Appendix 1: Nomenclature

In this book, all the symbols used are explained the first time they are used. This appendix includes a general list that could be consulted in case of doubt. It should be noted, however, that only the general or most used symbols are included in the following list and not variations, usually denoted with subscripts. The appendix initially presents the nomenclature used with respect to radiation and then the general list of symbols. Finally, a list of abbreviations is given.

Radiation nomenclature

G	Irradiance (W/m^2)
H	Irradiation for a day (J/m^2)
I	Irradiation for an hour (J/m^2)
R	Radiation tilt factor

Subscripts

B	Beam
D	Diffuse
G	Ground reflected
n	Normal
t	Radiation on tilted plane
c	Critical

Symbols

A	Aperture area (m^2)
a	Hellman coefficient
A_a	Absorber area (m^2)
A_c	Total collector aperture area (m^2)
A_f	Collector geometric factor
A_r	Receiver area (m^2)
A_R	Rotor area (m^2)
b_o	Incidence angle modifier constant-first order
b_1	Incidence angle modifier constant-second order
C	Collector concentration ratio, $=A_a/A_r$; capacitance rate; speed of light; useful accumulator capacity (Wh); mass concentration (kg of salts/kg of water); scale parameter
C_A	Cost per unit of collector area or area dependent cost ($/m^2)
C_b	Bond conductance (W/m °C)

- C_{F1} Cost of fuel during first year of operation ($)
- C_I Area-independent cost ($)
- c_p Specific heat at constant pressure (J/kg °C)
- C_P Power coefficient
- C_s Total cost of the solar equipment ($)
- C_T Thrust coefficient
- c_o Intercept efficiency, $= F_R(\tau\alpha)$
- c_1 First-order coefficient of the collector efficiency (W/m^2 °C)
- c_2 Second-order coefficient of the collector efficiency (W/m^2 °C^2)
- D Riser tube outside diameter (m); energy demand (J)
- d Market discount rate (%); interest rate (%); pipe diameter (m)
- D_i Tube inside diameter (m)
- d_m Mortgage interest rate (%)
- D_o Tube outside diameter (m)
- d_r Displacement of receiver from focus (m)
- d^* Universal nonrandom error parameter due to receiver mislocation and reflector profile errors, $d^* = d_r/D$
- E Emissive power (W/m^2 μm); exergy (W); voltage source (V); root mean square error; power density (W/m^2); collector effectiveness
- E_p Photon energy (J)
- E_{PV} Energy delivered from a PV array (J)
- E_{in} Exergy in (W)
- E_{out} Exergy out (W)
- F Annual fraction by solar energy; view factor; fin efficiency; cash flow ($); fraction of time night insulation is used; fraction of window shaded
- f Focal distance (m); monthly solar fraction; friction factor; fraction of steam in turbine bleed
- F' Collector efficiency factor
- F'' Flow factor
- F_R Heat removal factor
- F'_R Collector heat exchanger efficiency factor
- f_{TL} Fraction of total load supplied by solar including tank losses
- g Acceleration due to gravity (m/s)
- Gr Grashof number
- G_{on} Extraterrestrial radiation measured on a normal surface (W/m^2)
- G_{sc} Solar constant, $= 1366.1$ W/m^2
- h Hour angle (degrees); Specific enthalpy (kJ/kg); Plank's constant, $= 6.625 \times 10^{-34}$ (J s); shape parameter
- H Enthalpy (J)
- h_c Convection heat-transfer coefficient (W/m^2 °C)
- h_{fi} Heat transfer coefficient inside absorber tube or duct (W/m^2 °C)
- H_o Total extraterrestrial radiation on a horizontal surface over a day (J/m^2)
- H_p Lactus rectum of a parabola (m), = opening of the parabola at focal point
- h_p Height of the parabola (m)
- h_r Radiation heat transfer coefficient (W/m^2 °C)
- H_t Tower height (m)
- h_T Thermosiphon head (m)
- $\overline{H}_t$ Monthly average daily radiation incident on the collector surface per unit area (J/m^2)
- h_{ss} Sunset hour angle (degrees)

H_{ss}	Sunset time
h_v	Volumetric heat transfer coefficient (W/m^3 °C)
h_w	Wind heat-transfer coefficient (W/m^2 °C)
I	Irreversibility (W); current (A)
i	Inflation rate (%)
i_F	Fuel inflation rate (%)
I_o	Dark saturation current (A)
I_{ph}	Photocurrent (A)
I_{sc}	Short-circuit current (A)
J	Radiosity (W/m^2); mass flux (kg/m^2 s)
K	Extinction coefficient
k	Thermal conductivity (W/m °C); friction head (m)
K_{str}	Stratification coefficient
K_T	Daily clearness index
k_T	Hourly clearness index
K_θ	Incidence angle modifier
k_o	Intercept efficiency, $= F_R\eta_o$
k_1	First-order coefficient of the collector efficiency (W/m^2 °C), $= c_1/C$
k_2	Second-order coefficient of the collector efficiency (W/m^2 °C^2), $= c_2/C$
L	Half distance between two consecutive riser pipes (m), $= (W - D)/2$; collector length (m); latitude (degrees); annual energy required by the load (J); thickness of glass cover (m); pipe length (m); mean daily electrical energy consumption (Wh)
L_{AUX}	Annual energy required by the auxiliary (J)
L_m	Monthly load (J)
L_S	Load covered by solar energy (J)
M	Mass flow number; mass of storage capacity (kg); molar mass (kg/mole); mixing number
m	Air mass
$\dot{m}$	Mass flow rate of fluid (kg/s)
N	Days in month; number of moles; number of bends in serpentine collector
n	Number of years; refraction index; number of reflections
N_g	Number of glass covers
N_p	Average daily collector operating time (h)
n_p	Payback time (years); number of photons
N_s	Entropy generation number
Nu	Nusselt number
P	Profile angle (degrees); power (W); pressure (Pa)
P_a	Partial water vapor pressure of air (Pa)
P_h	Collector header pressure drop (Pa)
Pr	Prandtl number
P_s	Saturation water-vapor pressure at air temperature, t_a (Pa)
P_w	Saturation water-vapor pressure at water temperature, t_w (Pa), wind power (W)
PW_n	Present worth after n years
P_1	Ratio of life cycle fuel savings to first year fuel energy cost
P_2	Ratio of cost owed to initial cost
Q	Energy (J); rate (energy per unit time) of heat transfer (W)
q	Energy per unit time per unit length or area (W/m or W/m^2); heat loss (J/m^2 day)
Q_{aux}	Auxiliary energy (J)
Q_D	Dump energy (J)

$q'_{\mathbf{fin}}$	Useful energy conducted per unit fin length (J/m)
Q_g	Net monthly heat gain from storage wall (J)
Q_l	Load or demand energy (J); rate of energy removed from storage tank (W)
Q_o	Rate of heat loss to ambient (W)
q_o^*	Radiation falling on the receiver (W/m^2)
Q_S	Solar energy delivered (J)
Q_s	Radiation emitted by the sun (W/m^2)
Q_{tl}	Rate of energy loss from storage tank (W)
$q'_{\mathbf{tube}}$	Useful energy conducted per unit tube length (J/m)
Q^*	Solar radiation incident on collector (W)
Q_u	Useful energy collected (J); rate of collected energy delivered to storage tank (W); rate of useful energy delivered by the collector (W)
q'_u	Useful energy gain per unit length (J/m)
q^*	Irradiation per unit of collector area (W/m^2)
R	Receiver radius (m); ratio of total radiation on tilted plane to horizontal plane; thermal resistance (m^2 °C/W), membrane salts rejection rate
r	Ratio of total radiation in an hour to total in a day, Parabolic reflector radius (m); water recovery rate
Ra	Rayleigh number
r_d	Ratio of diffuse radiation in an hour to diffuse in a day
Re	Reynolds number
R_s	Ratio of standard storage heat capacity per unit area to actual, = 350 kJ/m^2 °C
R_{total}	Total thermal resistance (m^2 °C/W)
S	Absorbed solar radiation per unit area (J/m^2); Seebeck coefficient
s	Specific entropy (J/kg °C)
S_{gen}	Generated entropy (J/°C)
S_M	membrane active area (m^2)
T	Absolute temperature (K)
t	Time
T_a	Ambient temperature (°C)
$\overline{T}_a$	Monthly average ambient temperature (°C)
T_{av}	Average collector fluid temperature (°C)
T_b	Local base temperature (°C)
T_C	Absolute temperature of the PV cell (K), cold reservoir temperature (K)
T_c	Cover temperature (°C)
T_f	Local fluid temperature (°C)
T_{fi}	Temperature of the fluid entering the collector (°C)
T_H	Temperature of hot reservoir (K)
T_i	Collector inlet temperature (°C)
T_m	Public mains water temperature (°C)
T_o	Ambient temperature (K); temperature of the fluid leaving the collector (°C)
T_{oi}	Collector outlet initial water temperature (°C)
T_{ot}	Collector outlet water temperature after time t (°C)
T_p	Average temperature of the absorbing surface (°C); stagnation temperature (°C)
T_r	Temperature of the absorber (°C); receiver temperature (°C)
T_{ref}	Empirically derived reference temperature, = 100 °C
T_s	Apparent black body temperature of the sun, ~6000 K
T_w	Minimum acceptable hot-water temperature (°C)
T_*	Apparent sun temperature as an exergy source, ~4500 K

U	Overall heat-transfer coefficient (W/m^2 °C)
U_b	Bottom heat-loss coefficient (W/m^2 °C)
U_e	Edges heat loss coefficient (W/m^2 °C)
U_L	Solar collector overall heat-loss coefficient (W/m^2 °C)
U_o	Heat transfer coefficient from fluid to ambient air (W/m^2 °C)
U_r	Receiver-ambient heat-transfer coefficient based on A_r (W/m^2 °C)
U_t	Top heat-loss coefficient (W/m^2 °C)
V	Wind velocity (m/s); volumetric consumption (l); voltage (V)
v	Fluid velocity (m/s)
V_L	Load flow rate from storage tank (kg/s)
V_{oc}	Open-circuit voltage (V)
V_R	Axial velocity in the rotor plane (m/s); Return-flow rate to storage tank (kg/s)
V_w	Air velocity in the wake region (m/s)
V_∞	Undisturbed wind velocity (m/s)
W	Distance between riser tubes (m); net work output (J/kg)
W_a	Collector aperture (m)
X	Dimensionless collector loss ratio
x	Mass concentration of LiBr in solution; mole fraction
X_c	Corrected value of X; dimensionless critical radiation level
X'	Modified dimensionless collector loss ratio
Y	Dimensionless absorbed energy ratio
Y_c	Corrected value of Y
Z	Dimensionless load heat exchanger parameter
z	Solar azimuth angle (degrees)
z_0	Surface roughness length (m)
z_r	Reference height (m)
Z_s	Surface azimuth angle (degrees)

Greek

α_α	Absorber absorptance
α	Fraction of solar energy reaching surface that is absorbed (absorptivity); solar altitude angle; thermal diffusivity (m^2/s); interference factor (degrees)
β	Collector slope (degrees); misalignment angle error (degrees)
β'	Volumetric coefficient of expansion (1/K)
β^*	Universal nonrandom error parameter due to angular errors, $\beta^* = \beta C$
γ	Collector intercept factor; average bond thickness (m); correction factor for diffuse radiation (CPC collectors)
δ	Absorber (fin) thickness (m); declination (degrees)
Δ	Expansion or contraction of a collector array (mm)
ΔT	Temperature difference, $= T_i - T_a$
Δx	Elemental fin or riser tube distance (m)
ε	Specific exergy (J/kg)
ε_g	Emissivity of glass covers
ε_p	Absorber plate emittance
λ	Wavelength (m)
η	Efficiency; combined power coefficient

η_o	Collector optical efficiency
η_p	Plant efficiency
η_t	Tower efficiency
ν	Frequency (per second); kinetic viscosity (m^2/s)
π	Trans-membrane osmotic pressure
ρ	Density (kg/m^3); reflectance; reflectivity
ρ_m	Mirror reflectance
θ	Dimensionless temperature, $= T/T_o$; angle of incidence (degrees)
θ_c	Acceptance half-angle for CPC collectors (degrees)
θ_e	Effective incidence angle (degrees)
θ_m	Collector half acceptance angle (degrees)
σ	Stefan–Boltzmann constant, $= 5.67 \times 10^{-8}$ W/m^2 K^4
σ^*	Universal random error parameter, $\sigma^* = \sigma C$
σ_{sun}	Standard deviation of the energy distribution of the sun's rays at normal incidence
σ_{slope}	Standard deviation of the distribution of local slope errors at normal incidence
σ_{mirror}	Standard deviation of the variation in diffusivity of the reflective material at normal incidence
τ	Transmittance
τ_α	Absorber transmittance
$(\tau\alpha)$	Transmittance–absorptance product
$(\overline{\tau\alpha})$	Monthly average transmittance–absorptance product
$(\tau\alpha)_B$	Transmittance–absorptance product for estimating incidence-angle modifier for beam radiation
$(\tau\alpha)_D$	Transmittance–absorptance product for estimating incidence-angle modifier for sky (diffuse) radiation
$(\tau\alpha)_G$	Transmittance–absorptance product for estimating incidence-angle modifier for ground-reflected radiation
Φ	Zenith angle (degrees); utilizability
φ	Parabolic angle (degrees), the angle between the axis and the reflected beam at focus of the parabola
φ_r	Collector rim angle (degrees)

Note: A horizontal bar over the symbols indicates monthly average values.

Abbreviations

AEP	Annual energy production
AFC	Alkaline fuel cell
AFP	Advance flat plate
ANN	Artificial neural network
AST	Apparent solar time
BIPV	Building integrated PV
BP	Back-propagation
CLFR	Compact linear Fresnel reflector
COP	Coefficient of performance
CPC	Compound parabolic collector
CPV	Concentrating photovoltaic
CSP	Concentrating solar power
CTC	Cylindrical trough collector
CTF	Conduction transfer function

DAS	Data acquisition system
DD	Degree days
DS	Daylight saving
ED	Electrodialysis
ER	Energy recovery
ET	Equation of time
ETC	Evacuated tube collector
E–W	East–West
FF	Fill factor, fouling factor
FPC	Flat-plate collector
GA	Genetic algorithm
GMDH	Group method of data handling
GRNN	General regression neural network
HFC	Heliostat field collector
HVAC	Heating, ventilating, and air conditioning
ICPC	Integrated compound parabolic collector
ISCCS	Integrated solar combined-cycle system
LCC	Life cycle cost
LCR	Local concentration ratio
LCS	Life cycle savings
LFR	Linear Fresnel reflector
LL	Local longitude
LOP	Loss of load probability
LST	Local standard time
LTV	Long tube vertical
MCFC	Molten carbonate fuel cell
MEB	Multiple-effect boiling
MES	Multiple-effect stack
MPP	Maximum power point
MPPT	Maximum power-point tracker
MSF	Multi-stage flash
MVC	Mechanical vapor compression
NIST	National Institute of Standards and Technology
NOCT	Nominal operating cell temperature
N–S	North–South
NTU	Number of transfer units
PAFC	Phosphoric acid fuel cell
PDR	Parabolic dish reflector
PEFC	Polymer electrolyte fuel cell
PEMFC	Proton exchange membrane fuel cell
PTC	Parabolic trough collector
PV	Photovoltaic, pressure vessel
PWF	Present worth factor
RES	Renewable energy systems
RH	Relative humidity
RMS	Root mean square
RMSD	Root mean standard deviation
RO	Reverse osmosis

ROI	Return on investment
RTF	Room transfer function
SC	Shading coefficient
SEGS	Solar electric generating systems
SHGC	Solar heat gain coefficient
SL	Standard longitude
SOC	State of charge
SOFC	Solid oxide fuel cell
SRC	Standard rating conditions
TCF	Temperature correction factor
TDS	Total dissolved solids
TFM	Transfer function method
TI	Transparent insulation
TPV	Thermophotovoltaic
TVC	Thermal vapor compression
VC	Vapor compression