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Review

Exergy analysis of renewable energy-based climatisation systems for buildings: A critical view

Herena Torío [a], Adriana Angelotti [b,*], Dietrich Schmidt [a]

[a] Fraunhofer Institute for Building Physics, Department of Energy Systems, Gottschalkstrasse 28a, 34127 Kassel,Germany
[b] Politecnico di Milano, Building Environment Science and Technologies Department (BEST), v. Bonardi 3, 20133 Milano, Italy

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ABSTRACT

Exergy is naturally related to the concept of quality of energy. Therefore, exergy analysis has been widely applied in parallel with energy analysis in order to find the most rational use of energy. Within the built environment a wide margin for exergy saving may be found. Actually, buildings require mostly low quality energy for thermal uses at low temperatures and nowadays their energy demand is mainly satisfied with high quality sources. Exergy analysis of renewable energy-based climatisation systems may be considered an emerging field, where different and often contrasting approaches are followed. Then, in this paper a comprehensive and critical view on the most recent studies on this topic is presented. Special attention is paid to the methodological aspects specifically related to climatisation systems and renewables, and to the comparison of the results. Main renewable energy-based heating and cooling systems are considered in detail. Finally, conclusions regarding the state of the art and possible trends on this field are derived, with the aim to highlight future research issues and promote further developments of this method. Furthermore, conclusions regarding the usability of the exergy method as a tool to promote a more efficient use of available energy sources are also derived.

Contents

* Corresponding author. Tel.: +39 02 23995183; fax: +39 02 23995118.
E-mail address: adriana.angelotti@polimi.it (A. Angelotti).

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Nomenclature

A	area (m^2)
AHU	air-handling unit
ASHP	air source heat pump
CEC	cumulative exergy consumption
COP	coefficient of performance
c	specific heat (J/kg K)
C	thermal capacity (J/K)
DEC	direct evaporative cooling
DHW	domestic hot water
DIEC	direct–indirect evaporative cooling
EAT	entropy added tax
ECEC	ecological cumulative exergy consumption
EEA	extended exergy analysis
EER	exergy efficiency ratio
ELCA	exergetic life cycle analysis
e	specific total energy (J/kg)
E	total energy (J)
EPC	exergetic performance coefficient
ex	specific exergy (J/kg)
Ex	total exergy (J)
$\dot{E}x$	exergy rate (W)
FPC	flat plate collector
Fq	quality factor
G	solar irradiance (W/m^2)
GHEX	ground heat exchanger
GSASHP	ground source air source heat pump
GSHP	ground source heat pump
h	specific enthalpy (J/kg)
HGHE	horizontal ground heat exchanger
HVAC	heating ventilation air-conditioning
I	global irradiation (J/m^2)
$\dot{I}$	rate of irreversibility, rate of exergy consumption (W)
ICEC	industrial cumulative exergy consumption
IEC	indirect evaporative cooling
LCA	life cycle assessment-based
LNG	liquefied natural gas
m	mass (kg)
$\dot{m}$	mass flow rate (kg/s)
p	pressure (Pa)
PV	photovoltaic
R	specific gas constant (J/kg K)
REC	regenerative evaporative cooling
s	specific entropy (J/kg K)
S	entropy (J/K)
SAASHP	solar-assisted air source heat pump
SAGSHP	solar-assisted ground source heat pump
SAHP	solar-assisted heat pump
SDHW	solar domestic hot water
SH	space heating
SPEC	specific primary energy consumption
T	temperature (K)
t	time (s)
Q	heat (J)
$\dot{Q}$	heat transfer rate (W)
U	heat transfer coefficient (W/m^2 K)
W	work (or power) (J)
$\dot{W}$	rate of work (or power) (W)
x	solar thermal collector parameter (°C m^2/W)
y	mass fraction

Greek letters

ε	emissivity of the surface; exergy expenditure figure
η	energy (first law) efficiency
φ	relative humidity
μ	chemical potential (J/kg)
ν	specific volume (m^3/kg)
θ	temperature (°C)
σ	Stephan–Boltzmann constant ($W/(m^2 K^4)$); sensitivity exergy analysis
ω	humidity ratio (g/kg)
ψ	exergetic efficiency (%)
Δ	increment

Indices

0	reference or ambient state
*	restricted reference state
a	air
abs	absorber
AHU	air-handling unit
aux	auxiliary
boil	boiler
cw	condensate water
Carnot	Carnot
cc	cooling coil
ch	chemical
chill	chiller
circ	circulate
coll	collector
comb	combined
concr	concret
cond	condenser
cool	cooling