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Renewable energy for liquid desiccants air conditioning system: A review

Geleta Fekadu, Sudhakar Subudhi*

Department of Mechanical and Industrial Engineering, IIT Roorkee, Roorkee 247667, India

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ABSTRACT

In the era of demands in primary energy, utilization coupled with fossil fuel is increasing in the world for the application of thermal comforts. The energy consumption and relative problem need attention to search renewable energy. Energy consumption and demand are high for air conditioning mainly in hot and humid climates. Many previous studies have confirmed that technical and economical deficits associated with conventional air conditioning systems can be eliminated using liquid desiccant air conditioning (LDAC) technologies. This paper reviews studies on liquid desiccant air conditioning. The objective of this paper is to use liquid desiccant based air conditioning regenerated by renewable energy. Thermo-physical properties liquid desiccants are first realized to use as air conditioning. Regeneration temperature of saline salt and newly organic compound viz. Glycol-water solution desiccants is in a decreasing order of LiBr, LiCl, $CaCl_2$, LiCl-$CaCl_2$ mixture and glycol water solution, while the dehumidification is in an increasing order of $CaCl_2$, LiCl-$CaCl_2$ mixture, LiCl, LiBr and Glycol-water solution respectively. Main problems using liquid desiccant saline salt solutions are corrosiveness and crystallization and these can be resolved by using glycol water solutions and ionic liquids (ILs) which are attracting attention due to low regenerative temperature, non-corrosiveness, and higher dehumidification but these are volatile, viscous, and costly than the saline salt solutions.

1. Introduction

1.1. Environment and Renewable Energy

Since the beginning of mankind, the demand for energy consumption and their coupling with fossil fuels make situations to search a promising alternative energy for the world development and their sustainability as fossil fuel is getting depleted. The renewable energy sources are used for different activities viz. heating, lighting, cooking and air conditioning. The renewable energy sources are solar, wind, biomass, geothermal and hydropower. Increasing demand for air conditioning in recent years has caused a significant rise in energy resources as indicated in Fig. 3. The increase of urbanization and population is creating global warming and hence the searching of the energy, which is renewable and cost-effective, is obligatory [1–5].

The growing demand for air conditioning, particularly in hot and humid climates has caused a significant increase in energy resources [6,7]. Electric utilities have their peak loads in hot summer and are often barely capable of meeting the demand, with brown-out situations. It is a good application for solar energy due to the fact that the greatest demand for air conditioning occurs during times of highest insolation [8,9]. Development of cost-effective for satisfying energy requirement in the specific area using various alternative energy sources is different. The challenge in energy resource management is deciding how to utilize available renewable energy by satisfying the needs. Demand for conventional energy resources and human comfort condition is increasing and this induces global warming throughout the world [10].

Primary conventional energy sources are fossil fuels viz. oil, natural gas (NG) and coal. These energy sources are being consumed largely when compared to renewable. Apart from fast depletion of primary energy resources Fig. 1 burning of these fuels causes carbon dioxide (CO_2) emission [11].

Emission of carbon dioxide (CO_2) is increasing yearly mostly in developing countries as indicated in Fig. 2. The increased emission of CO_2 and other greenhouse gases (GHG) will cause many climatic disturbances because of increase in global temperature.

The heating, ventilating and air conditioning (HVAC) load of the world is estimated to rise 6.2% yr^{-1} as shown in Fig. 3.

Renewable energy which was not utilized so well in the earlier is attaining attention now because of cost inexpensive, commercial acceptance, maintenance is ease and operation, and its eco-friendliness. A major part of the primary energy consumed in the building is accounted for cooling or heating. To reduce the emission of carbon dioxide (CO_2) and chlorofluorocarbons (CFCs), the need for the renewable energies to the conventional cooling systems is needed [15]. Some review papers are published on using of liquid desiccant but still it is necessary to

* Corresponding author.
E-mail address: subudfme@iitr.ac.in (S. Subudhi).

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Nomenclatures

Acronyms

A_c	Collector area
A/C	Air conditioning
ASHRAE	American Society of Heating, Refrigerating, and Air, Conditioning Engineer
CEC	Combined evaporative cooling
CELD	Cost effective liquid desiccant
COP	Coefficient of performance
DEC	Direct evaporative cooler
EA	Exhaust air
EFF-DP	Dew point effectiveness
EFF-WB	Wet-bulb effectiveness
FA	Fresh air
GHG	Greenhouse gases
I	Solar radiation intensity
ILs	Ionic liquids
IDEC	Indirect evaporative cooler
$LAMEE_S$	Liquid to air membrane, energy Exchanging system
LDAC	Liquid desiccant air conditioning

Chemical symbols

$CaCl_2$	Calcium chloride
CFC_S	Chlorofluorocarbons
CH_4	Methane
CO_2	Carbon dioxide
DEG	Diethylene glycol
DPG	Dipropylene glycol
HCOOK	Potassium formate
LiBr	Lithium Bromide
LiCl	Lithium Chloride
MEG	Monoethylene glycol
$MgCl_2$	Magnesium chloride
NG	Natural Gas
N_2O	Nitrous Oxides
TEG	Tri-ethylene Glycol
T4EG	Tetraethylene glycol
PG	Propylene glycol

Greek letters

η	regenerator effectiveness
ε	effectiveness

LD	Liquid Desiccant
LDC_S	Liquid Desiccant cooling system
m_a/m_d	Ratio of air flow rate to solution flow rate
OA	Outside air
Q	Cooling rate of the desiccant cooling
Q_h	Total heat input to the regeneration
r	Evaporative latent heat of water
RH	Relative humidity
SA	Supply air
SDD_S	Solar Desiccant Dehumidification system
$SALDC_S$	Solar assisted liquid desiccant cooling system
SHR	Sensible heat ratio

SMLDAC Solar Membrane liquid desiccant air Conditioning

T_a	Temperature of air
T_{out}	Temperature out
T_{in}	Temperature in
VC	Vapor compression

Symbols

T	Temperature (^{0}C)
C_p	Specific heat capacity(J/(kgK))
w_a	Specific humidity ratio of air
m_r	Moisture removal rate

Subscripts

Sol	solution
ξ	mass fraction of solute
eq	equilibrium
fa	fresh air
oa	outside air
sa	supply air
i	inlet
o	outlet
a	air
d	dehumidifier
r	regenerator

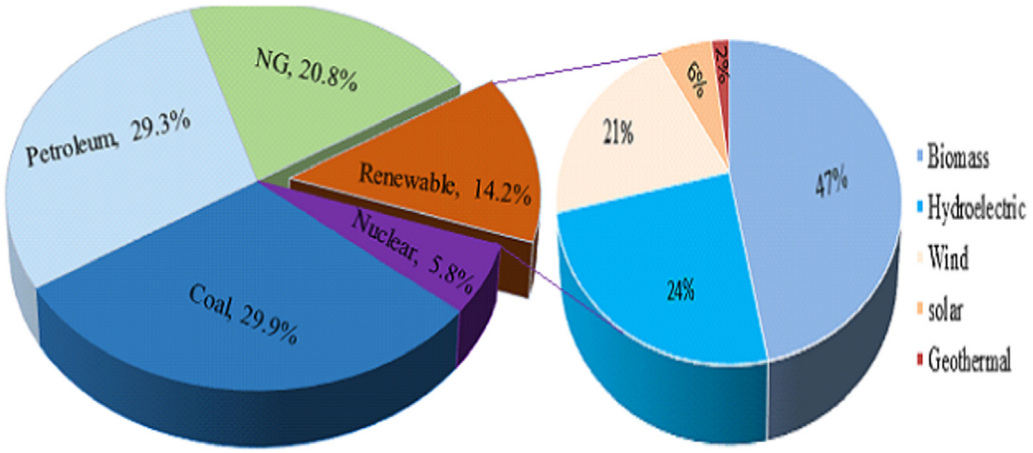

Fig. 1. Graphical representation of the world energy consumption [12].