lifecycle-integrity-decarbonisation/>. This paper does not repeat it. It exists to show the working.

SECTION 01

What is being counted

The unit of analysis is a single FRP pressure vessel over a **30-year plant horizon**, compared against a baseline vessel with a nominal ten-year service life.

Across that horizon the baseline requires three vessels; the engineered vessel requires one. **Two replacement events are therefore avoided**, and everything counted here follows from those two avoided events — the manufacture, transport, installation and disposal that would otherwise have occurred twice.

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30-year horizon ÷ 10-year baseline life = 3 vessels required
30-year horizon ÷ 30-year engineered life = 1 vessel required
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Avoided replacements = 2 → 2 ÷ 3 = **67% reduction in replacement frequency**

Three quantities are counted: **composite material** not manufactured, **embodied carbon** not emitted, and **embodied water** not consumed in manufacture. Operational water, operational energy and downtime losses are *excluded* — they are real, but they are not embodied impacts and counting them here would mix two different accounting boundaries.

SECTION 02

Method and basis

Every figure in this paper derives from one of four published factors. Each is stated here with its source and its boundary, so a reader can substitute their own and recompute.

FACTORS USED

Avoided composite material

200 kg per vessel

Cumulative across two avoided replacements, i.e. approximately 100 kg per unit, consistent with 8-inch FRP membrane pressure vessels built to **ASME Boiler and Pressure Vessel Code, Section X** (Fiber-Reinforced Plastic Pressure Vessels). Mass varies with diameter, element count and pressure rating; substitute a measured figure where one is available.

Embodied carbon of GFRP

5.04 kg CO_2e per kg · cradle-to-grave

Peer-reviewed comparative life cycle assessment of GFRP, covering production, transport, use and end-of-life (*Sustainability*, 2024). For reference, continuous filament glass fiber alone is **1.44 kg CO_2e/kg** at the factory gate (Glass Fibre Europe, 2023); the difference is resin, processing, logistics and disposal.

Embodied water of glass-fiber composite

`0.015 – 0.041 m³ per kg`

The upper figure is the published water footprint of glass fiber, **0.041 m³/kg** (*Polymers*, peer-reviewed water-footprint assessment). The lower is the industry average for production water use, **15 L/kg**, on a reported range of 2–44 L/kg (Glass Fibre Europe / PwC, 2023). The two differ by boundary rather than by disagreement: one counts supply-chain water, the other counts water drawn on site.

Passenger-vehicle equivalence

`4.6 tCO₂e per vehicle-year`

United States Environmental Protection Agency, typical passenger vehicle. Used only as a reader aid; it is not part of the calculation.

A note on the carbon boundary. The 5.04 kg CO_2e/kg factor is cradle-to-grave. A production-only boundary gives a materially smaller figure — roughly 2.5 kg CO_2e/kg — and some published assessments of avoided replacement count only production. **This paper uses the cradle-to-grave figure because the event being avoided is a whole replacement cycle**, which includes shipping a vessel across an ocean, installing it, and disposing of the one it replaced. A reader applying a production-only boundary should halve every carbon figure below.

Why this figure differs from a product-specific LCA. A verified cradle-to-grave life cycle assessment of an individual assessed vessel reports a materially higher per-unit carbon footprint than the figures here, and the two are not in conflict — they answer different questions. A product LCA measures *one specific vessel*, at its own mass, specification and supply chain, across modules A1–C4. The arithmetic below measures a *generic 8-inch vessel* using published literature factors, because this platform is component-agnostic and the calculation has to be reproducible by a reader who has no access to any manufacturer's inventory data. The product figure is the more precise measurement of that product; the figures here are the more portable measurement of the class. Where a verified product LCA is available for the vessel a reader actually operates, **that figure governs for that vessel**. Full reconciliation of both boundaries is set out in the Technical Appendix <https://impactfiltration.com/insights/technical-appendix/>.

SECTION 03

Per vessel

One engineered vessel, over a 30-year horizon, against a ten-year baseline:

AVOIDED IMPACT PER VESSEL OVER 30 YEARS

QUANTITY	AVOIDED	DERIVATION
Composite material	200 kg	2 avoided replacements × ~100 kg
Embodied carbon	≈ 1.0 tCO_2e	200 kg × 5.04 kg CO_2e/kg
Embodied water	3 – 8 m^3	200 kg × 0.015–0.041 m^3/kg
Replacement cycles	2 of 3	67% reduction in replacement frequency

FIGURE 1 — PER-VESSEL AVOIDED IMPACT

Each figure is the product of one mass and one published factor. Nothing here is an estimate of operational performance — these are embodied impacts avoided by not manufacturing a replacement. TIER 2 · PUBLISHED THIRD-PARTY FACTORS

SECTION 04

At plant scale

The per-vessel figures scale linearly, because each avoided replacement is independent of the others. Vessel counts below are fleet sizes, not plant-capacity equivalents. How many vessels a plant requires depends on element count, design flux, recovery and staging, and cannot be derived from capacity alone.

AVOIDED IMPACT BY FLEET SIZE, CUMULATIVE OVER 30 YEARS

VESSELS	MATERIAL	CARBON	EMBODIED WATER
1	200 kg	1.0 tCO_2e	3 – 8 m^3
250	50 t	250 tCO_2e	750 – 2,050 m^3
1,000	200 t	1,000 tCO_2e	3,000 – 8,200 m^3
2,500	500 t	2,500 tCO_2e	7,500 – 20,500 m^3

FIGURE 2 — AVOIDED IMPACT AT SCALE

Carbon figures are rounded from 5.04 kg CO_2e/kg; at 2,500 vessels the unrounded value is 2,520 tCO_2e. Replacement-frequency reduction is 67% at every scale, since it is a property of the service life ratio rather than of fleet size.

TIER 2 · PUBLISHED THIRD-PARTY FACTORS

SECTION 05

Worked example

A desalination plant producing **10,000 m³/day**, operating approximately **500 vessels**, specified for a 30-year service life rather than a ten-year baseline:

material 500 × 200 kg = **100 tonnes** of composite not manufactured

carbon 100,000 kg × 5.04 = **504 tCO_2e** not emitted

water 100,000 kg × 0.015–0.041 = **1,500–4,100 m^3** not consumed

504 tCO_2e ÷ 4.6 = **110 passenger vehicles** taken off the road for a year

That outcome requires no new technology, no additional energy input and no change to plant operation. It follows entirely from the specification decision made at procurement.

SECTION 06

What these figures are not

A quantification paper is only as useful as its stated limits.

- **They are not a life cycle assessment.** An LCA covers a defined product system under ISO 14040/14044 with third-party review. This is avoided-impact arithmetic using published factors, which is a narrower and weaker claim.
- **They are not site-specific.** Absolute emissions vary with grid mix, supply chain and shipping distance. Replacement frequency is the dominant variable, which is why this analysis addresses relative rather than absolute impact.
- **They exclude operational impacts.** Downtime, lost production and emergency logistics are real costs of failure, and they are quantified separately in Vol. 02 <https://impactfiltration.com/insights/hidden-economics-of-reliability/>. Mixing them into an embodied-impact total would double-count.
- **Vessel mass is an approximation.** 100 kg per unit is representative of 8-inch vessels, not universal. Diameter, element count and pressure rating all move it, and every figure here scales directly with it.
- **The water figures are a footprint, not a withdrawal.** They represent water embodied in manufacture across the supply chain, not water drawn at any single facility.

> **Reproducing these numbers.** Every figure above is one mass multiplied by one published factor. Substituting a measured vessel mass, or a different carbon or water factor, changes the result proportionally and requires no other adjustment. The arithmetic is deliberately simple so that disagreement can be specific.

References

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