

## Renewable and Waste-Heat Utilisation Technologies

Understand the science and engineering behind conventional and renewable heat loss recovery techniques with this thorough reference guide. This book provides you with the knowledge and tools necessary to assess the potential waste-heat recovery opportunities that exist within various industries and select the most suitable technology. In particular, technologies that convert waste heat into electricity, cooling or high-temperature heating are discussed in detail, alongside more conventional technologies that directly or indirectly recirculate heat back into the production process. Essential reading for professionals in chemical, manufacturing, mechanical and processing engineering who have an interest in energy conservation and waste-heat recovery.

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# Renewable and Waste-Heat Utilisation Technologies

Thermal Energy Recovery, Conversion, Upgrading  
and Storage

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## Acronyms

### *Roman Symbols*

$A$	heat-transfer area, $\text{m}^2$
$c$	velocity, $\text{m/s}$
$c_p$	specific-heat capacity, $\text{J}/(\text{kg K})$
$C$	cost, $\text{\$}$
$C_0$	total investment cost, $\text{\$}$
$C_c$	cost of electricity, $\text{\$/kWh}$
$C_g$	cost of natural gas, $\text{\$/kWh}$
$C_{\text{o\&m}}$	operation and maintenance costs, $\text{\$/kWh}$
$d_h$	hydraulic diameter, $\text{m}$
$D$	diameter, $\text{m}$
$D_s$	specific diameter
$D$	thermal diffusivity, $\text{m}^2/\text{s}$
$e_{\text{th}}$	thermal effusivity, $\text{J}/\text{m}^2/\text{s}^{1/2}/\text{K}$
$f$	friction factor
$F$	Martinelli parameter
$g$	acceleration due to gravity, $\text{m}/\text{s}^2$
$h$	enthalpy, $\text{J}/\text{kg}$
$k$	thermal conductivity, $\text{W}/(\text{m K})$
$L$	length, $\text{m}$
LCOE	levelised cost of electricity, $\text{\$/kWh}$
$m$	mass, $\text{kg}$
$\dot{m}$	mass-flow rate, $\text{kg}/\text{s}$
$n$	operating hours per annum
$N_s$	specific speed
$Nu$	Nusselt number
NPV	net-present value, $\text{\$}$
$P$	pressure, $\text{Pa}$
$\Delta P$	pressure drop, $\text{Pa}$
$P_r$	reduced pressure
PB	payback period, years
$PP$	heat-exchanger pinch point, $\text{K}$
$Pr$	Prandtl number

$q$	heat transfer per unit mass, J/kg, vapour quality
$Q$	heat transfer, J
$\dot{Q}$	heat-transfer rate, J/s, volumetric flow rate $\text{m}^3/\text{s}$
$r$	discount rate, %
$Re$	Reynolds number
$s$	entropy, J/(kg K)
$S$	annual savings, \$
SIC	specific investment cost, \$/kW
$t$	time/year
$T$	temperature, K
$\Delta T_k$	endo-reversible heat-pump temperature difference, K
$\Delta T_{\log}$	log-mean temperature difference, K
$\Delta T_{\text{sh}}$	amount of superheat K
$w$	specific work, J/kg
$W$	work, J
$\dot{W}$	power, W
$U$	internal energy, J, overall heat-transfer coefficient $\text{W}/(\text{m}^2 \text{K})$
$x$	fluid composition
$X$	exergy, J
$\dot{X}$	exergy rate, J/s
$z$	height, m

*Greek Symbols*

$\alpha$	heat-capacity ratio, heat-transfer coefficient, $\text{W}/(\text{m}^2 \text{K})$
$\beta$	heat-conductance ratio
$\varepsilon$	heat-exchanger effectiveness
$\eta$	thermal efficiency/isentropic efficiency
$\theta$	non-dimensional heat source temperature drop
$\mu$	dynamic viscosity, Pa s
$\rho$	density, $\text{kg}/\text{m}^3$
$\phi$	coefficient of performance (power-driven)
$\psi$	coefficient of performance (heat-driven)
$\omega$	rotational speed, rad/s

*Subscripts*

0	dead state
c	cold
ch	chiller
ci	cold-fluid inlet
cp	cold-fluid pinch
co	cold-fluid inlet
cr	critical point
e	expander
ev	evaporator
h	hot



---

hi	hot-fluid inlet
hp	hot-fluid pinch, heat pump
ho	hot-fluid outlet
i	inner
l	saturated liquid
min	minimum
max	maximum
n	net
o	outer
p	pump
ph	preheat
s	conditions after isentropic expansion
sh	superheater
v	saturated vapour
wf	working fluid
'	saturation conditions

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