

Exergy & Availability Cheat Sheet

Useful work potential, dead state, exergy destruction and exergy efficiency

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Closed-system availability (non-flow exergy)	$\Phi = (U - U_0) + P_0(V - V_0) - T_0(S - S_0)$	Subscript 0 = dead state (equilibrium with the environment)
Specific closed-system exergy	$\phi = (u - u_0) + P_0(v - v_0) - T_0(s - s_0) + V^2/2 + g z$	Add kinetic and potential terms when they matter
Flow exergy (steady flow)	$\psi = (h - h_0) - T_0(s - s_0) + V^2/2 + g z$	Exergy carried by a flowing stream
Exergy of heat	$X_Q = Q (1 - T_0/T)$	Heat at temperature T; same form as the Carnot factor
Exergy destruction	$X_{\text{dest}} = T_0 S_{\text{gen}} \geq 0$	Gouy-Stodola relation. Zero only for a reversible process
Exergy balance	$X_{\text{in}} - X_{\text{out}} - X_{\text{dest}} = \Delta X_{\text{system}}$	Unlike energy, exergy is consumed by irreversibility
Energy efficiency (1st law)	$\eta = \text{useful energy out} / \text{energy in}$	Ignores the quality of the energy
Exergy efficiency (2nd law)	$\eta_{\text{ex}} = \text{useful exergy out} / \text{exergy in}$ $\eta_{\text{ex}} = 1 - X_{\text{dest}}/X_{\text{in}}$	Always between 0 and 1

Key takeaways

- Exergy is the maximum useful work obtainable as a system comes to equilibrium with a reference environment. A system already at the dead state has zero exergy.
- Exergy depends on the environment as well as the system: the same hot water holds more exergy in winter than in summer.
- Energy is conserved, but exergy is destroyed by irreversibilities such as friction, finite- ΔT heat transfer and mixing.
- Exergy efficiency shows *where* and *how much* is lost; energy efficiency can hide this and can give COP values above 100%.
- Method (as in the article): split the process into sections, run mass and energy balances, pick a reference environment, compute exergy, then do exergy balances and efficiencies.
- Use it to find the biggest improvement target in heat exchangers, power plants and refrigeration systems.