



AF-TR-9700-001

Quantitative Methods and Worked Calculations

Space / Aviation / Defense

FIRST EDITION

AF 9700 SUPPORTING DOCUMENT



Document identity and use

FIRST EDITION MANUSCRIPT - Prepared for Aerospace Federation review

Field	Controlled identity
Document	AF-TR-9700-001 - Quantitative Methods and Worked Calculations
Parent standard	AF 9700 - Sustainable Aerospace & Lifecycle Management
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Family	Companions
Primary source anchors	8-13, 17, 22-23, 25, 28, 34-36; informative Annex O
Suggested local owner	Lifecycle / accounting / assurance specialist
Authority	Publisher approval and effective date are not assigned. Local use requires authorized adoption and completed parameters.

Use with the main standard

This document implements the identified AF 9700 clauses and annexes. Read the complete applicable requirements in the main standard. The source anchors are navigation references; a template does not replace technical judgement, evidence, permission or eligible approval.

AF-ML-9700-001 lists the complete supporting set. AF-CM-9700-001 maps the main clauses and annexes to working documents. AF-TP-9700-001 establishes the common local parameter baseline; add the relevant discipline profiles.

Record control

Identify the object, configuration, record owner and dates. Reference attachments by stable identifier and version. Keep superseded evidence and decisions traceable. Use the approved local retention, access and authentication arrangements. No technical limit, numerical limit, interval or acceptance value is assigned by a blank template.

Implementation model: Translate the stated responsibilities and controls into the actual organization. Informative examples remain explanatory; use approved programme-specific values for operational decisions.

1 Use of quantitative examples

All values and cases in this companion are synthetic. They explain assumptions, calculations and limitations; they are not system limits, product evidence or mandatory default parameters. Select and approve the actual model and values before relying on a calculation.

2 Worked calculations

Status: Informative. All values are synthetic and are not mandatory thresholds, actual project results or approved operating parameters. Each example states assumptions and the limits of its conclusion.

0.1 Absolute and intensity performance

A facility reports 1,000 t CO₂e while producing 100,000 equivalent units in its base period. A later period reports 1,080 t CO₂e and 120,000 equivalent units with unchanged boundaries and equivalent product mix.

Base intensity = $1,000,000 / 100,000 = 10$ kg CO₂e/unit

Later intensity = $1,080,000 / 120,000 = 9$ kg CO₂e/unit

Intensity change = $(9 - 10) / 10 = -10\%$

Absolute change = $(1,080 - 1,000) / 1,000 = +8\%$

The facility improved intensity while increasing total emissions. Both results shall remain visible. This calculation cannot attribute the change to a particular intervention without additional evidence.

0.2 Lifecycle fuel blend on an energy basis

Assume two compatible pathways evaluated on the same lifecycle boundary: reference fuel 90 g CO₂e/MJ and alternative fuel 30 g CO₂e/MJ. The delivered energy is 100,000 MJ, with 20% attributed to the alternative pathway. Technical eligibility and valid custody are separate prerequisites.

Blend intensity = $0.80 \times 90 + 0.20 \times 30 = 78$ g CO₂e/MJ

Blend result = $100,000 \times 78 / 1,000,000 = 7.8$ t CO₂e

Reference result = $100,000 \times 90 / 1,000,000 = 9.0$ t CO₂e

Difference = 1.2 t CO₂e; relative reduction = 13.3333%

A 20% blend does not imply a 20% lifecycle reduction. The example does not establish zero combustion emissions or quantify non-CO₂ effects. A mass or volume blend shall first be converted using valid energy properties.

0.3 Electricity accounts and unmatched consumption

A site consumes 1,000 MWh. Its physical grid-average estimate is 400 kg CO₂e/MWh. In a separate contractual account, 600 MWh has eligible cancelled attributes with an illustrative generation factor of zero; 400 MWh uses an appropriate unmatched factor of 500 kg CO₂e/MWh.

Physical grid estimate = $1,000 \times 400 / 1,000 = 400$ t CO₂e

Contractual account = $(600 \times 0 + 400 \times 500) / 1,000$

Contractual account = 200 t CO₂e

These are different accounting views, not additive emissions and not proof of a 200 t physical reduction. Upstream lifecycle burdens are not automatically zero and must be included where the declared footprint requires them.

0.4 Co-product allocation sensitivity

A shared process has 1,000 kg CO₂e of burden and produces 80 kg of product A and 20 kg of product B. Mass allocation is selected for the base model. A sensitivity case uses economic outputs of 160 currency units for A and 240 for B, with no change in total process burden.

Mass allocation to A = $1,000 \times 80 / 100 = 800$ kg CO₂e

Mass intensity A = $800 / 80 = 10 \text{ kg CO}_2\text{e/kg}$

Economic allocation to A = $1,000 \times 160 / 400 = 400 \text{ kg CO}_2\text{e}$

Economic intensity A = $400 / 80 = 5 \text{ kg CO}_2\text{e/kg}$

The result halves solely because of the allocation choice. The study shall justify its chosen causal or other basis and disclose material sensitivity; selecting the more favourable number is not an environmental improvement.

O.5 Material yield and actual recycling

A process takes 1,000 kg of material and produces 700 kg of qualified product. It generates 250 kg of collected scrap and 50 kg of other losses. The recycler recovers 80% of the scrap as usable secondary material; its remaining 20% is documented residue.

Product yield = $700 / 1,000 = 70\%$

Recovered material = $250 \times 0.80 = 200 \text{ kg}$

Recycler residue = $250 - 200 = 50 \text{ kg}$

Balance = $700 + 200 + 50 + 50 = 1,000 \text{ kg}$

The collected scrap rate is 25% of input; actual recovered material is 20% of input. Neither is the recycled content of the manufactured product. Residue destinations and losses still require evidence.

O.6 Water balance and concentration versus load

A site withdraws 1,000 m³, discharges 650 m³, consumes 300 m³ and increases stored water by 50 m³. Internal recirculation is measured separately. A treatment change reduces discharge from 100 to 50 m³/day while concentration increases from 10 to 15 mg/L.

Water balance = $650 + 300 + 50 = 1,000 \text{ m}^3$

Initial load = $100 \times 1,000 \times 10 / 1,000,000 = 1 \text{ kg/day}$

Later load = $50 \times 1,000 \times 15 / 1,000,000 = 0.75 \text{ kg/day}$

Pollutant load falls by 25% while concentration rises by 50%. Neither result alone establishes compliant discharge or acceptable receiving-water conditions; the applicable concentration, load and receptor criteria still apply.

O.7 Repair-versus-replace break-even

For equivalent future service, a replacement requires 500 kg CO₂e upfront and then 1 kg CO₂e per service hour. Repair requires 100 kg upfront but the repaired asset uses 1.2 kg per service hour. Both options are technically eligible for the assessed service; past common burdens are excluded consistently from this decision model.

Replacement = $500 + 1.0 \times H$

Repair = $100 + 1.2 \times H$

Equal burden: $500 - 100 = (1.2 - 1.0) \times H$

Break-even H = $400 / 0.2 = 2,000 \text{ hours}$

At 1,000 hours, repair is 1,300 kg and replacement is 1,500 kg. At 3,000 hours, repair is 3,700 kg and replacement is 3,500 kg. Actual remaining life, maintenance and performance determine which scenario is credible.

O.8 Reusable packaging with loss-adjusted use

A reusable container has 40 kg CO₂e production burden and 0.8 kg per completed cycle for return transport and cleaning. A single-use package has 3 kg per delivery. Ignore final treatment only for this explicitly limited example and assume every counted cycle provides equivalent protection.

Reusable burden per cycle = $40 / N + 0.8$

Break-even N = $40 / (3 - 0.8) = 18.1818 \text{ cycles}$

At 20 completed cycles: $40 / 20 + 0.8 = 2.8 \text{ kg/cycle}$

At 10 completed cycles: $40 / 10 + 0.8 = 4.8$ kg/cycle

At least 19 complete cycles are needed to beat 3 kg in this model. Claimed design life cannot replace realized or justified expected cycles. Loss, damage and final treatment may change the result.

O.9 Dependent uncertainty in a total

Two independent estimated contributions are 100 and 200 t CO₂e with standard uncertainties of 10 and 20 t. A separate scenario assumes correlation 0.5 because both use a shared uncertain factor. Normality is assumed only to illustrate approximate expanded intervals.

Total = $100 + 200 = 300$ t CO₂e

Independent $u = \sqrt{10^2 + 20^2} = 22.3607$ t

Correlated $u = \sqrt{10^2 + 20^2 + 2 \times 0.5 \times 10 \times 20}$

Correlated $u = \sqrt{700} = 26.4575$ t

Approximate $k=2$ expanded uncertainty = 52.9150 t

Ignoring positive dependence understates uncertainty. The approximate interval is not a guaranteed bound, and model or scenario gaps may not be represented by these standard uncertainties.

O.10 Shared launch service allocation

An illustrative shared launch lifecycle has 100 t CO₂e and carries two payloads of 200 and 300 kg. A mass-based allocation is used for this stated study purpose. The first payload delivers 1,000 qualified service units with an additional 15 t CO₂e from manufacture, ground operation and final treatment.

Payload A share = $100 \times 200 / 500 = 40$ t CO₂e

Payload A lifecycle = $40 + 15 = 55$ t CO₂e

Service intensity = $55,000 / 1,000 = 55$ kg CO₂e/unit

This does not demonstrate causal marginal launch emissions, equivalent payload functions or acceptable orbital effects. Another justified allocation or a different service duration may materially change the result.

O.11 Lifecycle cost with separate physical impacts

Option A costs 100,000 currency units now, then 10,000 at the end of each of three years, and 5,000 at the end of year three for retirement. A real annual discount rate of 5% is assumed and all cash flows use the same real price basis.

$PV = 100,000 + 10,000/1.05 + 10,000/1.05^2$

$+ 15,000/1.05^3 = 131,551.6683$ currency units

The retirement cost is included once, alongside the third operating payment. Inflation must not be mixed into this real-price model without reconciliation. Physical emissions and waste quantities remain undiscounted inventory results unless a separate explicitly justified impact method says otherwise.

O.12 Attribute inventory reconciliation

A custody account opens with 100 eligible units, adds 500 eligible units, transfers 450 units to another owner and cancels 80 units for the reporting entity's own bounded claim. No conversion or loss occurs in this simplified account.

Closing eligible balance = $100 + 500 - 450 - 80 = 70$ units

Accounted quantity = $450 + 80 + 70 = 600$ units

Only 80 units are cancelled for this entity's claim; the transferred 450 cannot also support its retained use claim. A positive balance does not by itself prove eligibility, physical delivery, project quality or an emissions reduction.