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Energy and exergy analysis of typical renewable energy systems

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ABSTRACT

The use of renewable energy systems for real life applications has been increasing for the last few decades due to the growing concern about the global warming and environmental pollution. The renewable energy sources are clean and freely available in the nature, however, the efficient utilization is still a cause of concern among the scientific and business communities. This paper presents an extensive literature review on both the energy and exergy analyses of typical renewable energy systems including, solar thermal, solar photovoltaic and biomass cookstove. Some important conclusions from the literature survey has been drawn and summarized in this paper. Among all important aspects studied and summarized in this paper, it is found that most of the analysis carried out for renewable energy systems so far is based on the energy analysis. Also for all renewable energy systems, the performance based on exergy analysis, in general, is found to be lesser than that of the energy analysis.

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Nomenclature

A	area of the collector (m^2)
C_p	specific heat (J/kg-K)
C_{pw}	specific heat of water (kJ/kg-K)
c_1	calorific value of wood (kcal/kg)
c_2	calorific value of kerosene (kcal/kg)
C_{PAl}	specific heat of aluminium (J/kg K)
d	density of kerosene (g/cc)
E	energy (W)
Ex	exergy (W)
g	gravitational constant (m/s^2)
g_c	constant in Newtons Law
h	Plank constant
h_{ca}	heat transfer coefficient
h	specific enthalpy (kJ/kg)
H	enthalpy (kJ)
I_b	beam radiation (W/m^2)
I_d	direct radiation (W/m^2)
I_{sc}	short circuit current (Amps)
I_m	current corresponding to maximum power point (Amps)
I_s	intensity of solar radiation at any particular site (W/m^2)
M_1	initial mass of the cookstove with test fuel (kg)
M_2	mass of the cookstove, after burning the test for half an hour (kg)
m_{pot}	mass of pot (kg)
m	mass flow rate of air (Kg/s)
m_w	mass of water (kg)
m_{wd}	mass of wood (kg)
n_{ph}	number of photons falling on the surface of PV module
n	total number of vessels used
P_1	first pot
P_2	second pot
P_3	third pot
P_4	fourth pot
Q_c	energy incident on the collector (W)
Q_f	energy absorbed (W)
s	entropy (J/kg-K)
ΔT	temperature difference (K)
T	temperature (K)
u	specific internal energy (kJ/kg)
v	wind speed (m/s)
V_{oc}	open circuit voltage (V)
V_m	voltage corresponding to maximum power point (V)
w	mass of water in vessel (kg)
W	mass of vessel complete with lid and stirrer (kg)
x	volume of kerosene consumed (ml)
X	mass of fuel consumed (kg)
z	altitude coordinate (m)

Greek letters

α	absorptance of collector
ε	thermal exergy at temperature T
$\varepsilon(T_i)$	thermal exergy at temperature Ti
τ	transmittance of the collector
η	energy efficiency (%)
ψ	exergy efficiency (%)
η_{pce}	power conversion efficiency (%)

Subscripts

1	initial state
2	final state
a	ambient
Al	aluminium
cell	cell
chem	chemical
d	destroyed
elec	electrical
fp	final state of pot
fw	final state of water
htm	hytherm oil
in	input
ip	initial state of pot
iw	initial state of water
o	output
oc	open circuit
pce	power conversion efficiency
ph	photon
sc	short circuit
therm	thermal
wd	wood

1. Introduction

The present world energy scenario exhibits that most of the energy requirements are met from fossil fuels which cannot be newly formed at any significant rate therefore, the present stocks are finite. Also these fossil fuels are not environmental friendly and emits significant amount of pollutants causing serious environmental issues such as, global warming, ozone layer depletion and climate change. Renewable energy sources, with advantages of being environment friendly and abundant in availability are the promising option to meet the increasing demand of energy worldwide. However, the renewable energy systems suffer from low conversion efficiency therefore using the renewable energy systems for real life applications in regular practice requires special consideration. Performance of most of the renewable energy conversion systems is given based on energy analysis which is basically only the accounting of energies entering and exiting. Energy is based on the first law of thermodynamics and gives the quantity of energy only. While exergy is based on the second law of thermodynamics and represents the quality of energy and involves the irreversibility while analysing system efficiency. Exergy analysis identifies the causes, locations and magnitude of the system inefficiencies and provides the true measure how a system approaches to the ideal [1].

The main source of all the renewable and conventional energy sources is the sun, which is freely and abundantly available round the year and hence can be utilized directly or indirectly. Directly can be used by photosynthesis or converting it into electricity using solar photovoltaic (SPV) modules. Basically three different technologies viz. Mono-crystalline silicon (m-Si), multi-crystalline silicon (mc-Si) and ribbon silicon based SPV modules are present in the market. In general it has been found that the mono-crystalline-silicon wafer is more expensive than that of multi-crystalline-silicon wafer and as far as the efficiency is concerned, m-Si based module is better than mc-Si module [2]. The conversion efficiency of commercial types of mc-Si cells are found to be in the range of 12–15%, however, it can be enhanced up to 20% by using more sophisticated solar cell designs [3]. Indirectly it can be